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ESMAC Abstracts 2004

Thursday 23rd September 2004

Session 1 (oral): 9:15 to 10:27

Gait

S1.1: Comparison of early post-operative temperospatial outcome measures between patients receiving minimally invasive and traditional hip replacement surgery — a prospective blinded study

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Summary

Stride analysis was used to detect early post-operative differences in walking ability between patients who received a hip replacement using the relatively new minimally invasive technique and the traditional technique.

Conclusions

The minimally invasive group did not display any statistically significant improvement in the gait parameters under investigation, thereby suggesting no short-term post-operative benefit to walking ability using this new surgical technique. Further study needs to quantify any specific economic benefits that this new technique may offer the health service.

Introduction

Minimally invasive hip replacement is a relatively new orthopaedic technique which offers the potential benefits of reduced soft tissue damage, blood loss and pain. Speedier rehabilitation and reduced hospital stay post-operatively may also be achieved. Studies to date have been largely descriptive and retrospective and authors have noted the lack of objective data to demonstrate the benefit of the procedure [1–3]. Prospective studies have analysed relatively late outcomes at 3, 6 and 12 months [4]. Early mobilisation and walking is a good indicator of improved function. This study assesses patients' immediate post-operative function using a 10 m walking test and provides the first large-scale prospective blinded trial involving this new and controversial technique.

Patients/materials and methods

A convenience cohort of 67 patients was chosen for stride analysis from the main study cohort. The main cohort consists of 200 patients who are randomised into two groups of 100 patients (study ongoing). One group had a custom THR implanted using a small incision (<10 cm) while the second group had the same custom THR implanted using the traditional long incision (15–25 cm). All health professionals treating patients (physiotherapists, occupational therapists) were blinded as to the technique used. An identical protocol was used pre and post-operatively with both groups. Stride analysis was performed 2 days post-operatively (or the earliest post-operative ambulant day) with patients required to walk 10 m. Inked pads were attached to patients footwear and step length, stride length, cadence and velocity were measured. A one-sample Kolmogorov–Smirnov test was used to establish that all outcome measures followed a normal distribution. Statistical analysis was carried out using Student's *t*-test with a 5% level of significance being set.

Results

No significant difference between the groups was recorded for the gait parameters summarised in the table.

	Minimally invasive	Traditional incision
Walking speed (m/s)	0.29 (0.19)	0.30 (0.16)
Cadence (steps/min)	43.35 (16.73)	47.90 (16.38)
Stride length (m)	74.83 (19.66)	72.40 (17.72)
Step length (operated side (OP)) (m)	44.52 (8.13)	43.25 (7.77)
Step length (non-operated side (NP)) (m)	30.15 (14.41)	29.06 (13.54)
Ratio of step length (OP):step length (NP)	1.63 (1.00)	2.56 (3.84)

Discussion

Results showed no statistical differences between the two surgical approaches however, the minimally invasive group showed more equality of step length between the operated and non-operated limbs, possibly indicating a more normal gait pattern. Three dimensional gait analysis would be required to describe in detail any further differences in gait patterns between the groups.

References

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S1.2: The body position of six-year-old children during walking

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Summary

The paper is devoted to the position of the body during normal walking of 33 6-year-old girls and boys. The angular position of consecutive segments of trunk and head were described in the sagittal plane and also the position of the gleno-humeral joint in relation to the trunk. The children exhibited a forward positioning of the abdomen and frequently a downward inclination of the neck with the head inclined upward. Only two children had the shoulders positioned significantly forward.

Conclusions

The investigation of posture in a static situation is only one way to monitor children's health. An investigation carried out while performing a function, here during normal walking, is an important additional test and one which must be used for all small children.

Introduction

Investigations of human posture in static conditions are extremely common. They are carried out by means of subjective and objective techniques [1]. Other work has dealt with various body positions in the workplace [2]. During everyday life the most frequent position of the body is that adopted during walking. As evidenced by the available literature, there has been little work on children's body position during walking. The aim of this paper was to investigate the set of the body parts of children during walking.

Materials and methods

Of the 252 6-year-old children investigated, 33 (19 girls, 14 boys) were selected with normal posture during standing. For the analysis of children's body positioning during walking the phase was chosen during which the child's centre of gravity was above the rear part of the foot (the heel) (Fig. 1A). The centre part (centroid) of the body was divided into the pelvis, abdomen, thorax, neck, and head. The angular position of each of these segments in relation to the neighbouring lower segment was described in the sagittal plane (Fig. 1B). The centre points of the trunk depth were marked on the basis of the anthropometric landmarks: *tro*, *om*, *xi*, *c*, *t* and *V*. These points were connected to each other, thus giving a broken line. The position of the humerus head (*caput humeris*) in relation to the trunk depth was presented with the help of an index of the horizontal shoulder setting *Ihss* (Fig. 1C).

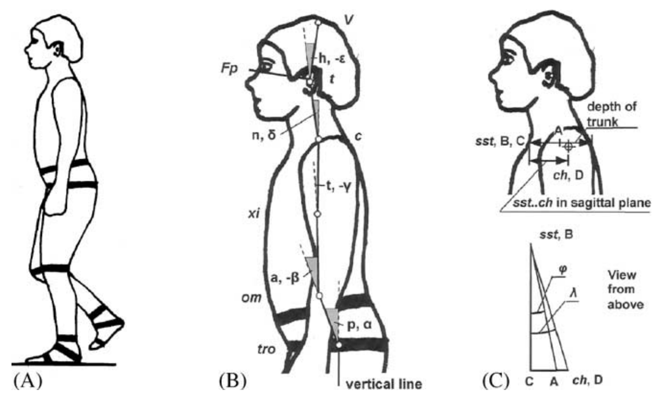

Fig. 1. Method: (A) walking phase investigated; (B) angle investigated of: p—pelvis, a—abdomen, t—thorax, n—neck, h—head, Fp—Frankfort plane; C—position of shoulder (*caput humeris*, *ch*) according to the centre (A) of trunk depth at *sst* level. Index of the horizontal shoulder setting: Ihss = λ/φ. A value of 1.0 means D point is at the centre of the trunk depth, i.e. at point A [3,4].

Results

The mean angles of inclination of the centroid segments were as follows (one standard deviation in parentheses): $\alpha = 14.9^\circ$ (5.2), $\beta = -18.0^\circ$ (6.2), $\gamma = -2.2^\circ$ (3.7), $\delta = 18.3^\circ$ (9.6), $\varepsilon = -6.6^\circ$ (7.0). This meant that the pelvis was inclined forward and the abdomen was inclined backward, the neck was inclined forward and head was inclined backward. The mean value of the index of the horizontal shoulder setting was 0.91 (0.20).

Discussion

The greatest sum for one child of the pelvic and abdominal absolute angles was 54.5° (22° for the pelvis and −32.5° for the abdomen). The highest neck inclination in relation to the position of the thorax was 40°. The value of the mean index of the horizontal shoulder setting shows that the arm joint (point D) was positioned slightly forward in relation to the centre point of the trunk A. Only two children had their shoulders positioned considerably forward so that the Ihss equalled 0.29 and 0.39, respectively.

References

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S1.3: Kinematic and EMG analysis in patients with osteoarthritis of the hip joint

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Summary

Patients with osteoarthritis of the hip joint often adapt an antalgic type of gait as their disease progresses. It is unknown if gait adaptation is mainly related to the severity of the disease, pain, muscle weakness, or limitations in a passive range of motion. Protecting the hip may influence the motion of other joints of the lower extremities. In our presentation we analysed the resulting changes in functional gait patterns in patients with unilateral osteoarthritis of the hip with ultrasound-based motion analyser and surface EMG.

Conclusions

Asymmetry of the range of hip motion was observed in patients with unilateral osteoarthritis of the hip joint during walking. The results suggest that compensatory mechanisms greatly involved the other joint. Major limitations in physical function were detected.

Introduction

Patients with osteoarthritis of the hip joint suffer from pain and functional impairment of the hip over a long period. Although different functional scores are widely used to assess improvements after surgery, the patients' responses are often subjective and disparities between the patients' and doctors' evaluations can be significant [1]. Therefore, objective and quantified data from gait analysis could be useful. Patients may adapt their gait in response to pain, deformity or laxity in the joints of the lower extremities. The objective is to analyse the resulting changes in functional gait patterns in patients with unilateral osteoarthritis of the hip.

Patients and methods

The study was performed on 12 male and 9 female patients (61.8 $\pm$ 7.51 years, 72.3 $\pm$ 8.34 kg, 1.68 $\pm$ 0.23 m) with unilateral osteoarthritis of the hip. Gait analysis was performed using a zebris ultrasound based system with a 19-point biomechanical model [2] and sixteen-channel electromyography. Surface EMG electrodes were attached to m. vastus medialis and lateralis, m. rectus femoris, m. adductor longus, m. biceps femoris, m. gluteus medius, m. gastrocnemius medialis and lateralis. From the spatial coordinates of the investigated antropometrical points the kinematical data (step length, step width, knee, hip and pelvic angles) were calculated. Muscle-activities are characterized by EMG envelope-curves in time-function.

Results

The results of the osteoarthritis side were compared with those of the healthy side. The difference in the step width and the step length between the two sides is not significant. Significant statistical differences in joint angles were observed between the non-affected and affected limbs. The EMG results suggest that the muscles biceps femoris, gluteus medius, and gastrocnemius lateralis showed decreased activity during both phases of the gait compared to the non-affected side. Six patients exhibited an adductor longus avoidance gait pattern, which means that the adductor longus produced EMG activity only during the early stance and late swing phases.

Discussion

In this research, spatial gait parameters did not show significant asymmetry, although all patients had unilateral hip diseases. This may occur when the patient walks with short steps or when compensatory movements of other joints are involved. Asymmetry was observed in the range of hip motion as well as knee motion. The maximum hip flexion and extension on the affected side were inversely correlated with the maximum hip extension and flexion on the non-affected side. Therefore, it was suggested that the increased motion of the opposite hip was a compensatory function. The study showed that the increased pelvic obliquity directly correlated with the range of hip flexion. When the range of hip motion is decreased, it might be expected that increased pelvic obliquity would occur as compensation. The present study detected an influence of the decreased range of affected hip motion on the ipsilateral knee as a decreased range of knee joint motion. Evidence of adductor longus avoidance patterns was observed in 43% of investigated patients. It suggests that the reduced rotation of the pelvis could result in a reduced rise in adductor longus EMG activity during pre-swing. The reduced activity of m gluteus medius, m. gastrocnemius and m. biceps femoris activity could be verified by the reduced range of hip motion, gait speed, and step length.

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S1.4: Sagital motion of the foot in relation to the ground based on gait analysis graphs. Should foot-ground angle be included in gait analysis reports?

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Summary

This paper describes the foot-ground angle normal graph of and its use for more accurate evaluation of foot motion.

Conclusions

The normal foot-ground angle graph was plotted and described. A better understanding of the foot motion was achieved when beside ankle joint angle, the angle between foot and ground was included. Using both graphs, foot motion is more clearly described, deceptive instances are revealed (i.e. true equinus, early heel rise, etc.) and a more accurate evaluation of the underlying pathology is achieved.

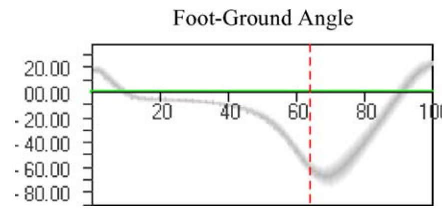
Introduction

Usually gait analysis reports are measuring foot motion using only ankle joint angle [1,2]. This can lead to misinterpretations of foot motion relative to the ground. The purpose of the study was to plot and evaluate sagital foot motion based on usual gait analysis data and the foot ground-angle.

Patients/materials and methods

3D BIOKIN Motion Analysis System was used to capture a 19 vertexes model, which included: trunk, pelvis, thigh, shank and foot. None of the above markers was a virtual marker. The foot-ground angle was measured by calculating the angle between the heel—third metatarsal axis and the ground level. Positive angles indicated toes pointing upwards. Negative angles indicated toes pointing downwards. Various cases of different foot behaviors have been identified from our pool of measurements.

Results



Normal graph of sagital plane foot motion to the ground level has been established. This graph shows a 20° foot-ground angle at initial contact. At loading response the foot angle drops to $-5°$ (first rocker) which remains almost unchanged, until pre swing phase, where heel starts to rise rapidly (40% of gait cycle).

At the beginning of swing an angle of $-60°$ to $-70°$ is reached and then a very rapid decrease occurs. At 90% of the gait cycle the foot is parallel to the ground and at the end of the swing the foot has reached a 20° angle preparing for the next gait cycle.

Discussion

By defining the normal graph of sagital foot-ground angle, changes of foot angular positions were documented. Knowing these changes and comparing to various pathologic cases, useful information were collected. For example foot-ground angle showed clearly the early and late heel rise at stance phase, true and apparent equines [3], drop foot behavior, etc. This information is missing from Gait Analysis reports and is considered to add to the foot motion evaluation. It was observed that in cases with valgus or rocker-bottom foot, the foot-ground axis is being distorted. Careful evaluation of this angle should be considered in these cases.

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Botulinum Toxine

S1.5: Kinematic and functional assessment of botulinum a toxin injections into the upper limbs of children with cerebral palsy

Z.C. Robertson[1], S.F. Attfield[1], J. Nicholson[2], A.E. Uutela[1], R.E. Morton[2]

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Summary

This study examined the effects of injecting elbow flexors, wrist flexors and pronator muscles with Botulinum A Toxin (BTA). A kinematic analysis of a standardized reach was carried out at baseline, 6 and 12 weeks post injection. To access changes in daily living a PEDI assessment was used at each session and a carer questionnaire given at the 12 week session. The hypothesis of the study was that there would be an improvement in function after the Botulinum Toxin injections.

Conclusions

Variable results were seen indicating that BTA injections to the upper limbs may not always improve active function, and can sometimes interfere with joint control resulting in reduced usage. Patients should be carefully selected for this treatment, with specific goals being set and objective assessments afterwards to ensure there is benefit.

Introduction

The benefits of using Botulinum toxin for treatment of the lower limb muscles of children with Cerebral Palsy have been widely investigated and demonstrated [1]. More recently the use of BTA has been extended to the upper limbs. Two previous studies have looked at the functional effects of BTA treatment to the upper limb [2,3]. The first of these indicated that functional and self-help skill could be improved in hemiplegic children [2] and the second suggested that improvements were seen in most subjects but in some there was a reduction in function [3]. The conclusion of this second study was the variability of the outcome when performing upper limb injections.

A 3D movement analysis model of the upper limbs had previously been developed and this was used in this study [4]. The hypothesis for the study was that the treatment given would improve upper limb movements at the elbow and wrist joints assessed by performing kinematic analysis, standardised assessment of daily living skills and specific goals for each subject.

Patients/materials and methods

Twelve subjects aged 4–18 years (seven male and five female) were selected for treatment to one arm, nine with hemiplegia and three with quadriplegia. The patients were injected with BTA (Dysport) into elbow flexors, wrist flexors and pronators according to need after an initial assessment. The patients attended a baseline assessment and then an assessment at 6 and 12 weeks. Kinematic analysis using a six camera Elite (BTS Milan) system was performed at each of these sessions whilst the participants performed a standard reaching task. A PEDI assessment was also carried out at each session to assess daily living skills at the final session a carer questionnaire was issued.

Maximal joint excursion, range of excursion and root mean square of error (RMSE) were measured and used to analyse the data.

Results

The results suggest that individuals respond differently to BtA in the upper limb as the mean changes in the treatment group in terms of increased movement were small but the range large thus suggesting that BtA can be useful in selected patients. The results of the study were looked at as a series of case studies to look at individual aims and outcomes.

The carer questionnaires indicated the injections were often perceived to be beneficial and that the parents would support further injections. They also indicated that the main benefit was easier dressing.

Discussion

We found that collecting kinematic data for the upper limb was quite difficult due to the variety of movements possible in the upper limb and problems of markers being obscured. The results from movement analyis are variable. Cosmetic benefits were reported by carers as were improvements in movement which made more tasks easier for carers. The results suggest that if people are motivated to use the affected limb then greater improvements after treatment may be seen.

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S1.6: The effects of ankle–foot orthoses on the gait of children with cerebral palsy after treatment with botulinum toxin a: effects on temporal–spatial parameters and kinematics and kinetics of the proximal joints

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Summary

In this retrospective study, we focussed on the effects of ankle–foot orthoses (AFOs) on the proximal joints after multilevel injections with botulinum toxin A (BTX). Therefore we analysed the gait pattern of 23 children with Cerebral Palsy (CP). The use of AFOs after BTX results in additional beneficial effects on temporal–spatial parameters and kinematics and kinetics of the proximal joints, compared to the effects of AFOs before BTX.

Conclusions

Compared to barefoot walking, the use of AFOs introduced a more economic gait and improved kinematics of hip and knee and kinetics of hip after BTX, which were not obvious (or less significant) pre BTX. However, kinetics of the knee with AFOs post BTX showed that the alignment of the ground reaction force with regards to the knee is not always appropriate. Therefore, retuning of AFOs is of major importance after BTX.

Introduction

AFOs and injections with BTX are both known as successful treatments for children with CP. The positive effects of BTX on the gait pattern are well-described [2,5,6]. But it doesn't always provide the expected effect. The use of AFOs often results in better temporal–spatial parameters and a better position of the ankle in the sagittal plane [1,3,4]. However, for the proximal joints, there is less consistency in the results in literature [1,4]. Therefore, in this study, we mainly focussed on the effects of AFOs after BTX, compared to the results of AFOs before BTX, more specific for the proximal joints.

Patients/materials and methods

Twenty-three children with predominantly spastic type of CP were selected for this study. All of them had a 3D gait analysis with and without AFOs (posterior leafsprings) before and 2 months after BTX. Gait analysis and clinical examination was used for fine-tuning the BTX treatment, resulting in a combination of the following muscles: psoas, hip adductors, hamstrings, gastrocnemius and soleus. As part of the integrated approach, all children received physical therapy and serial casting pre or post treatment. A 3D gait analysis included video-analysis, kinematics, kinetics and EMG using an eight camera VICON data capturing system and three AMTI force plates. Sixty-six parameters, including temporal–spatial parameters, kinematics and kinetics of pelvis, hip, knee and ankle were selected and analysed using the following statistical techniques: paired *t*-test and the mean and RMS *Z* values for the parametric data and Wilcoxon signed rank test for the non-parametric data. A Bonferoni correction was applied per level and per group of parameters resulting in a critical *P*-value of 0.005. Raw data were compared to the data of 31 healthy children.

Results and discussion

Before BTX, the use of AFOs significantly improved gait velocity ($P < 0.0001$), due to an increase in step length ($P < 0.0001$). After BTX, the same gait velocity was reached with an increased step length ($P < 0.0001$) and a decreased cadence ($P < 0.0005$), resulting in a more economic gait. There were no significant changes in the kinematics of the pelvis. At the hip, AFOs significantly decreased internal hip rotation at initial contact pre and post BTX and at midstance and terminal stance (TSt) only post BTX ($P < 0.001$). In the sagittal plane at TSt, AFOs created a more significant increase in hip extension post BTX ($P < 0.0001$) compared to pre BTX. This, in combination with the significant increase in hip flexion at IC ($P < 0.0001$) pre and post BTX, may explain the previously mentioned increase in step length. AFOs combined with multilevel BTX, compared to the AFO gait pre BTX, resulted in an improvement of the maximum knee extension in stance ($P < 0.01$). Increasing knee flexion velocity in swing was found by applying AFOs, both in pre and post BTX condition. AFOs positively influenced the total range of sagittal knee motion, only after BTX ($P < 0.005$). In pre and post BTX condition, the AFOs slightly corrected the prolonged hip extension moment. The maximum knee extension moment increased pre ($P < 0.001$) and post ($P < 0.05$) BTX. Although a better knee extension with AFOs was found in post BTX situation, the knee extension moment increased. This can be explained by an inappropriate alignment of the ground reaction force. This indicates that a good retuning of the AFOs is of major importance after BTX.

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Keynote lecture 1: 11:00 to 11:40

Bringing mathematically optimized biomechanics to clinical gait analysis

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Keynote summary

The current use of biomechanics to diagnose and treat sequelae of cerebral palsy (i.e., associated impairments and disabilities) follows a long history of human movement studies. Instrumented gait analyses appeared in the scientific literature more than a century ago [1,2]. A benchmark three-dimensional study in 1950 used inverse dynamics to estimate forces at the joints [3], but calculations for a single stride took nearly a year to complete. The advent of computers greatly reduced this time, and in the early 1980s clinical gait analysis became practically implemented through a biomechanical model that would become known as the Conventional Gait Model, CGM [4–8]. This protocol forms the basis for the majority of clinical gait analyses performed today in the United States and abroad, but it does so without taking advantage of important technological advances. Unfortunately, the CGM was developed at a time when multiple camera views were hand digitized, limiting the number of motion picture cameras that could be used for data collection. Several undesirable mathematical consequences resulted. There was a lack of control in identifying axes of rotation at joints of interest. Body segments were not tracked independently, but rather, markers on one segment were used to define virtual markers that tracked adjacent segments in a mathematically exact solution. This allowed errors to cascade from the pelvis, through the thigh, shank, and foot segments. Finally, the foot was modeled using only two rotational degrees of freedom.

We believe these fundamental limitations cause inaccurate results in coronal and transverse plane rotations at joints of the lower extremities (classic problem areas for children with cerebral palsy), yet these limitations are no longer necessary. More eloquent, mathematically optimized solutions have been used in research settings [9], allowing body segments to move independently in three-dimensional space by tracking three rotations and three translations (i.e., sliding or gliding motions) for a total of six degrees of freedom (6DOF). A least squares 6DOF approach (LS-6DOF) offers additional accuracy by using an over-determined set of physical markers to track individual segments while accounting for measurement error [10–12]. Least squares kinematics provide more complete input for induced acceleration analyses [13], and may eliminate the need for computationally more demanding least squares kinetics in muscle modeling [14,15].

In this presentation, we compare the CGM with two LS-6DOF models: one in which joint centers and local reference frames are identical to those in the CGM but where LS-6DOF tracking is used, and the other where the hip and ankle centers change as well. We do this theoretically and experimentally, through the study of twenty-five normal pediatric subjects for whom identical strides are analyzed using the various techniques. We interpret statistically significant differences among 20 key gait analysis variables in light of modeling differences and expected levels of accuracy. We also present preliminary results for patients with cerebral palsy.

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Session 2 (oral): 11:40 to 12:52

Gait

S2.1: The influence of 3-month body-weight-loss treatment on selected kinematic gait parameters in obese women

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Summary

The effect of the body weight-loss-treatment on gait parameters were analyzed in 25 obese women. Their spatial and temporal limb movement parameters were compared before and after the treatment and contrasted then to those parameters recorded in the control group consisting of 20 age-matched, lean woman. Gait parameters were recorded while walking with a preferred speed on 10 m computerized gait mat. For analysis purpose the obese group was split into groups A and B, with weight reduction respectively greater and smaller than 9%. After the treatment gait in subjects from the A group was characterized with a decreased single and double support phases and with a longer swing cycle and did not differ significantly from the normal gait profile recorded in the control group. Such positive effects were not observed in the group B.

Conclusions

The body weight reduction (of more than 9% of initial body weight) after 3-month treatment resulted in the adaptive changes of the gait parameters. After the treatment these parameters approached value of these parameters observed in the control group. The direction of the changes suggests that excessive body weight makes the obese women walk differently in order to counteract the altered biomechanical conditions.

Introduction

Now in Europe about 20–30% of adult population is obese. The evidence is overwhelming on the association of obesity to a number of medical conditions. These include: insulin resistance, hypertension, coronary artery disease, dyslipidemia, certain types of cancer, etc. [1]. Excessive body weight and amount of adipose tissue also affects function of locomotor system by limiting joint range of motion and forcing the muscle system to work in altered biomechanical conditions during various physical activities, including walking [2]. Treatment of obesity includes mainly appropriate diet modifications and increased physical activity. Weight loss of more than 10% of initial body weight within the first 3 months of treatment is considered as a desirable outcome of the therapy [1].

Patients and methods

Experimental group consisted of 25 obese women divided into group A (weight loss of >9% of initial weight): $n = 12$, age 23–49 (33.7 ± 7.3 year), BMI_{before}: 30.1–42.8 (36.4 ± 4.5 kg/m^2) – BMI_{after}: 24.3–38.8 (31.3 ± 4.7 kg/m^2) and group B (weight loss of <9% of initial weight): $n = 13$, age 20–53 (35.2 ± 11.6 years), BMI_{before}: 30.6–45.5 (37.3 ± 5.1 kg/m^2) – BMI_{after}: 28.3–35.3 (35.3 ± 4.7 kg/m^2). The control group C consisted of 20 lean women: age 21–52 (37.3 ± 10 years), BMI: 18.7–24.5 (21.5 ± 1.7 kg/m^2) The following gait parameters were evaluated on a 10 m computerized gait mat: walking velocity—v (m/s); stride length (m); cadence—F (cycles/min), gait cycle (s) and time duration of: swing, stance and double support (2support) (% of the gait cycle).

Results

Mean values of the parameters recorded before and after the treatment in group A are presented in table (*t*-test), none of respective parameters recorded in group B showed any statistical significance.

	V (m/s)	Stride (m)	F (steps/min)	Gait cycle (s)	Swing (%)	Stance (%)	2support (%)
A before	1.09	1.23	105.7	1.15	34.41	65.41	15.5
A after	1.12	1.25	106.4	1.14	35.4	64.44	14.62
P	NS	NS	NS	NS	<0.02	<0.04	<0.03
Control	1.03	1.23	99.9	1.21	35.51	64.49	14.49

Discussion

After the weight loss of more than 9% of initial body weight, swing phase of walking becomes longer and support and double support phases become shorter. These changes reflect decreased mechanical load in the limbs. The recorded parameters after the treatment in group A are similar to these observed in control group. Such changes of temporal gait parameters (mainly shortening of support phases) suggest that after the desirable weight loss treatment women do not have to counteract increased impact forces during heel strike and do not need to generate increased propulsive forces required for transferring of their body weight [3].

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S2.2: A prospective study to gait related risk factors for exercise-related lower leg pain

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Summary

A prospective study was conducted to investigate the relationship between gait biomechanics and exercise-related lower leg pain.

Conclusions

The findings of this study suggest that altered biomechanics play a role in the genesis of exercise-related lower leg pain and thus should be considered in prevention and rehabilitation of this pathology.

Introduction

Exercise-related lower leg pain, as stress fractures of the tibia, medial tibial stress syndrome, periostitis, compartment syndrome, is a common and enigmatic overuse problem in athletes and military populations [1]. Especially runners, track athletes and athletes participating in jumping sports as basketball, volleyball and dancing are diagnosed with exercise-related lower leg pain.

Retrospective studies have noted excessive dynamic foot pronation in subjects with a history of exercise-related lower leg pain [2,3]. In addition, static foot posture in subjects with exercise-related lower leg pain also showed pronated foot alignment [4]. However, cross-sectional studies only allow clinicians to establish relationships. Only longitudinal prospective studies can determine cause. Hitherto, no studies have been undertaken to scientifically determine biomechanical intrinsic risk factors of exercise-related lower leg pain on a prospective basis. Therefore, the purpose of the current study was to prospectively determine risk factors for exercise-related lower leg pain in order to increase knowledge of the aetiology.

Patients/materials and methods

Subjects were 400 healthy undergraduate physical education students. Lower leg alignment as plantar-dorsiflexion range of motion, inversion–eversion range of motion, position of the calcaneus and flexion–extension range of motion at the first metatarsophalangeal joint, was determined. 3D-gait kinematics combined with plantar pressure profiles were collected during barefoot running at a speed of 3.33 m/s. The experimental set-up consisted of a 2 m × 0.4 m force platform set into a 16.5 m indoor running surface. Video data were collected at 240 Hz using seven infrared cameras (Proreflex) and Qualisys software. For plantar pressure data a footscan pressure plate (RsScan, 2 m × 0.4 m, 16384 sensors, 480 Hz, dynamic calibration with AMTI), mounted on top of the force platform was used. After the evaluation, all sports injuries were registered by the same sports physician during a certain period. During this period, 46 of the subjects developed exercise-related lower leg pain, of whom 29 subjects had bilateral complaints. So 75 symptomatic lower legs, 35 left and 40 right were classified into the exercise-related lower leg pain group. As control group, bilateral feet of 167 subjects who had no injuries at the lower extremities were selected.

Results

Cox regression analysis revealed that the gait of subjects who will develop exercise-related lower leg pain has typical characteristics of a central heel contact at first foot contact. In addition, at forefoot flat and heel off, these subjects show a foot type, which is more pronated and accompanied with more pressure underneath the medial side of the foot. Resupination is increased and the roll off does not happen across the hallux, but more laterally, probably because of the diminished support at the first metatarsophalangeal joint.

Discussion

The results of this study affirm an earlier statement that increased pronation is associated with an increased incidence of exercise-related lower leg pain. When the rearfoot pronates, the foot becomes a mobile adaptor that allows shock attenuation. Because the rearfoot and knee are mechanically linked by the tibia and because of the inclined axis of the subtalar joint in the sagittal plane, pronation in the foot normally leads to internal rotation at the knee [5,6]. However, as we see in our study that pronation at the rearfoot is increased in our injury group but the internal rotation at the knee is not increased, these motions could be absorbed by musculoskeletal structures in the lower leg itself. This could lead to excessive midtibial torsion stress during the stance phase. On the other hand, increased inversion moments may be associated with the excessive pronation as the invertor musculature attempts to control the motion. This may lead to excessive eccentric traction to the plantar flexor and invertor musculature which has their origin on the medial and posterior region of the tibia. During running, each foot strikes the ground approximately 600 times per kilometre. When each heel strike then generates a strain on the midtibial musculoskeletal structures, the musculoskeletal system may become overloaded and overuse injury is likely to occur.

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S2.3: Movement patterns in frontal plane in Legg–Calvé–Perthes disease

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Summary

The movement pattern in the frontal plane of 33 patients with Perthes disease was analysed. Two different types could be identified: one corresponds to the “Trendelenburg” gait without any load reduction for the affected hip, the other type leads to an unloading of the hip by a shift of the thorax to the ipsilateral hip while the pelvis is in level or elevated during single stance phase.

Conclusion

There are gait deviations in the frontal plane in patients with Perthes disease. A movement pattern which reduces the hip load should be trained and may influence the final result.

Introduction

Legg–Calvé–Perthes disease is a self-limiting, iuvenile osteonecrosis of the femoral head among children 4–10 years of age. The final outcome is dependant on the deformity of the femoral head and the congruity of the hip joint. Till now follow-up- and outcome-evaluations are analysing only subjective results, clinical parameters like range of motion measurements and radiological changes. There are no studies evaluating the functional impairments during gait.

Materials and methods

Thirty-three children (24 males, 9 females, average age 8.0 years) were included in the study. Inclusion criteria were: (1) unilateral hip involvement, (2) age ≥ 6 years, (3) no previous surgical treatment at the hips, (4) no other disorder leading to gait deviations. All children were investigated clinically and radiologically. Three-dimensional gait-analysis was performed with a VICON 512 system. Patients walked at a self-selected speed—barefoot. Kinematic parameters of the thorax, the pelvis and the hip and the kinetic parameters of the hip in the frontal plane were evaluated during single stance and compared to a group of normal children (n = 30, 14 male, 16 female, average age 8.1 years). Therefore the values of all the data points during single stance were averaged from five trials and these were included in the final analysis.

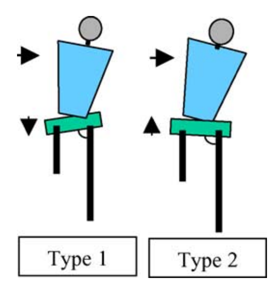
Results

Two pathologic movement patterns could be detected compared to the normal group
Type 1 (n = 3):

- thoracic tilt (in relation to pelvis) towards involved side < 2 s during single stance,
- pelvic tilt towards non-involved side during single stance and/or maximum pelvic tilt,
- during stance phase > 2 s,
- hip adduction during single stance and/or maximum hip adduction during stance > 2 s.

Type 2 (n = 12):

- thoracic tilt (in relation to pelvis) and/or thoracic tilt (in relation to the global system),
- during single stance towards involved side <2 s,
- pelvic tilt during single stance and/or maximum pelvic tilt during stance <1 s,
- hip adduction during single stance and/or maximum hip adduction in stance <1 s,
- at least two criterions fulfilled.



Fourteen patients showed a physiologic movement pattern in the frontal plane. The pattern of the other four patients could not be assigned to either of the types. The abductor moment of the involved side during single stance was reduced in type 2 (0.24 ± 0.09 N m/kg) compared to type 1 (0.43 ± 0.11 N m/kg) and to the normals (0.40 ± 0.08 N m/kg).

Discussion

The load of the hip joint is mainly depending on the internal abduction moment during single stance phase which itself depends on the muscle strength of the abductors. These are commonly weak in Perthes disease. Abductor weakness can be compensated either by a pelvic drop to the swinging limb in combination with a compensating thoracic tilt to the stance limb (Trendelenburg gait) or by a thoracic tilt to the stance limb with the pelvis stabilised (Duchenne gait).

The type 1 pattern corresponds well to the Trendelenburg pattern and can now be defined quantitatively: pelvic drop to swinging limb during single stance >4° and/or maximum pelvic drop in stance phase >8°, thoracic tilt in relation to pelvis to stance limb during single stance phase > 5°, hip adduction during single stance phase >9° and/or maximum hip adduction in stance phase >11°. The increased adduction of the hip joint and the pelvic drop leads to a reduction of the coverage of the femoral head and doesn’t change the load of the hip joint. Therefore this movement pattern is unfavourable for the joint and should be treated by physiotherapy.

The characteristic of the type 2 pattern is a thoracic tilt in relation to the global system of >3° to the stance limb in combination with a pelvis either in level or elevated on the swinging limb side. The ipsilateral trunk lean decreases the external moment about the hip in single-limb support by decreasing the external moment arm of the body weight force and consequently leads to a load reduction of the joint. So this type of movement pattern should be trained in children with Perthes disease.

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S2.4: Are we taller during walking than during standing?

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Summary

Preliminary results are presented concerning spine movements during walking. The distance between C7 spinal process and Sacrum (overall spine length) has been analysed in relation to changes of kyphosis and lordosis in normal subjects (20 teen agers, 14 adults). The mean value computed in

walking was approximately 5% higher than in standing for boys in the 10–12 years age range. Girls in the same age range exhibited relatively smaller percentages of spine length increase (3.6%). Looking at adult groups a negative correlation with age seems to exist.

Conclusions

The increase of the overall spine length during walking, which is related to a reduction of the physiological spine curves, can in turn be related to the state of muscle contraction required to activate the locomotory system. The negative correlation with age, if confirmed, could be explained with a reduced spine mobility. To exploit the potential of these findings in clinical application, these data need to be validated on a wider population, in order to better understand their implications in terms of biomechanics and motor control.

Introduction

Most of the gait analysis studies refer to lower limb joints, and little attention is usually deserved to the trunk. As it is presumable that a reduced spine mobility can affect the gait pattern in a specific way, we have developed a quite comprehensive protocol oriented to the trunk movement analysis [1]. Retroreflective markers were put on lower limbs, pelvis, shoulders, and on eight spine processes from C7 to Sacrum. Looking at the distance between C7 and Sacrum we found out that, surprisingly, during walking this distance was always greater than in standing upright posture. A preliminary investigation was then carried out to confirm and try to understand this phenomenon.

Patients/materials and methods

Ten male and 10 female subjects, in the age between 10 and 12 years old, were analysed through a TV-based motion analysis system while walking barefoot at their natural cadence. The protocol of marker's positioning was the one mentioned above [1]. Additional data were collected on eight male students (24–30 years age range), three female students (20–21 years age range), and one elderly subject (male, 67 years old) with a different, total body protocol, which also included the markers on C7 and Sacrum [2]. The kyphosis and lordosis angles were defined on the basis of the spine markers and were analysed in relation to the overall spine length.

Results

The overall spine length, as defined above, was in all subjects higher during walking than during quite standing. Periodic length changes along the stride, expressed as percent of the standing upright spine length, were in the range from 0.6% (males in the teen agers group) to 1.3% (males in the university students group) with maximum occurring within single limb support, and minimum during double limb support. The average length, computed along the stride cycle as a percentage of the standing upright length, was 5.1% (2.1 S.D.) in the male teen agers, 3.6% (2.6 S.D.) in the female teen agers, 1.2% (1.4 S.D.) in the male university students, and 1.0% (1.1 S.D.) in the female university students. In the elderly subject this value was 1.3% (0.8 S.D.).

Discussion

Two findings are worth investigating: (1) the increase of the average spine length during walking, and (2) the reduction of such an increment with age. First of all the possibility that skin motion artefacts can affect our spine length measurement should be carefully rejected. Some evidence is in favor of the reliability of our data. In fact the physiological spine curves are shown to become less pronounced in correspondence with the increase of spine length. However a special testing protocol is under definition to validate our results, and a systematic testing of different age populations is on planning.

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Muscle

S2.5: Gastrocnemius: a three joint muscle

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Summary

This study uses a musculoskeletal model to analyse the action of the gastrocnemius muscle at the knee, ankle and subtalar joints. The results assist in understanding both the normal function and the effects of pathology.

Conclusions

Gastrocnemius tends to stabilise the normal subtalar joint, hence tightness alone does not account for the subtalar mal-alignment often seen in conditions such as cerebral palsy.

Introduction

Gastrocnemius is a three joint muscle, crossing the knee, ankle and subtalar joints. As such its normal action is complex, becoming more so in the presence of pathology. Musculoskeletal models are useful tools for examining the relationships between cause and effect, particularly when considering muscles which cross more than one joint.

Materials and methods

A musculoskeletal model was constructed using the SIMM software package. It was scaled to average adult male dimensions and validated against published data. The model included knee, ankle and subtalar joints and represented the paths of the two heads of the gastrocnemius muscle separately as a series of straight-line sections. The moment arm of a muscle gives its leverage about a particular joint. Those for gastrocnemius were examined at all three joints. A geometrical analysis of the subtalar axis direction was also carried out for different foot postures, by rotating the foot about an axis through the metatarsal heads.

Results

Gastrocnemius has its greatest moment arm at the ankle joint. The subtalar moment arm is small and posture dependent. Tension in gastrocnemius will tend to pull the subtalar joint towards an alignment of 12° of inversion.

The geometric analysis revealed that the projection of the subtalar axis into the transverse plane moves laterally across the forefoot as the heel rises.

Discussion

Gastrocnemius provides gentle stabilisation for the subtalar joint, inverting an everted heel and moderating extreme inversion. It is perfectly designed to balance normal loading without locking the subtalar joint too solidly.

In children with cerebral palsy, gastrocnemius tightness is frequently seen with subtalar mal-alignment. In fact the subtalar posture and subsequent foot deformity are often seen as consequences of muscular tightness. This study shows that the link is indirect, as the normal action of the gastrocnemius muscle promotes subtalar stability. Other factors must be sought to explain subtalar deformity in cerebral palsy. These might include,

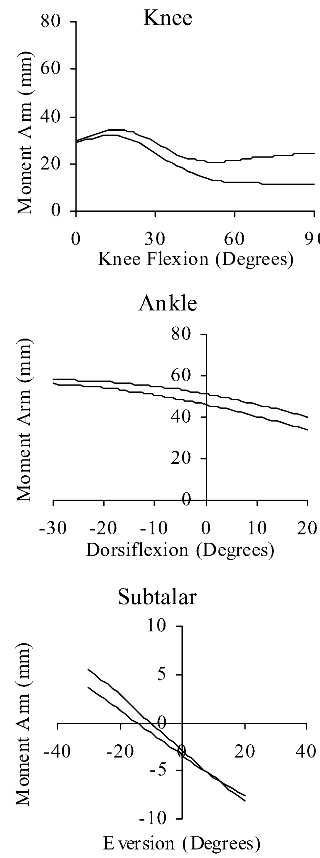

Fig. 1. Moment arm of gastrocnemius (medial and lateral heads) at the knee, ankle and subtalar joints.

- A predominance of forefoot loading, which will have an everting effect when the foot is flat, moving towards inverting as the heel rises.
- Gastrocnemius weakness, either as part of the pathology or as a consequence of treatment.
- Spasticity or weakness of other muscle groups.
- Mal-alignment of the subtalar joint axis or joint disarticulation.

S2.6: Lower limb muscle activity patterns and contraction modalities in gait for healthy growing children and adults

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Summary

Lower limb EMG activity, as well as muscle length patterns were estimated for a large group of healthy growing children. Variability in EMG phases and contraction modalities were described for six age groups.

Conclusions

Different types of EMG patterns were observed for different age groups. Except for the quadriceps, the duration of activity (expressed in percentage of gait cycle) decreased with increasing age. Differences between age groups were mainly found in stance phase. Except for the triceps, the contraction modalities (concentric, eccentric, isometric) were mature at 3 years of age.

Introduction

Significant differences in normal activity patterns of major muscle groups during walking have been described for adults. The main purpose of the study was to quantify muscular activity patterns and contraction modalities for a group of normal children and adults ($N = 78$).

Methods

Sixty-five healthy children, divided in five age groups (from 3 to 4 ($N = 13$), 5 to 6 ($N = 10$), 7 to 8 ($N = 14$), 9 to 11 ($N = 14$) and 16 to 17 years ($N = 14$)), as well as 13 adults, underwent a full body 3D gait analysis. Kinematic and kinetic data were collected using an eight camera VICON system (612) and three AMTI forceplates. Muscle activity of eight lower extremity muscle groups were obtained bilaterally, using a surface EMG system (High-pass filter, 20 Hz, 18 dB/oct + low-pass filter). For each subject, EMG on/offset determination was performed by visual evaluation of the EMG traces (definition of detectible rise in EMG activity above the steady state with 2 S.D. from the rest phase signal as a reference for steady state), for six gait trials at self-selected speed. The activity patterns were averaged per limb. The muscle lengths of Gastrocnemius (GAS), Soleus (SOL), Tibialis anterior (TA), Rectus Femoris (REF), Vastus Lateralis (VL), Biceps Femoris, Semitendinosis and Gluteus Medius were estimated using a four segment musculoskeletal model [1] with lower limb segment and joint kinematics as input for the model. For each age group, frequency of different activity profiles (timing and duration of on/off phases), as well as contraction modalities (shortening, lengthening or isometric condition defined from muscle length patterns) were described and compared to normal adults. Between group differences of activity profiles and duration were compared by the Wilcoxon signed rank test.

Results and discussion

GAS and SOL showed similar activity patterns in the different age groups, however with a slightly increased duration of activity for the youngest children. Triceps activity in terminal swing was frequently observed, especially in the 3–4 years old children. The onset of GAS activity, expressed in % in the gait cycle, delayed from 20.1% for the 3–4 years old children to 27% for adults. The most common contraction modality was eccentric contraction of GAS (lengthening) until 46% of the gait cycle, usually followed by a short period of concentric contraction (shortening of GAS) until 51% of the gait cycle. However, concentric GAS contraction at terminal stance was not recognized for 37.2% of the children of the 3–6 years group, 14.3% of the 7–11 years group and 7.8% for 16 years-adults, which may be related to the electro-mechanical delay. Similar patterns were found for the SOL. Young children more frequently show prolonged activity of TA in stance (46.5% of the children for 3–6 years group, 32.1% for 7–11 years group, and 26.9% in the 16 years-adult). TA activity and contraction modalities in swing were similar for the different age groups, starting with 5% eccentric, followed by 20% concentric activity, a period of variable muscle length, and finally eccentric activity at the end of swing. Terminal swing is characterized by cocontraction of TA and GAS. REF was active from terminal swing until 10–15% of the gait cycle. The EMG amplitude decreased and the duration of activity increased with increasing age. The main contraction modality for REF is eccentric for all subjects, starting at the end of swing phase, preceded by a period of concentric activity in mid-terminal swing. Thirty-three percent of the subjects also showed an eccentric activity for REF around toe off. Hamstrings (HAM) activity was characterized by increased duration of concentric activity in stance for the youngest children compared to adults. Terminal swing showed isometric co-contraction patterns for REF and HAM in all subjects.

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Session 3 (oral): 14:30 to 15:30

Energy Consumption

S3.1: Objective assessment in cervical dystonia

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Summary

The result of the investigation showed no significant difference between Energy Expenditure Index (EEI) from test to retest for patients with cervical dystonia (CD) however there was a significant difference between EEI for the controls. More energy is required for most of the patients with CD to perform active movements in the neck than for healthy persons in this study.

Conclusions

The EEI seems to be a useful measure for detecting and quantifying movement disorder in CD. EEI provides an objective assessment of the movement disorder in CD as supplement to existing scoring systems based on clinical judgement. It may enable an objective outcome measure of the response to treatment and in comparing effectiveness of different therapies.

Introduction

The aim was to characterize and quantify the irregular movements in CD by using an estimate of the mechanical power and work involved in the movements, described through an energy expenditure index (EEI) and to present EEI as an objective measure for assessment of CD.

Patients/materials and methods

Six subjects with CD were compared with six healthy subjects in this pilot-study. A three-dimensional motion capture system (ProReflex camera system) was used. The subjects were seated in front of a screen with a laser pointer attached to a headband while they performed standardized movements. A test-retest was performed.

Results

There was no significant difference between EEI from test to retest for the CD patients however there was a significant difference between EEI from test to retest for the controls. The mean value of EEI was significantly higher for the CD patients than for the controls.

Discussion

It is interesting to note that the result showed no significant difference between EEI from test to retest for the CD patients however there was a significant difference between EEI for the controls. This might be due to an effect of learning which the CD patients were unable to obtain. The movement disorder seemed to dominate over the effect of learning. As a result of treatment patients with CD often find it less demanding to perform active movements compared with before the treatment. The use of an energy concept, applied as an EEI in this study, might catch the subjective feeling of an easier and smoother way to perform active movements for CD patients after treatment. One limitation of the method is the requirement of a sitting position because many patients find that the deviation is maximal only in connection with dynamic activity such as walking. The EEI focuses on the external feature of CD and so far it is not known if this measure changes that are important for the patient themselves.

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S3.2: The one-minute walk test as a predictor of oxygen cost in chilren with cerebral palsy

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Summary

The ability of a 1 min walk test at a child's maximum walking speed to predict energy efficiency during gait in children with bilateral cerebral palsy (CP) was assessed. Distance covered during a 1 min fast walk was compared to steady state oxygen consumption during a 5 min walk at self-selected speed.

Conclusions

A moderate correlation between the walking test and energy efficiency was demonstrated.

Introduction

Walking tests are used frequently in respiratory medicine to quantify exercise tolerance. Simple measures such as walking speed over short distances have correlated strongly with measures of function in children with CP [1], however the ability of a 'fast' walk test to predict energy efficiency in the CP population has not yet been assessed.

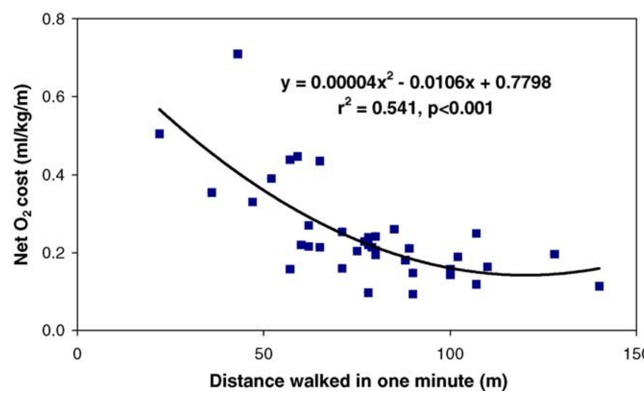
Patients/materials and methods

Sixty-three children with bilateral CP gave consent to participate in this study. All participants were able to walk at least 10 steps with or without assistive devices, but the assistance of another person was not permitted.

The 1 min walk test was carried out on an oval 20 m level track. After resting for 5 min, children were asked to walk as fast as possible around the track for 1 min. Distance was calculated using markings on the track. Oxygen consumption was recorded using the Cosmed K4b^2 telemetric system. Children rested for 5 min, then walked around the 20 m track for 5 min at their normal walking speed and finally rested again for 5 min. Net oxygen cost recorded during the final 2 min of the walk was used for analysis.

Results

Thirty-seven children (15 female, 22 male; range 4–16 years; mean age 11.79 [±3.24]) were able to complete both tests. Of the 26 children who did not complete the O_2 consumption protocol, 8 refused to participate, 12 were too physically restricted and 6 and were unable to comply with the procedure due to learning disability. A quadratic model offered the highest unadjusted correlation coefficient and demonstrated a moderate correlation ($r = 0.736$) between the two variables as shown in the figure below.



Discussion

The moderate correlation obtained between distance walked during a 1 min fast walk and the net oxygen cost of gait suggests that the 1 min walk test may be an adequate predictor of energy efficiency in children with bilateral CP in the absence of more sophisticated oxygen consumption testing equipment. The reduced compliance with the O_2 protocol further suggests that a 1 min fast walk may be a useful adjunct for testing more disabled children in the clinical environment.

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S3.3: The effect of walking speed on net-nondimensional oxygen cost

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Summary

A new normalization scheme was applied to oxygen data acquired from able-bodied volunteers walking at various speeds.

Conclusions

Net nondimensional (*NN*) oxygen cost is markedly different than traditional (mass normalized) cost. Many of the features of the *NN* cost versus nondimensional speed plot appear consistent with a suitable measure of gait efficiency.

Introduction

Gross oxygen utilized per unit distance (O_2 cost) is a widely accepted indicator of overall gait efficiency. Because O_2 cost varies with the size of the subject, the data is usually divided by subject mass (*G*/*m* normalization). The *G*/*m* normalization scheme has been shown to be inadequate in several previous studies [1–3]. The current study examines the speed dependence of a new normalization scheme that is based on the use of net oxygen consumption (Gross–Rest) and the non-dimensional gait variables proposed by Hof et al. [3,4].

Materials and methods

Existing data from 194 able-bodied volunteers were analyzed. The test protocol consisted of 3 min quiet sitting followed by 6 min of barefoot walking at free, slow, and fast speeds with rests between conditions. Volume flow and oxygen concentration of inspired and expired gases were measured on a breath-by-breath basis. Steady state values for sitting cost, gross walking cost, and walking speed were computed. The O_2 costs were computed using the two normalization schemes (Table 1).

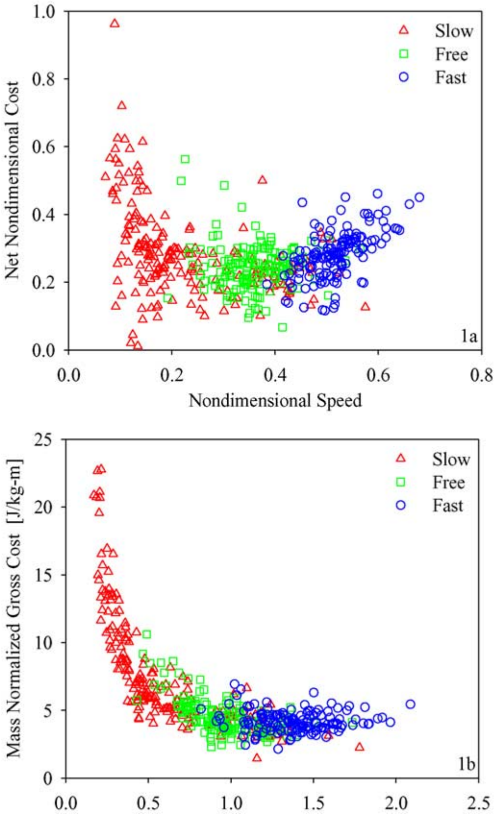

Fig. 1. Cost vs. speed. The *NN* curve exhibits a broad minimum about the free (self-selected) walking speed and a rising trend at higher speeds. In contrast, the *G/m* cost strongly resembles 1/speed.

Table 1. Cost normalization schemes

	G/m	*NN*
Speed	v	$\frac{v}{\sqrt{gL_{\text{leg}}}}$
Consumption	$\dot{O}_2^{\text{gross}}$	$\frac{\dot{O}_2^{\text{gross}} - \dot{O}_2^{\text{rest}}}{mg\sqrt{gL_{\text{leg}}}}$
Cost	$\frac{\dot{O}_2^{\text{gross}}}{mv}$	$\frac{\dot{O}_2^{\text{gross}} - \dot{O}_2^{\text{rest}}}{mgv}$

Results

The *NN* and *G/m* costs are plotted relative to their corresponding speed variables (Fig. 1).

Discussion

NN oxygen cost exhibits a physically plausible dependence on normalized speed; a broad minimum centered about the free speed and a concave upward curvature at high speeds. In contrast, *G/m* cost clearly exhibits implausible traits; an asymptotically rising cost at decreasing speeds, and constant (or falling) cost with increasing speeds. While *NN* cost appears to rise at slow speeds, the exact form of the curve in this region is still uncertain due to the wide variation in the data and possible underestimation of resting energy. This has significant implications for patient populations (such as cerebral palsy) where slow walking speeds are the norm.

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S3.4: A study on maturation of oxygen rate and cost during walking and the influence of net non-dimensional normalization using sitting and standing data

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Summary

To study maturation of energy expenditure (EE) it is suggested that obtained data should be normalized for height and body weight. We studied the normalization for mass and leg length using the generally accepted normalization to body mass and the net non-dimensionally method recently proposed by Schwarz et al. [2] for a group of children between 3 and 17 years and adults.

Conclusions

EE during walking decreases with increasing age suggesting a mechanical and/or physiological maturation. The tendency seen on mass normalized data does not change after net non-dimensional normalization. Both sitting and standing data can be used for net non-dimensional normalization of walking data.

Introduction

Oxygen rate (VO_2/kg/min) and cost (VO_2/kg/m) are widely accepted criteria to estimate EE during walking. In order to study maturation normalization to body weight is widely accepted. The purpose of this study was to evaluate the development of O_2-consumption data in growing children and to verify wetter the differences on mass normalized data remain when parameters are net non-dimensionally normalized to mass, leg length and time.

Patients/materials and methods

In this study 38 healthy children, divided into three age groups (3–6 years ($N = 13$), 9–11 years ($N = 13$), 16–17 years ($N = 12$)), and 13 healthy adults received a breath-by-breath O2-consumption measurement (Cosmed K4b2) using a protocol of 5 min sitting, 3 min standing and 8 min walking on a figure eight shaped track at a self-selected speed [1]. Average data on O_2-rate were calculated for the last 2 min of sitting, the last minute of standing and a steady state of 3 min in the second half of walking, as well as velocity and O_2-cost. Obtained data for velocity, O_2-rate and cost were normalized twice by the net non-dimensional method using both sitting and standing data to calculate net O_2-consumption [2]. For all age groups mean and S.D. were calculated and visualized in graphs. We used the Wilcoxon signed rank test as a common heuristic to decide upon the statistical significance of the observed differences between the groups.

Results and discussion

O_2-*rate* decreased significantly by increasing age ($P < 0.02$), only the difference between the first two age groups was not found to be significant. *Net normalized rate* also decreased significantly by increasing age, but the difference between the two youngest and the to eldest age groups was no longer significant. O_2-cost decreased significantly ($P < 0.01$) through all age groups, but for *net normalized cost* the difference became less significant. These results indicate mechanical and/or physiological maturation of EE during walking, where gait pattern and/or aerobic capacity become more efficient. When influence of mass and leg length is corrected by net non-dimensional normalization, difference between age groups remains but, becomes less significant.

No significant difference was found between net non-dimensional normalization for rate and cost, using either sitting or standing rate to calculate net O_2-consumption. These results are confirming our findings for mass normalized rate and cost, where we could not find a difference between sitting and standing data. This implicates that final results would not be influenced by using sitting data for net normalization in children and adults. If the same could be observed in patient population, disabled children and adults could benefit from these findings.

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S3.5: Age related kinetic changes in normal children from 3 to 16 years of age: energy flow is a learning process

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Summary

Kinetic profiles were described for children from 3 to 17 years of age. Power and moment normalized to body mass in general increased with increasing age and non-dimensional power (normalized to mass, length and time) decreased at the ankle and knee and increased at the hip. Young children use the ankle as the main power generator, whereas adults use both ankle and hip as power generators.

Conclusions

Kinematic results of the study indicated that 6 years old children showed maturity for the majority for the gait parameters, while kinetics revealed that fine tuning of the energy profiles still develop significantly at a later age. Lack of control of mainly bi-articular muscles results in an immature control of gravitational forces.

Introduction

Normal subjects potentially have the muscular capacity to generate the movements by the best ‘energy management’ solution that they can adopt. However, what is true in adults is not necessary true in children. The purpose of the study was to report and delineate significant kinetic differences during gait, observed between age groups in a large pediatric database.

Methods

Sixty-five healthy children, ranging in age from 3 to 4 ($N = 13$), 5 to 6 ($N = 10$), 7 to 8 ($N = 14$), 9 to 11 ($N = 14$) and 16 to 17 years ($N = 14$), as well as 13 adults, underwent a full body 3D gait analysis. Kinematic and kinetic data were collected using an eight camera VICON system (612) and three AMTI forceplates. Muscle activity of eight lower extremity muscle groups were obtained bilaterally, using a surface EMG system. Three representative trials (at a self-selected speed) were selected bilaterally, and averaged. Both joint moments and powers were normalized with respect to the subject body mass, and were presented as non-dimensional parameters as described by Hof (Gait and Posture, 1996: 222–223), to normalize for all body dimensions (mass, length and time). Mean data and S.D. for 49 gait parameters, as well as averaged joint angles, moments and power graphs were calculated. The Wilcoxon Signed Rank test was used to compare the differences between the mean data of the different age groups. An analysis of covariance was conducted for a selection of the gait parameters to evaluate the possible influence of gait velocity on the differences between age groups. Mean power of hip, knee and ankle per age group were integrated over the time, representing the total work done at each joint.

Results

The present study mainly focused on kinetic data: internal joint moments, power, and total work done. *When normalized to body mass*, the hip abduction moment during stance significantly increased from 3 to 16 years ($P < 0.0001$). Young children showed premature, but significantly reduced hip and knee flexion moment in stance, increased moments in swing and decreased peak plantar flexion moment in terminal stance ($P < 0.0001$). With increasing age, ankle power absorption and generation (A1, A2) increased, however, the latter parameter was found to be significantly influenced by walking velocity. The H1 hip power generation burst and the K3 knee power absorption burst were significantly decreased ($P < 0.0005$) in young children, with a mature pattern established at 9 years of age. Except for hip extension moments, *non-dimensional moments* were stable, however, non dimensional ankle and knee power (A1, K1 and K4) significantly decreased with increasing age ($P < 0.0001$). Non-dimensional hip power generation (H1 and H3) significantly increased with increasing age ($P < 0.0001$). *The mean work* output of the different hip power bursts was found to be 0.33 J/kg in normal adult walking, with a gradually decrease to −0.03 J/kg in 3–4 years old children.

Discussion

Power and moment normalized to body mass in general increased with increasing age, however, non-dimensional power bursts decreased at the ankle, knee and increased at the hip. Careful study of the power graphs and of the total work done during one gait cycle revealed young children fail to create sufficient positive hip work. Adults use both the hips and the ankle joint as power generators (respectively 43.7% and 44.6% of the total amount of positive work), while at the knee joint, power is mainly absorbed. For young children, the ankle joint is the main power generator (56%) and power is absorbed both at the knee and the hip.

Poster Session 1: 15:30 to 16:30
Gait

P1.1: Toe-walking gait patterns

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Summary

A cluster analysis was applied to the kinematic ankle gait pattern of 27 toe-walking children with different diseases. Three distinct groups were revealed. Some causes of these different patterns were identified by a statistical analysis of clinical measurements according to groups.

Conclusions

Gait analysis and cluster analysis highlighted three groups in toe-walkers with clinical characteristics. Further studies will be required to understand all the causes of different ankle gait pattern in toe-walking.

Introduction

Toe-walking is associated with several neuromuscular diseases such as cerebral palsy, myopathy, neuropathy, spinal dysraphism and pervasive development disorders [1] and idiopathic toe-walking when no cause was known. Studies [2–7] investigated a way of differentiating between diseases in comparing averages and peaks of kinematic, kinetic, EMG variables during gait or functional exercises. The ascending hierarchical cluster method was used with success to classify gait patterns [8]. This study sets out to investigate the pattern of ankle kinematic during the stance phase not to distinguish between diseases but to understand toe-walking.

Methods

Twenty-seven children (five suffering from muscular dystrophy, three from neuropathy, five from mild cerebral palsy, five presenting a pyramidal syndrome and nine classified idiopathic toe-walkers) were selected for their toe-walking pattern. A 3D optoelectronic system (Vicon 512) was used to acquire kinematic. Each side was studied independently, so 54 ankle patterns were considered. The mean of three to six trials per subjects was processed. A physical examination was performed including range of movement, manual muscular testing and spasticity by the same physical therapist. An ascending hierarchical cluster method was used to classify the 54 ankle kinematic patterns during the stance phase. Clinical measurements of groups obtained were compared with ANOVA and Tukey post hoc ($P < 0.05$).

Results

Three groups were revealed by cluster analysis. The first group (G1) had a short dorsiflexion followed by a long plantarflexion. The second group (G2) revealed an "M" aspect of the ankle flexion/extension. The third group (G3) presented a long dorsiflexion with a subsequent short plantarflexion. G1 showed a significant higher passive dorsiflexion knee flexed than G3, and a significant lower plantarflexion than G3 and G2. G3 presented a lower strength in the triceps surae and in the tibialis anterior than G1 and G2, and a lower spasticity than G2.

Discussion

Toe-walkers were classified according to kinematic ankle gait pattern in three groups which seemed correspond functional clinical characteristics. Toe-walking causes in group G3 were muscular weaknesses, maybe the incapacity of tibialis anterior to raise up the foot during the swing phase or compensation for quadriceps weakness. The difference between group G1 and G2 could be the ability of using stored energy in triceps. The group G1 could have more contractures and G2 could have an abnormal triceps surae contraction as suggested by Tardieu et al. [9]. These findings could be influence directly the therapeutic management of toe-walkers.

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P1.2: The value of gait analysis as a decision-support tool for pediatric physical and occupational therapists: a pilot study

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Summary

Eight pediatric physical and occupational therapists (PTs and OTs) without training or experience in gait analysis (GA) participated in a pilot program to assess its value of as a decision-support tool. The program included a training session, the opportunity to participate in GA of a patient immediately before and after a therapeutic intervention, participation in the processing and presentation of GA data, and discussion of the results with other participants in the program.

Conclusions

Every therapist felt that the information obtained via GA enhanced the quality of their decision-making relative to the patient in question, and expressed disappointment that regular access to GA was not available.

Introduction

Computer-assisted gait and movement analysis technologies have more than 35 years of history as a research tool, and more than 25 years of increasing use as a decision support tool for pediatric orthopedic surgeons. An NIH workshop in 1996 included the recommendation that gait analysis be considered part of the "standard of care for ambulatory children with cerebral palsy prior to surgery" [1]. In contrast, GA is seldom used as a decision-support tool by PTs or OTs, even though the improvement in quality and quantity of information about gait that GA offers relative to visual observation could significantly improve the development, implementation, evaluation, and modification of interventions.

Patients/materials and methods

Eight pediatric therapists (seven PTs and one OT) participated in this pilot program. The program included 12 h of lectures and demonstrations about gait, biomechanics, computer-assisted videography, force platforms, and surface EMG. Then, each therapist selected a patient from their caseload in need of a decision regarding the efficacy of a therapeutic intervention relative to gait. The interventions included a variety of orthotic devices, heel lifts, supportive garments, weighted garments, and walkers. The potential clinical significance of the analyses were discussed in a classroom setting, related research literature was obtained, and GA was performed, including the collection of three-dimensional kinematics, surface EMG of selected muscles, and foot-to-floor forces with an integrated hardware and software system provided by Ariel Dynamics Inc. (San Diego, CA, USA).

Results

Each patient demonstrated clinically significant differences in their gait before and after the interventions mentioned above. Most interesting to the therapists were previously unnoticed changes in transverse plane joint kinematics, patterns of muscle activation, and patterns of foot-to-floor forces. Without exception, each therapist felt that the data gathered in the laboratory enhanced the quality of their decision making relative to the patient and intervention in question, and expressed disappointment that access to a GA laboratory was not generally available to pediatric physical and occupational therapists.

Discussion

The use of gait analysis as a decision-support tool for PTs and OTs does have value, at least in the judgment of a small group of therapists with specific training and experience. A recent pilot project directed at orthotists had similar results [2]. It took many years for GA become established as a decision-support tool relative to pediatric orthopedic surgery, and it is likely that a similar process will occur relative to physical and occupational therapy. Much more rigorous research will be required to establish the objective value of GA relative to its contribution to the quality and/or cost-effectiveness of pediatric physical and occupational therapy interventions.

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P1.3: 3D gait analysis of transfemoral amputee

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Summary

This paper reports on a study concerning gait analysis of nine transfemoral amputees. Ground reaction force evaluation is associated to measure of kinematic data to put in relief general patterns in relation with amputee's handicap. Individual scheme are also determinate to guide prosthese's components' choice and to propose reeducation program.

Conclusions

The evaluation of nine trans-femoral patients has been performed with the protocol described in this paper. Measures will be realised on a great number of patients to confirm these preliminary results. We will construct a data base which will be very useful to determine the influence of prosthetic components on gait.

Introduction

Gait analysis studies on trans-femoral amputee generally concern motion analysis of joints during gait but are limited to the sagittal plane [1,2]. This paper reports on a protocol developed for studying kinematics of prosthetic and sound side joints, pelvis and trunk in three planes. An evaluation of the ground reaction force is associated to the kinematic study. Coping mechanism are shown for nine trans-femoral patients using motion analysis results.

Materials and methods

The kinematics were recorded using a 5 camera Vicon 250 motion analysis system (oxford Metrics). Synchronised with the sampling of the kinematic data, three components of ground reaction force and moment are measured by 2 AMTI force plates. Two video cameras are used to capture movie data. Gait analysis is non-invasive. The procedure begins with a clinical examination. Secondly a static trial is captured to locate anatomical landmarks. Finally, the patient performs 10 trials (45 min per patient). The biomechanical model is composed of six articulated rigid bodies located by 15 reflective markers. Mathematical treatment with the software Matlab produces kinematic and ground reaction forces curves in three planes. Results are normalized according to the gait cycle and compared to motion analysis of a group of 19 asymptomatic subjects.

Results

Results shows common gait defaults for the nine patients tested as for example concerning pelvis tilt or asymmetry of gait phases. We also can analyse the individual coping mechanism of each patient by reading curves of different joints motions at the same time. For example we show a great anteversion of the pelvis for one patient which is associated to a significant deficiency of flexion of the prosthetic knee during swing phase.

Discussion

The choice of prosthetic materials (foot and knee) affects pelvis and hip motions. Gait analysis can then help for this choice. However, an other essential parameter of amputee's gait quality is reeducation. General and individual results of gait analysis are useful to propose a scheme of reeducation adapted to the patient and evaluate its efficiency.

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P1.4: Kinetic abnormalities in idiopathic toe-walkers

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Summary

This study looks at the kinetics, electromyography (EMG), and temporal parameters of idiopathic toe-walking children (ITW) compared with children who have spastic diplegic cerebral palsy (CP) and able-bodied children walking on tip-toe (AB).

Conclusion

Many similarities have been demonstrated in the kinetics, EMGs and temporal parameters between ITW, CP and AB. However, certain subtle differences have been shown which may assist in the diagnosis and therefore treatment of these patients.

Introduction

Idiopathic toe-walking was first described in 1967 by Hall et al. [2]. It is a condition in which children persistently toe-walk and develop tightness of the plantarflexors but no distinct neurological abnormality is detected. As a consequence of toe-walking and plantarflexor tightness, in the older child, a planovalgus foot deformity may occur. Several previous studies have assessed the kinematic differences between ITW and AB [1,3]. The kinetics of this latter group have also been compared with that of children with spastic diplegia [1]. No studies, to our knowledge, have looked at the kinetics and temporal parameters of ITW. The aim of this study was to identify differences and similarities in these parameters between the three groups (ITW, AB and CP) to aid differential diagnosis.

Methods and results

Internal moments and powers of 29 ITW have been compared with AB and CP. Expected similarities between all three groups that were observed included: (1) early increase in plantarflexion moment at the ankle with a 'double bump' pattern; (2) decreased terminal stance plantarflexion moment; (3) increased peak ankle power absorption at loading response; (4) decreased ankle power generation at terminal stance; (5) premature gastrocnemius activity. The ITW group were found to resemble more closely the AB group than children with CP. Decreased hip power in terminal stance is shown in AB and the majority of ITW but not in CP. As expected, sagittal knee moments in early stance are flexor in the ITW and AB groups, but extensor in CP.

Unlike the AB group, ITW showed a decreased hip abduction moment in stance and a decreased knee valgus moment in stance. In the literature, it is suggested that AB children walking on their toes show co-activation of tibialis anterior and gastrocnemius in stance (1). We have not shown this to be the case. In the AB group, tibialis anterior did not display the usual second burst of activity. A variety of patterns were seen in CP patients. In ITW, the second burst was either absent or a period of continuous activity in swing was observed. Double limb support, as a percentage of the gait cycle, was found to be increased in the AB group and those with cerebral palsy, but decreased in the ITW. Velocity tended to be reduced in all three groups.

Discussion

The kinetics, EMGs and temporal parameters of the three groups have been examined in an attempt to determine which of the gait analysis findings are a result of the biomechanics of toe-walking and which are due to the underlying abnormality. The extensor knee moment which was observed in the CP group was due to abnormal knee flexion in early stance. This differentiated it from the other groups. The EMG findings in the ITW group were similar to AB subjects walking on their toes. However, changes in hip and knee moments in the ITW were a distinguishing feature of this group and may be due in part to planovalgus positioning of the feet. This may be a relative indication for treatment of the tight plantarflexors to avoid possible long-term secondary effects on the more proximal joints. The increase in double limb support seen in the AB children may be due to their lack of fluency with toe-walking. However, this is the preferred gait for ITW and may account for the reduction in double limb support.

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P1.5: Navicular drop as a predictor of rearfoot motion during gait in healthy adults

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Summary

Previous research has tried to identify a correlation between static foot measures and dynamic foot function with controversial results. Navicular drop and rearfoot motion of 16 healthy subjects without excessive pronation were measured and no statistically significant correlations were found.

Conclusions

Navicular drop appears not to be an appropriate static measurement which correlates with rearfoot motion in healthy subjects. Nothing can yet been said about the correlation in subjects with abnormal pronation.

Introduction

To date there is no significant evidence to suggest that static measures will predict dynamic foot function. So far, controversial results have been published. The evidence shows that no correlation could be found between (1) footprint analysis and gait [3], (2) medial longitudinal measures and gait [2] and (3) various angles of the lower leg and dynamic function [4]. In running, a correlation between rearfoot motion and X-ray measurements could be found (Navocenski et al., 1998) and McPoil and Cornwall [4] reported a correlation between navicular height test and total rearfoot excursion. Navicular drop (ND) is one static measurement and is thought to measure the amount of pronation where ND > 15 mm was seen as abnormal [1].

The aim of this study was to analyse if ND is correlated with maximum eversion and rearfoot range of motion (ROM) during the stance phase of gait.

Patients/materials and methods

Healthy subjects without impairment in walking and no excessive pronation (ND < 15 mm) participated in this study. Ethical approval for the study was granted by Glasgow Caledonian University and verbal consent was given by all subjects. ND was defined by the difference between the distance from the tuberositas naviculare to the supportive surface in subtalar neutral and relaxed standing position. The mean of three measurements was used for analysis. Gait analysis was carried out with seven ProReflex cameras and a Kistler force plate with a sample frequency of 100 Hz. Markers were attached to define the shank and heel segment. Subjects were asked to walk as normal as possible. Force data were used to identify heel strike and toe off. Rearfoot ROM and maximum rearfoot eversion were calculated using Visual 3D Software and correlations were calculated with SPSS 11.5 for Windows.

Results

Sixteen subjects with a mean age of 30 years (22–42), mean height of 1.75 m (1.63–1.88), mean weight of 78.2 kg (59–104) and a mean ND of 10 mm (3–14) participated. The results of Pearson's correlation between the maximum eversion and ND, and the total rearfoot ROM and ND are shown in Table 1. Level of significance was $P < 0.05$.

Table 1. Results Peason's correlation (r)

	Left foot	Right foot
Max. eversion-ND	$r = -0.431$ ns	$r = -0.165$ ns
Rearfoot ROM-ND	$r = 0.435$ ns	$r = -0.324$ ns

Discussion

This study indicates a non-significant correlation between rearfoot ROM and ND and maximum eversion and ND. This does not confirm the findings of McPoil and Cornwall [4] although it is not clear from their paper if they assessed navicular drop or navicular height. The results of the present study must be viewed with caution due to the small sample of subjects with a ND < 15 and therefore further research is required.

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P1.6: Does a change in functional assessment score predict a change in gait?

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Summary

Repeated scores from the Gillette Functional Assessment Questionnaire (GFAQ) were compared with changes in walking speed assessed in the gait laboratory, and estimated walking distance (EWD), in 20 subjects with cerebral palsy. A change in the GFAQ correlated well with changes in non-dimensional walking speed (NDS). However an unchanged score did not appear to indicate unchanged walking ability and large changes in speed were seen in this group. There was a poor correlation between EWD and both the GFAQ and NDS.

Conclusions

This study shows a good level of agreement between changes recorded in a repeated GFAQ and changes in walking speed in the laboratory. However large changes in self selected walking velocity were seen even when there was no change in the GFAQ, suggesting that an unchanged score may wrongly imply maintenance of previous levels of walking ability. Estimated walking distance appears to be a poor indicator of function.

Introduction

The GFAQ is a validated method of assessing walking ability in children with cerebral palsy [1]. Subjects attending our laboratory for gait analysis routinely complete the GFAQ and also estimate the distance that they are able to walk in the community without a rest. We wondered if changes in walking function were reflected by changes in the GFAQ score or EWD. Self selected walking speed is acknowledged to be a consistent and repeatable measure, which is reduced in proportion to the severity of the disability [2] and is correlated with many other gait parameters [3].

Patients/materials and methods

Data was reviewed from 20 independent ambulators with cerebral palsy who had attended the laboratory for repeat gait analysis. The mean interval between analyses was 13.2 months. There was no intervention between the two analyses. The subjects or their carers completed the GFAQ and gave an estimation of walking distance on both occasions. Spatio-temporal data were collected during independent barefoot walking at self selected speed using a motion analysis system (Vicon). Non-dimensional walking speed was calculated from five trials recorded at each visit [4]. The NDS, EWD and GFAQ scores from both sessions were compared, and changes recorded.

Results

Analysis of the changes using the Spearman's rank correlation coefficient showed a significant correlation between the change in GFAQ score and the change in NDS ($r_s = 0.602$, $P_s = < 0.01$). There was a poor correlation between the changes in EWD and GFAQ ($r_s = 0.24$, $P_s = > 0.05$) and between EWD and NDS ($r_s = 0.123$, $P_s = > 0.05$) (Fig. 1). When the changes between the two sessions were examined further 20% had a decrease in both the GFAQ score and in the NDS. Forty percent had an increase in the GFAQ score and of these, 75% also had an increased NDS. The GFAQ score was unchanged in 40% of subjects and in these subjects with 37.5% had an increased NDS and 62.5% a decreased NDS.

Discussion

The results show that a change in the GFAQ score is related to a change in NDS. The results are less clear in subjects where no change of GFAQ score was recorded between two analyses, where large differences in walking speed were recorded. Unfortunately there are insufficient data in this study to fully assess the sensitivity and specificity of the score. Estimations of walking distance correlate poorly with both NDS and GFAQ. It would be informative to re-examine the changes

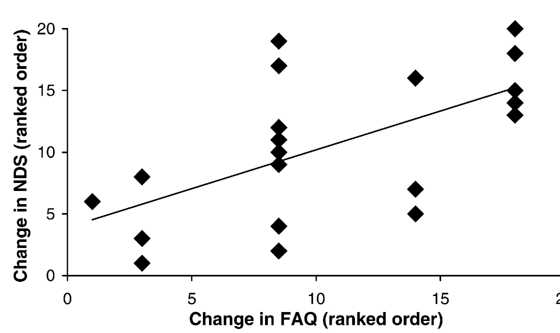

Fig. 1. Correlation in the change in GFAQ and NDS ranked order.

in GFAQ scores in relation to a larger number of variables from the gait data, and with a larger sample.

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P1.7: Gait kinematics and kinetics using biokin motion analysis system

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Summary

This paper presents the procedures used in ELEPAP Gait Analysis Center, for collecting gait kinematics and kinetics, using the BIOKIN motion analysis system.

Conclusions

ELEPAP Gait Analysis Center has already analysed more than 150 patients using BIOKIN motion analysis system. BIOKIN motion analysis system has been proved a reliable low cost solution for collecting and analysing gait kinematics and kinetics.

Introduction

As computing power is getting more affordable and flexible to collaborate with various peripherals, different motion analysis systems are being developed for Gait Analysis. BIOKIN motion analysis system is a low cost reliable solution, for the analysis of kinematics and kinetics. The system has been developing since 1992 and is being used for Gait Analysis in ELEPAP Gait Analysis Center since 2001.

Patients/materials and methods

BIOKIN motion analysis system [1,2] is based on the technology of digital video, computer hardware and software. A calibration frame is used for the Direct Linear Transformation (DLT) [3] of 3D coordinates. Two AccuGait AMTI force platforms are used for collecting kinetics. BIOKIN software provides tools to measure the spatial coordinates of vertexes of interest. These vertexes have first to be defined in the software and declared as the model of the analysis. A 19 vertexes model, which includes: Trunk, Pelvis, Thigh, Shank and Foot is used for Gait Analysis. The system grabs videos from four synchronized cameras. The phase of digitisation of vertexes is done by manual and semi-automatic methods. Various digital filters are available for raw data smoothing. A database system supports the data storage and retrieval processes. The system automatically calculates trajectories, velocities, accelerations, segment angles, angles between segments, angular velocities and accelerations etc. A force visualization module is also available. More than 150 patients have been analysed using BIOKIN system.

Results

Results of kinematics and kinetics are represented by various methods which include qualitative and quantitative data. 2D and 3D stick figures together with video images, graphs, normal graphs and tables are available to organize and present the data. For direct comparison of movements, the systems allows overlapping two or more trials, and includes functions to synchronize movements on a specific vertex or a specific time moment. Results are available for export to other applications making report creation an easy task.

Discussion

As gait analysis is getting more and more accepted as a clinical tool for the management of gait disorders, the need of affordable solutions is raising. ELEPAP Gait Analysis Center has found a reliable and affordable solution, by using the BIOKIN motion analysis system.

References

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P1.8: An assessment of DynaPort®Minimod for identifying gait cycle events during normal and pathological gait

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Summary

The DynaPort®Minimod system is shown to identify gait cycle events automatically in a range of patient pathology in close an agreement with those identified using a conventional 3D/forceplate combination.

Conclusions

The DynaPort®Minimod system appears to offer a practical alternative to foot switch systems in identifying gait cycle events which is particularly relevant in cases of severe gait pathology. The study demonstrates a clinically acceptable degree of agreement between the classic 3D and force plate combination gait analysis system and a DynaPort®Minimod for identifying gait cycle events.

Introduction

Initial (heel strike in normal gait) and final foot contact (toe off in normal gait) are the absolute cornerstones for the analysis of gait as a cyclic activity. However, the identification of initial and final foot contact with the floor during walking can often prove a difficult, time consuming and unsatisfactory part of the processing of 3D/EMG gait analysis studies. The claim that the DynaPort®Minimod system provides a means for identifying gait cycle events accurately and automatically is challenged in a blind comparative study carried out in a range of patient pathologies and severities.

Patients/materials and methods

A DynaPort®Minimod system was applied to the sacral area (just between and above the PSIS's) of patients' who attended the Ghent Gait Laboratory for routine clinical gait analysis. A series of walks along a 12 m walkway were recorded according to the normal laboratory data collection protocol. The laboratory consisted of a full 3D motion analysis system (VICON 612) with two force plates (Kistler). The electronic outputs of a modified DynaPort®Minimod module remote control unit were used with the external electronic start/stop trigger facility (input) on the VICON 612. This enabled the desktop DynaPort®Minimod stop/start button unit to be used to synchronously start and stop both the DynaPort®Minimod datalogger (100 samples per second) and the VICON data collection (120 samples per second). The force plate data and marker trajectories were used to identify gait cycle events using the VICON software according to standard laboratory practice.

Results

Preliminary results based only on the initial contact show a mean absolute difference between the DynaPort®Minimod based and conventional 3D/Forceplate System based identification of 0.013 s (S.D. = 0.012) with a maximum absolute difference of 0.05 s.

Discussion

Typically, the vertical component of force plate data during a single foot strike (the gold standard reference) together with ankle/foot marker data (secondary/silver timing reference) are used to identify gait cycle events during a single walk through the 3D calibrated volume of a gait laboratory. This methodology is supported by automated software routines in the VICON Workstation software and works very well for many subjects/patients. However in the more severe pathology where short and variable step lengths are more often observed obtaining a single foot strike on a force plate is more difficult. Furthermore, the ankle and foot marker trajectories, used to identify non-force plate initial and final foot contacts using a logical correlation process, become much more varied. Eventually the correlating relationship between force plate strikes and more variable ankle/foot marker data becomes inaccurate and finally fails. Frustratingly it is in these more severe patient groups that the muscle firing patterns and the evolution of kinematics and kinetics is more critical. Furthermore such patients are least able to perform more walks/trials in order to statistically improve the representative sample of their gait parameters. Foot switch systems [1] are an ideal solution but the availability of commercial patient and user friendly systems is very limited. In addition the effort of applying foot switch systems to the patient is yet another time consuming task which adds to an already labour intensive gait assessment. This study illustrates the potential cost effectiveness and ease with which the DynaPort®Minimod system can be integrated with 3D movement analysis tools such as the VICON system.

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P1.9: Joint siffness and gait pattern of patients with down syndrome

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Summary

In this study a quantitative objective evaluation of the gait pattern of Down's syndrome (DS) children is presented. In particular the relationship within ligament laxity, which is a typical aspect related to DS, flat foot condition and joint stiffness is investigated.

Conclusions

This study quantify the great differences of walking pattern of children with DS. An high percentage of patient with DS demonstrated flat foot and alteration in ankle and hip joint stiffness. These alterations seems to be related to ligament laxity and hypotonia that occur in these patients. These information may be useful in order to better define rehabilitation program of these patients for that sometimes a not specific treatment is applied. In these last years this problem is more and more important because the life expectation of DS subjects is increasing. The demand to know closely the locomotor problems and their importance to increase the quality of life is born from these considerations.

Introduction

Down's syndrome (DS) is often related to cardiac problems, respiratory insufficiency, mental retardation and orthopedic anomalies of medium or high entity. The pathology presents effects also at a motor level: it is possible to notice that people with Down's syndrome present a general hypotonia and a ligament relaxation that, together with an insufficient development of cerebellum and the peripheral nervous system, concur to retard the learning of the various movements and posture. The main treatments are focused, first of all to solve the great problems that permit to the patients to live and after that orthopaedic intervention are evaluated. The intervention in the sphere of locomotor recovery are aimed to the resolutions of orthopedic problems with orthesis as preliminary treatment at surgery operation in the gravest state. Besides this from the evaluation of clinical literature seems that there isn't a valid rehabilitation program for all cases: every single child is different from the others and he needs a therapy that faces his specific situation. The aim of this work is defining locomotor patterns of Down syndrome, with a particular reference to the ligament laxity, and its possible consequences in particular flat foot condition and joint stiffness alteration, to identify therapeutical courses that improve the general condition of a patient.

Materials and methods

Nine-eight children with DS (mean age 11.7 years, range 6–15 years) and 30 children without pathologies (CG) (mean age 11 years, range 5–13 years) participated in this study. All the subjects were volunteers and their parents gave their informed consent to participate in the study. All patients were analyzed with an interdisciplinary clinical functional assessment, RX analysis of the foot, video-recording, Three-Dimensional Gait Analysis and evaluation of plantar pressure distribution (pedobarography). Parameters of particular interest were: Temporal–spatial parameters (Gait speed, Stride length); kinematic indexes (angles at Initial Contact (IC), maximum flexion angle, minimum flexion angle, range of motion for each joint in sagittal plane); kinetics indexes based on flexion extension joint pattern. The evaluation of flat foot condition was done by using the data of electronical pedobarography. The dynamic hip, knee and ankle (Kh, Kk, Ka) joint stiffness were computed by plotting the values of flexion–extension moment versus flexion–extension angle in the second rocker interval and fitting data with a linear regression: the angular coefficient of linear regression corresponds to the joint stiffness index.

Results/Discussion

Subjects with DS underlined a decrease of gait speed (0.42 ± 0.08 m/s cm) and of stride length (0.29 ± 0.04) versus the values of CG (gait speed 0.85 ± 0.06 m/s cm; stride length 0.89 ± 0.09). Hip: in pathological gait the trace of hip flexion–extension has the same shape of control group but it is shifted in flexion position during all the gait cycle. From initial contact to midstance the moment is flexor, even if in a progressive decrease after a maximum at 15% of gait cycle. Knee: at IC pathological group showed an increase of flexion. Also the increase of flexion at midstance confirms the attitude of subjects with DS to maintain thigh flexed during stance. Ankle: at IC the ankle of subjects with DS was in a plantar-flexion position more accentuated than in CG, that confirms the attitude of pathological to effect the IC with forefoot rather than heel. The kinetic data revealed the absence of the plantar-flexor moment for the DS patients: in this condition the ground reaction was in an anterior position respect the ankle and produced an immediate dorsal-flexor moment. Joint stiffness: K_a shows a decrease for subjects with DS (0.058 ± 0.05 N m/kg °) versus CG (0.103 ± 0.014 N m/kg °): this decrease could be associated to the presence of ligament laxity and hypotonia, that often occurred in DS; Kh showed a general increase in patients with DS (0.058 ± 0.025 N m/kg °) despair the CG (0.028 ± 0.007 N m/kg °): this increase may be related to a mayor cover by the acetabolum on hip joint (1) that can limit the natural movement of hip. Flat foot condition was present in the 93% of DS patients.

Reference

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P1.10: Biomechanical gait analysis of obese children

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Conclusions

The degenerative articular deformations, such as problems with the hip and knee joints, at the early age are significant. In childhood because of obesity the articular surfaces are unilaterally loaded and the fat accumulates on the thighs resulting in valgus angulation which predestinates the early arthrosis of those joints.

Introduction

The increasing incidence of childhood obesity raised concern in 1990, when around 18 million children under the age of five were declared overweight [6]. Unfortunately, their number is still increasing in spite of the known data.
One UK survey [2] revealed that the ratio of overweight pre-school children rose from 14.7 to 23.6% and obese children from 5.4 to 9.2% between 1989 and 1998 [4].

Patients and methods

The gait of 10 obese but otherwise healthy children (age: 8.6 ± 2.6) was recorded by video. During three-dimensional video analysis and digitization 3D kinematical parameters were assessed on the basis of which the gait sample could be analyzed.

The recordings were taken with two cameras. The analysis was carried out with the APAS video image processing and motion analyzer system developed by Ariel Life System Incorporated (San Diego, California, USA) [1]. Two whole step lengths were examined, the evaluation of which was carried out with the help of an 18-point body model.

Results

Even in case of the youngest child we experienced deviations compared to the healthy way of motion. The differences in the kinematical parameters: the step-length decreases significantly ($P < 0.05$) and the same statement is true for the whole step cycle. On the other hand, they do not keep up with step cycle that increases together with the age. The width of step increases significantly ($P < 0.05$) and it shows a unidirectional, positive relation with overweight, while with age it does not. The longitudinal axis of feet, the angle between the feet and the gait direction is connected with the extent of obesity and is often (80%) accompanied by walking on the inner side of the feet (tilted ankle) [5].

The step length and number of steps per minute did not show any definite result.

Among the elements of harmonic gait, the angle of the pelvis is significantly larger 8 ± 2°, while the lateral movements of the pelvis are greater than the physiological value (60%).

Discussion

The gait sample of heavily overweight children changes due to their body structure and their supposedly lower need for exercises [3]. On the basis of the biomechanical analysis advice can be given both to the therapeutical team and the parents in order to prevent childhood obesitas and to start an early, effective therapy.

Due to the deviations in the motion structure they have to live with articular deformities. As they become older the situation usually gets worse as a result of adult obesity, often to an extent that influences the quality of life significantly.

On the basis of the experienced biomechanical deviations a possibility to prevent articular problems that start at the early age is suggested.

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P1.11: Predicting the progress of recovery based on gait analysis in post stroke patients

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Summary

The aim of this paper is to use gait analysis to classify patients who have suffered a stroke. Using measured kinematic parameters of patients' gait and neurological deficit scales, we attempted to predict the progress of recovery after rehabilitation therapy.

Conclusions

1. Post stroke patients can be classified into three groups (forefoot, flat foot, heel) based on their initial foot contact with the ground.
2. There is a correlation between these groups and patients' test scores.
3. The greatest progress of recovery can be expected in the "forefoot" group.

Introduction

Stroke is regarded as a leading cause of disability throughout the world [1]. It is very difficult to predict the progress of recovery in patients after stroke. This difficulty is related to variability in the severity of the neuromotor deficit, weakness of muscle function and the presence of concomitant medical disorders [2]. It would be useful to be able to predict patients' improvement in a way that is simple, clinical, but confirmed by biomechanical instruments which are precise and reliable. The objective of this study was to examine the relationship between patients' gait pattern and their disability scale scores and to evaluate which group demonstrated the greatest progress of recovery.

Materials and methods

Seventy-five subjects in the early recovery period, up to 6 months after the first incident of stroke, volunteered to participate in the study. Morphological characteristics of the subjects are presented in Table 1.

Two types of assessments were performed: (1) a clinical assessment based on the results achieved from three neuromotor deficit scales (Rivermead, Barthel, Scandinavian) which were performed twice, before and after the rehabilitation therapy, and (2) a walking assessment performed while each subject walked unassisted for 5 m, recorded by two cameras operating at a frequency 60 fr/s. A motion analysis system (APAS) was used for collecting data. Three types of patients were selected: the "forefoot," "flat foot" and "heel" groups.

Table 1. Characteristics of the subjects participating in the present study

	Females (30)			Males (45)		
	Age (years)	Mass (kg)	Height (cm)	Age (years)	Mass (kg)	Height (cm)
Mean ± S.D.	56 ± 12	65.6 ± 7.4	163 ± 3.6	59 ± 8	79.7 ± 6.9	174.3 ± 4.1
Range	28 ÷ 75	51 ÷ 82	158 ÷ 172	33 ÷ 72	59 ÷ 100	165 ÷ 186

The differences in the mean values of the disability index (defined as the weighted sum of normalized scores from the assessments performed) between groups of different initial foot contact patterns were evaluated using ANOVA for repeated measures. Newman-Keuls' test was applied to check if the groups differed from each other and in which one the greatest progress was observed.

Results

The mean values of the disability index in the second measurement amounted to 0.2 in the "forefoot" group, 2.8 in the "flat foot" group and 4.0 in the "heel" group. The ANOVA test for repeated measures revealed the presence of significant differences between groups ($P < 0.001$) as well as a significant correlation between groups and measurements. The increase in the Scandinavian and Barthel tests was significantly different in each group ($P < 0.05$). Progress was observed in each group and the greatest improvement was noticed in the first group. The increase of this index amounted to 2.9, 2.7 and 1.4, respectively.

Discussion

Quantitive gait analysis can be used to evaluate functional abilities [2]. Gait patterns demonstrate a close relationship with the neurological deficit and determine the improvement in post stroke patients. Our findings suggest that a classification based on the groups presented above is useful in predicting the progress of recovery.

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P1.12: Prognostic functional test in muscular dystrophy: progressive stenic defect in DMD walking

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Summary

Gait features in a Duchenne muscular dystrophy population were analysed in relation to a number of test parameters and Vignos functional assessment scale. The results showed a good correspondence between the different observations, although the dynamic information obtained from gait analysis allowed us to identify many different behaviours within the same functional group. This can help understanding the adopted compensation strategies, and to help preserving their efficacy.

Conclusions

Degeneration of gait patterns in Duchenne muscular dystrophy is tightly related to the progressive weakening of muscles and the need for compensation attitudes. A comprehensive analysis of biomechanical variables can lead to precise classification and patient monitoring.

Introduction

Many different parameters can be used to describe the functional ability of myodystrophic patients. Locomotion, however, is a complex task in which not only muscle force, but motor coordination as well is fundamental for a good performance. This makes the relation between the usual functional assessment parameters and walking capability quite complex. The objective of the present study was to find out correlations between several functional assessment approaches and patterns of walking as they can be quantified through gait analysis.

Materials and methods

Our test population was composed by 24 subjects (age range 4–11 years), whose Duchenne muscular dystrophy (DMD patients) was documented by total absence of dystrophine and deletion. Gait analysis was performed according to Davis protocol [1]. A relevant quantity of kinematic and kinetic variables was obtained, although our attention was mainly focussed on few of them: pelvic orientation in space, as a mean to reveal dynamic compensation along progression of the disease, and flexion–extension angles at hip, knee, ankle joints, as a mean to put in evidence the anti-gravitary effort in presence of progressive muscle weakness. Muscle force was assessed through subjective scores in the range 0 (no appreciable force) to 5 (normal force)—our patients scored 3–4 concerning the antigravitary muscles), and presence of joint deformity (few subjects had knee flexion contracture and equinus-varus supination of the foot). The following functional tests were considered: capability of rising from lying on the floor without assistance (time was measured); possibility of walking fast (or to accelerate to a given extent); capability of climbing and descending stairs (at least five steps, 16 cm high), without any external support; capability of standing up from a progressively lower chair (45, 30, 20, 10 cm of seat high). The locomotory ability was assessed as follows: heel walking possible; heel walking impossible, but plantar foot support physiologic; early appearance of dynamic hyper-lordosis; hyper-lordosis accompanied with anserine gait (wide trunk oscillations in the coronal plane); terminal walking (hyper-lordosis, anserine gait, equine foot). The test population was subdivided into five groups according to the Vignos functional scale [2].

Results

The four patients in the first Vignos group exhibited an almost normal gait pattern, with a enhanced horizontal rotation of the pelvis, and occasionally forward tilt. In the second Vignos group the anteversion and pelvic obliquity were more evident, in addition to large horizontal rotation, on almost all the patients. Patients in the third Vignos group exhibited a further enhanced pelvic obliquity. This same attitude became a constant determinant in the Vignos groups 4 and 5. Concerning the joint angles, few inconsistent abnormalities appeared in patients in Vignos group 1. As far as the Vignos score worsened, the patients exhibited: (a) a progressive tendency toward a constant hip flexion (the first appearance was a reduction of the hip extension at mid stance); (b) a progressive reduction of the knee yielding at load acceptance (the knee became completely rigid (extended or partially flexed) in patients in the Vignos group above 3); (c) the foot progressively assumed the equinus-varus-supinated attitude, still exhibiting a physiologic Initial Contact in Vignos 1, flat foot or digitigrade initial contact in Vignos 2, pronounced plantarflexion and supination in Vignos 3 (few cases had a structured deformation at one foot), severe foot deformation in Vignos 4 and 5 (15–20° of lacking dorsiflexion, in most cases bilaterally) that corresponded to a quite reproducible double bump pattern, wide pelvic rotation and obliquity, flexed hip and rigid knee during stance phase, enhanced rising of the knee joint during swing phase.

Discussion

The severity of walking pattern exhibited by our DMD patients was quite consistent with their functional score. However within the Vignos groups a diversity of motor behaviour was observed, according to the different individual conditions. As a consequence it appears that a combination of different quantitative observation can contribute to better understand the functional limitations and the compensation strategies.

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P1.13: Repeatability of ground reaction force data during normal gait

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Summary

The repeatability of the ground reaction force (GRF) data was determined, along with the minimum number of trials required to achieve a certain level of reliability, during the analysis of normal gait. A piezoelectric force platform was used to record the GRF data during 15 gait trials. Appropriate statistical measures were then used to determine the repeatability of the GRF data and the least number of trials that should be performed during gait analysis.

Conclusions

It was found that the repeatability of all GRF data was very high. Moreover, three trials were enough to achieve a more than sufficient level of reliability for the GRF data, during the analysis of normal gait.

Introduction

Gait analysis is widely used for diagnostic and treatment planning purposes, in subjects with several neuromuscular dysfunctions in the lower limbs. However, the measurement of gait characteristics is still subjected to various sources of errors, which contribute to the variability of the measured data, of both normal and pathological gait. Thus, the soundness of the conclusions drawn on gait analysis depends on the repeatability of the gait data. Repeatability is also closely related with the appropriate number of trials that must be performed, in order to obtain reliable measures, during gait analysis [2]. The purpose of the current study was the determination of the repeatability of ground reaction force data during normal gait.

Materials and methods

Twelve subjects with a mean age of 21.2 ± 1.1 years and no neuromuscular dysfunctions in the lower limbs, voluntarily participated in the study. The subjects performed 15 gait trials, at a normal speed, on a walkway 20 m long. The vertical (Fz), horizontal fore-aft (Fy) and medial–lateral (Fx) components of the GRF were recorded during the right stance phase of the gait cycle, in each trial, by a piezoelectric force platform (Kistler) that was located in the middle of the walkway, at a sampling frequency of 1200 Hz. To determine the repeatability of the ground reaction force data, the coefficient of multiple correlation (CMC) [4] and the intra-class correlation coefficient (ICC) [1] were used. Moreover, the Spearman-Brown prophecy formula [2] was used to calculate the least number of trials required to achieve a 0.95 level of reliability, which is considered particularly high for reliability purposes [3].

Results

The results showed that all coefficients were very high for both Fz and Fy components. More specifically, for Fz the ICC_{15} value was equal to 0.999 in all subjects, while the mean values of the ICC_1 and the CMC_{15} were 0.990 ± 0.003 (range: 0.985–0.995) and 0.994 ± 0.001 (range: 0.992–0.997), respectively. For Fy, the mean values of the ICC_{15}, the ICC_1 and the CMC_{15} were 0.998 ± 0.0 (range: 0.998–0.999), 0.989 ± 0.004 (range: 0.982–0.996) and 0.994 ± 0.002 (range: 0.991–0.998), respectively. Regarding Fx, the mean values of the ICC_{15} and the CMC_{15} were 0.994 ± 0.002 (range: 0.990–0.997) and 0.961 ± 0.014 (range: 0.935–0.981), respectively. Moreover, the mean value of the ICC_1 was 0.925 ± 0.026 (range: 0.876–0.964). The results also showed that for the vertical and horizontal fore-aft GRF a single trial was more than enough to produce reliable data during gait analysis. However, up to three trials were required to achieve the 0.95 level of reliability for the horizontal medial–lateral GRF data.

Discussion

It was found that the repeatability of the vertical and horizontal fore-aft GRF was greater than that of the medial-lateral GRF. This is in close agreement with the findings of previous studies [2,4]. However, since all gait parameters have to be measured together, it was suggested that three gait trials have at least to be examined, in order to obtain reliable force measurements during gait analysis.

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P1.14: Plantar pressure distribution asymmetry during normal gait in healthy Greek adults

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Summary

The plantar pressure distribution during normal gait was measured, in healthy Greek adults, by two insoles equipped with capacitive sensors. Peak plantar pressure and maximum average pressure was then calculated for several anatomical regions of the two feet. The results showed large asymmetry of both parameters, between the two feet, in all regions.

Conclusions

It was found that the limits of normality, regarding plantar pressure distribution asymmetry during gait, are large. Nevertheless, they can be used to relate the results from a given patient, in order to support the diagnosis of foot pathologies.

Introduction

The asymmetry of a patient's plantar pressure data between his two feet, in comparison with that of a healthy person, is often used to support the diagnosis in various foot pathologies. In these cases, the establishment of proper normal reference range for plantar pressure asymmetry during normal gait is crucial. These normal range have to be derived from large samples of healthy human population in order to be representative and this can be accomplished by many independent studies, in several human samples [1]. The purpose of the current research was to determine the normal range of plantar pressure distribution asymmetry during gait, in healthy Greek adults.

Materials and methods

Fifty-seven healthy men (age: 24.02 ± 5.4 years) participated in this study. They walked on a 20 m long walkway with natural speed. Plantar pressures were recorded at 50 Hz from both feet using two insoles (Novel GmbH, Munich). Each insole was equipped with 99 capacitive sensors (sensor area 1 cm^2). The subjects performed 10 trials and the recordings were made for both feet during one gait cycle, in the middle of the walkway. During data reduction each footprint was divided into 10 regions [1]: medial heel (MH), lateral heel (LH), medial midfoot (MM), lateral midfoot (LM), first metatarsal (1 M), second metatarsal (2M), lateral metatarsals (LMe), hallux (Ha), second toe (2T) and lateral toes (LT). To determine the asymmetry, between the two feet, in the regional peak and average maximum pressures, the symmetry index (SI) proposed by Robinson et al. [2] was calculated.

Results

The results showed that large asymmetry existed both in the peak plantar pressure and the maximum average pressure, between the two feet, in each region. The mean SI for the regional peak plantar pressure ranged between 14.32% (2M region) and 44.55% (LT region), while that for the maximum regional average pressure ranged between 13.67% (2M region) and 36.80% (LM region). The limits of normality were then defined by the 95% confidence intervals for the SI in each region.

Discussion

The large asymmetry in plantar pressure distribution between the two feet, during normal gait, may be related to the asymmetries that have been found in other gait parameters, in previous studies [3]. Although the reasons for this natural asymmetry remain unclear, it could be associated with the different contribution of each lower limb to the propulsion and control of the body during gait [3].

References

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P1.15: The analysis of the correction of a flat foot in rheumatoid arthritis based on the investigation of the ground reaction forces during walking

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Summary

The flat foot is a very common deformation in rheumatoid arthritis (ra). The correction by using of insole (wedge) under the head of the first metatarsal bone was investigated. The function of this insole was reproducing the active point of the support of the foot in this place. The distribution of the ground reaction forces (length of the propulsion of the foot) by Computer Dyno Graphy System was measured.

Conclusions

The investigation has shown, that after using the insole, the length of the propulsion of the foot during the single limb stance increased and became similar with the control group. The insole also corrected deformation and relieve the load the painful callosities pleased under the heads of the II, III and IV metatarsal bone.

Introduction

The flat foot is a very common deformation in ra. It becomes more and more deformed and painful while the progress of the inflammatory process. It may contribute to the overloading of different segments of the locomotor's system particularly the knee joint. From that reason using the proper insoles both relieve the load, correct and may prevent from the overloading of the higher segments. The deformation characterises the heel valgus and supination of the forefoot against tarsus. One of the three supports of the foot, the head of the first metatarsal, is elevated and does not play the stabilising role. One of the methods correcting the deformation is using the insole (wedge) below the head of the first metatarsal.

Patients/materials and methods

Fifty-six flat feet (rheumatic) of 40 patients (mean age 53 years) were examined. Control group consisted of 30 women (mean age25). The locomotion was examined by using the Computer Dyno Graphy system, which measured the ground reaction forces on a sole of the foot during walking. Examination was performed before and after the foot correction.

Results

The analysis of the ground reaction forces shows that the length of the propulsion in a single limb stance after using the insoles increased significantly ($P < 0.001$, Wilcoxon, $z = 4.05$). The mean value before the correction was 7.43 + 2.9, after 8.29 + 2.63 cm.The length of the propulsion in patients had smaller values both before and after the correction comparing to the control group (mean 11.68 $\pm$ 1.25). The increase of the length of the propulsion after the correction approximated to the results achieved in the control group. The correction improved as well the foot position and subjective senses of the patients.

Discussion

The problem of the rheumatic foot is complex (pain, the restriction of the range movement, muscles weakness). These symptoms cause that the insoles in rzs should be selected individually with special care. The correction of the tarsus by Thomas heel, if it is possible, does not bring the expected effects very often. It depends on the stage of the foot deformation [3]: if the foot is movable when it bears body weight, or it is unmovable when it bears body weight, but it is movable relieve the load or it is stiff. For better foot position it is often necessary to use the wedge under the head of the first metatarsal with the additional support (wedge) of the medial arch. Such kinds of the insole relieve the load painful callosities placed very often under the heads of II, III and IV metatarsals. The orthopaedic insole is a very important element of the whole process of physiotherapy.

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Table 1. Schematic outline of the systematic evaluation of gait parameters. Upper rows: box 1–5 (see text); final rows: example for one item (HA = hamstrings; QF = quadriceps femoris)

box 1		box 2		box 3		box 4		box 5
description of required 21 kinematic parameters (in specific gait phases) derived from conditions I – V	→	observation of deviations of each reference kinematic parameter	→	identification of each observed problem with tests for differential diagnosis (*physical exam (PhEx); EMG*)	→	describing specific targets for treatment	→	definition of rationale for treatment and expected outcome related to gait (and conditions I-V)
example for 1 item (out of 21)								
reference parameter		***observation:***		***identification (differential diagnosis)***		***target for treatment:***		***clinical decision***
#17: full knee extension in loading response to terminal stance for condition I, II, IV, V	→	. limited knee extension (in load response to terminal stance)	→	see below	→	. muscle shortening HA	→	**rationale of treatment**: lengthen HA to achieve full knee extension in stance. **expected outcome on conditions:** **I.** more stability in stance **II.** better contralateral foot clearance **IV.** increased step length **V.** more efficient gait

possible cause?	*test*	*+/-*
. bony limitation ?	PhEx	-
. muscle length HA ?	PhEx	+
. spasticity HA ?	PhEx	-
. hyperactivity HA ?	EMG	-
. flexion synergy ?	PhEx	-
. muscle strength QF?	PhEx	-
. co-activation HA –QF?	EMG	-
. compensation ?	---	-

P1.16: A systematic interpretation of gait analysis and physical examination parameters in relation to treatment hypotheses

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Summary

A structured system to interpret (kinematic) parameters of gait and physical examination in relation to treatment hypotheses is introduced, based on the five conditions of walking defined by Gage [1]. Twenty-one kinematic deviations are recognized and related by differential diagnosis to either possible primary causes or compensations. This finally yields targets for intervention and expected outcomes that can be evaluated for success of treatment.

Conclusions

The systematic evaluation is a practical way to interpret the outcome of gait analysis and physical examination in relation to primary pathological causes and compensation strategies to support treatment decisions.

Introduction

To assess the neuro-musculo-skeletal status of a patient with pathological gait, different examinations are available: first, gait analysis (video recordings, kinematics, kinetics, kinesiological EMG): second, the standard clinical examination (range of motion; testing muscle strength and control, assessment of balance, observation of functional tasks, X-rays); third, the examination of range of motion under general anesthesia. Each of these examinations contributes significant and specific information to attain final treatment hypotheses. It is quite complicated to combine all types of information; to distinguish between primary and secondary gait parameters (i.e. cause and compensation); to decide about a treatment plan; and to predict the expected outcome of each specific intervention on the general gait pattern. This paper aims at defining a systematic evaluation guided by the five major conditions for gait [1], i.e. (I) stability in stance; (II) sufficient foot clearance; (III) appropriate foot-positioning at terminal swing; (IV) adequate step-length; (V) energy conservation.

Methods and results

Table 1 shows the five subsequent steps of the systematic analysis in the upper rows of boxes. Starting-point for the systematic evaluation is describing the kinematic parameters in gait that are required to meet each major treatment condition (I–V). This is outlined in a reference table of 21 kinematic parameters (box 1), related to the movement characteristics of the joint in specific gait phases. This reference table is used as a checklist during the evaluation of pathological gait, i.e. to describe all deviations to these 21 kinematic parameters (box 2). To identify possible causes (differential diagnostics) of kinematic deviations, a set of standard tests (mainly based on physical examination and EMG during gait) is linked to each parameter (box 3). This part of the process is intended to distinguish between primary causes and compensation. When no primary causes are found for a specific kinematic deviation, this might be attributed as a compensation. However, this compensation must be in relation to another observed kinematic deviation for which a primary cause has been established. This results in definition of all treatment targets (box 4). Finally, an explicit rationale for specific treatment must be described, which directly defines the kinematic parameters that should be improved in order to conclude successful treatment after evaluation, i.e. the expected outcome (box 5). The final rows of Table 1, show an example for only one of the possible 21 kinematic parameters of gait. This example is drawn from a complete decision scheme on a clinical case of a child with CP that is evaluated pre- and postoperatively.

Discussion

In general, clinical decision making will benefit from explicit reasoning. The introduced system is based on theoretical and common sense considerations about the relation between kinematic parameters and the five conditions of gait [1]. It is aimed to reduce the complexity of clinical decision making especially in an educational context. For this purpose it appears to be a clear and a quick way to interpret and combine all information from gait analysis and physical examination. Next step is implementation and validation of this systematic evaluation as a basic template in regular clinical practice. Also further refinement (e.g. the role of muscle length testing under anesthesia) will be necessary.

Reference

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Methodology

P1.17: The footprint method of transmalleolar axis measurement: repeatability and comparison with other methods

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Summary

Three clinical methods of measurement of determining the transmalleolar axis (TMA) were investigated for repeatability and agreement between methods.

Conclusions

There was poor agreement between the methods suggesting that they should not be used interchangeably. The footprint method proved easy to use and was the most repeatable of the three methods tested.

Introduction

Transmalleolar axis (TMA) measurements are frequently used to determine tibial torsion. The TMA estimates the angle formed between a line intersecting the medial and lateral malleoli and the transverse axis of the knee.

Method

Twelve normal subjects (three male, nine female, age range 21–61 years, mean age 38) were studied. The left and right limbs of each subject were measured using each method. The measurements were repeated for six subjects between 5 and 10 days later. All measurements were undertaken by the same assessors.

The *prone* method: With the subject prone and the knee flexed to 90°, two marks were made on the sole of the foot vertically above the malleoli, and a line drawn between them. A manual goniometer was used to measure the angle between this line and the estimated knee axis (assumed to be 90° to the long axis of the thigh).

The *footprint* method: With the subject in sitting, the hip in neutral rotation and the tibial tubercle facing forward, the foot was placed on a piece of lined paper. The paper was lined up with the long axis of the thigh, so that the lines were parallel with the knee axis. Two marks were made vertically downwards from the centres of the malleoli using a small set square. A line was drawn between these two marks and the angle measured between this line and any line on the paper.

The *jig* method: The lower limb was placed in a tropometer, with the tibial tubercle aligned with a central marker. A distal frame attachment allowed the location of centres of the malleoli to be identified, and the angle read off on the attached scale.

Results

The footprint and prone mean values were close to those found previously using similar methods [2,3]. The jig method produced lower values than those found in a comparable study [4].

The mean TMA values, repeatability [1] of each method and agreement between the measures was as follows:

Method	Mean value (n = 24)	Coefficient of repeatability (n = 12)	Methods	Mean difference	Standard deviation	Limits of agreement
Footprint	12.5° (S.D. 3.5)	5.36	Footprint and jig	2.46°	3.71	−5.0 to 9.9°
Jig	10.6° (S.D. 4.1)	9.04	Footprint and prone	−8.28°	8.25	−24.8 to 8.2°
Prone	21.2° (S.D. 10.1)	14.67	Jig and prone	−10.74°	8.90	−28.0 to 7.1°

Negative is external.

Discussion

The large coefficient of repeatability for the prone method may have been due to variation of foot position when marking the sole, and lack of control of knee rotation when using this method. A variation in tropometer design may explain the lower mean values found for the 'jig' method in this study.

References

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P1.18: A new technique for accurate measuring of knee flexion–extension angle using body-fixed sensors

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Summary

A new method of measuring 2D knee angle using a combination of accelerometers and gyroscopes is presented. The method proposes a minimal sensor configuration with one sensor module mounted on each segment. In the proposed technique, the joint angle is found without the need for integration, so absolute angles can be obtained which are free from any source of drift. The model considers anatomical aspects and is personalized for each subject prior to each measurement.

Conclusions

The proposed method based on body-fixed sensors gave an accurate (<0.70 ± 2.0° error) estimation of absolute knee angle in sagittal plane. The algorithm was able to provide joint angles in real-time, and to be used in gait analysis. Technically, the system was portable, easily mountable, and it could be used for long term monitoring without hindrance to natural activities. The method was found promising, and the next goal is to estimate lower limbs trajectory during daily activities.

Introduction

In the quest for an alternative to optical motion analysis systems which are often used in the study of human movement, body-fixed sensors have been recently used. Body-fixed miniature sensors consisting of accelerometers and gyroscopes can be used to obtain joints and segments kinematic values, allowing to realize low-power, ambulatory recording systems carried by the subject for long-term measurements. This study presents a new method for real-time and accurate estimation of knee angle in sagittal plane. It is based on a combination of accelerometers and gyroscopes.

Patients/materials and methods

Two modules of sensors, each containing two accelerometers and one gyroscope, were used. The sensors were mounted on the left shank and thigh segments using a strap. The model is based on processing the outputs of a pair of virtual sensors placed at the joint center of rotation on the adjacent segments. The relationship between a physical accelerometer reading (S_i) at P_i and its corresponding virtual accelerometer reading (S'_i) at C (Fig. 1) can be expressed as:

$$S'_i = R_{-\beta_i}\left(R_{\alpha_i}\begin{bmatrix} S_{xi} \\ S_{yi}\end{bmatrix} + \begin{bmatrix} -r_i\omega_i^2 \\ r_i\dot{\omega}_i\end{bmatrix}\right),$$

where the index *i* gets the values 1 and 2 corresponding to thigh and shank, ω is the gyroscope reading, R_α and R_β are axis rotation matrices of the physical and virtual sensors to the direction of *r* by angles α and β, respectively. Since both S'_1 and S'_2 express the acceleration of the same point C, they should have the same modulus, while their arguments' difference yields the knee joint angle (φ). The model was personalized by including anthropometric data and accurate position of sensors obtained by photography. Ten healthy subjects, aged between 44 and 70 years, participated in this experiment. The volunteers performed three 30 s flat treadmill walking trials at speeds 2 km/h, 3 km/h and 4 km/h, as well as a freely arbitrary flexion and extension of knee such as sitting, standing and swinging. For comparison, a motion measurement system (Zebris, D) was used as the reference system.

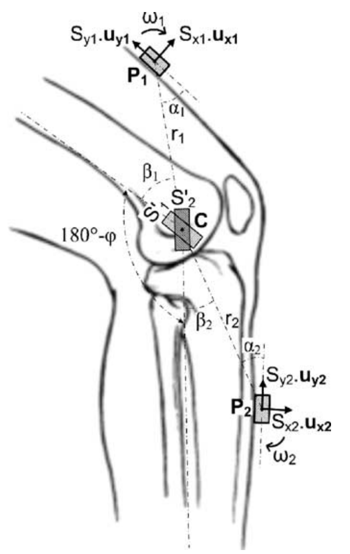

Fig. 1. Position of thigh and shank sensors and their corresponding virtual sensors on the knee joint center of rotation.

Results

The results of all tests were very close to those of the reference system and presented very small errors (mean < 0.70°, standard deviation < 2.0°) and excellent correlation coefficients (>0.994).

Discussion

Excellent agreement was found between the results of body-fixed sensors and those of the reference system. The results showed that fusing the information from accelerometers and gyroscopes increased the accuracy of the estimate of knee angle [1,2]. In addition, the model considered more anatomical aspects and was personalized for each subject prior to each measurement; which lead to higher accuracy in the results. The algorithm was capable to provide the absolute knee angle in real-time for any type of activity. The angles were found without the need for integration, so the results were not distorted by any sources of drift. The body-fixed sensors did not hinder natural movement, were easily mountable, and could be used outside a laboratory environment for long-term monitoring. Unlike electro-goniometers, the proposed system provides also anterior–posterior rotations of shank and thigh independently, which can further be used to obtain lower limbs trajectory.

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P1.19: Development of a contact free, noninvasive method for spinal analysis under dynamic conditions

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Summary

From surface analyses of the human back, biomechanical models can be calculated for the diagnosis of spine, pelvis and scapula parameters by detecting relevant anatomical landmarks. Up to now the method of white light stereographic analysis (rasterstereography) can be performed under static conditions. The use of improved camera techniques and the development of new algorithms to calculate the surface reconstruction improved this method in such a way, that a back surface analysis can be done under dynamic conditions.

Conclusions

The use of this 4D (i.e. spatial coordinates + time) body scan technique enables a contact free, radiation free, 3D analysis of the back under more functional conditions. The calculation of biomechanical models for the spine, pelvis and scapula provides clinically relevant information for diagnosis. Especially in case of scoliotic patients or subjects with deficits in postural control this method is suitable for longitudinal screenings. Furthermore, the control of rehabilitation treatments in the field of lower back pain may benefit from this diagnostic tool.

Introduction

In clinical diagnostics the analysis of spine curvatures is particularly relevant, especially in scoliosis or patients suffering from low back pain. The disadvantage of radiological methods is that potentially harmful radiation is used, and that – in most cases – images are made under non-functional conditions. Alternatives are video based systems or ultrasound systems using markers which must be placed on the skin. These systems can do dynamic analyses but the preparation time is high and the error of bone to skin movement is still an unsolved problem. With rasterstereography, a method for diagnosis is available with which an objective and reliable back shape analysis is possible [1,2]. However, up to now this method has only been applied to static standing. Therefore the goal of this study was to develop this method toward a contact free measuring tool to analyze anatomical structures of the trunk during functional behavior.

Methods

The application of this method in humans was tested for a group of young athletes who performed different movements like stepping, trunk bending or arm elevation for 30 s (Matthias Test) under different load conditions. The sequences were sampled with a maximum frequency of 15 Hz. After a 3D-reconstruction of the back surface, the vertebra prominens is detected as a significant convex fix point. In the lower spine the lumbal dimples are detected as concave areas. Knowing these relevant anatomical fix points, a biomechanical model is computed from which different anatomical parameters like trunk length, kyphotic and lordotic angle, surface rotation, pelvic tilt and scapula position can be calculated.

Results

In this presentation only qualitative results are figured. Fig. 1 shows as an example an arm elevation with 10% BW. From the symmetry line clinically relevant parameters can be calculated.

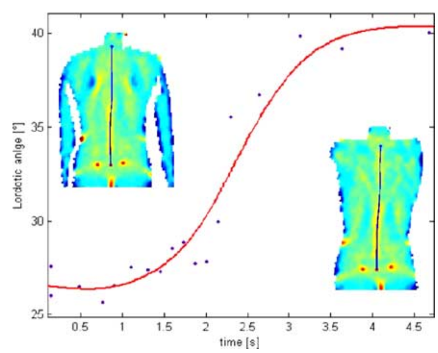

Fig. 1. Change of the lordotic angle during arm elevation. The blue dots are the values calculated from the measurement data. A spline (red line) is fitted through these points in order to estimate the behaviour of the lordotic angle in time. The inlays represent the surface map at the different arm positions.

Discussion

The system is able to analyze body motion at limited movement speeds. Compared to static measurements, a continuous recording during a predetermined motion can be done. Especially in subjects with deficits in posture control this method may serve as a possible way to get objective values from the spine, pelvis and scapula. The non-invasive implementation of this measurement technique predestines this method for the use in screening investigations and follow-up clinical diagnoses. Particularly scoliotic subjects may benefit due to the reduced need of radiological checks.

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P1.20: Crosstalk and coactivation in bipolar surface EMG data: a new methodology for detection, discrimination and quantification

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Summary

In this paper, a new procedure for the detection of crosstalk in conventionally measured bipolar surface EMG is presented. The methodology especially aims at the reliable discrimination between crosstalk and coactivation of antagonistic muscles. The procedure is validated by measurements with children suffering from brachial plexus lesion and the resulting coactivation of m. biceps brachii and m. triceps brachii on the affected side of the body. The results on the affected side were verified by comparing them with measurements on the healthy side.

Conclusion

The results show that by utilising the procedure presented together with conventional surface electromyography, discrimination between crosstalk and coactivation becomes possible. Additionally, a "crosstalk risk factor" (CRF) is introduced, allowing the individual affinity for crosstalk to be quantified.

Introduction

Crosstalk is a common phenomena and well known problem in the measurement of conventional surface EMG. In the past, different approaches to minimize crosstalk or to completely eliminate it were presented, but in most cases these approaches did not lead to satisfying results. However, crosstalk becomes a serious problem, if the information about the muscular coordination pattern is to be used for clinical diagnosis or therapy planning. At the Helmholtz-Institute a methodology has therefore been developed, which allows the determination of a confidence value for the assumption that an EMG signal is not affected by crosstalk but coactivation. The applicability of this technique has been experimentally validated in several patient measurements.

Patients and methods

In total, 28 children, age range 5–10 years, suffering from a lesion of the plexus brachialis nerve were analysed. For one of several test movements, e.g. elbow flexion, measurements included the recording of conventional bipolar surface EMG of m. biceps brachii and m. triceps brachii according to the SENIAM standard (Fig. 1). In a first step, the EMG phases of muscular activity are determined by an "on"/"off" phase detector. The threshold is defined mainly on the basis of specially recorded EMG rest phases, were the patient is asked to completely relax the associated muscles. To quantify the likelihood of the occurrence of crosstalk for each patient separately, we introduced a "cross talk risk factor" (CRF). Firstly the CRF is calculated only from the "on" phases of the patient's healthy side. It's based on the energy ratio as well as on the commonly used cross-correlation of the measured EMG signals between the antagonistic muscles. In a second step, a fuzzy system combines the information obtained from cross-correlation and CRF of the muscular active phases on the healthy side. The system then calculates a confidence value for the non-existence of crosstalk in the considered "on" phases for the contralateral (affected) side.

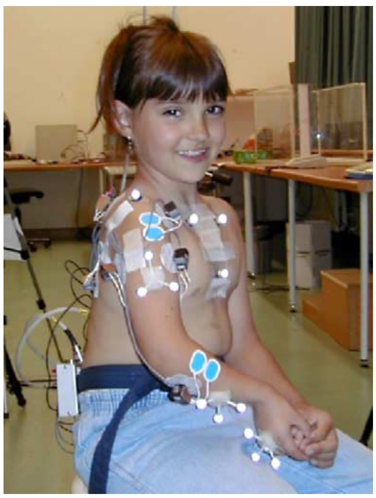

Fig. 1. Measurement setup for upper extremity analysis with markers and ECG electrodes.

Results and discussion

Preliminary results show that by utilising a fuzzy combination of cross-correlation and the CRF, the discrimination between crosstalk and coactivation becomes possible. In several case studies actual coactivation on the affected side was detected with high reliability, whereas on the healthy side the confidence value for coactivation was near zero.

P1.21: Which parameters are important in identifying osteoarthritic knee function? A comparison between an objective analysis and clinical opinion

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Summary

The method developed by Holt et al. [1] was used to analyse the knee function of 22 osteoarthritic (OA) and 20 normal (NL) subjects during level walking. The Dempster–Shafer (DS) method [2] was then applied to the variables collated during this knee function clinical trial to automatically classify the subjects to one of two groups: OA or NL knee function. A ranking of variables was undertaken to identify those most influential in the classification process.

Conclusions

It is clinically significant that the important variables identified by the automated DS classifier are those that are often cited as being relevant in distinguishing OA and NL knee function in a clinical setting.

Introduction

A highly accurate method has been developed that is able to automatically classify OA and NL knee function [2,3]. However, it is important when developing an automated objective classification system to compare the outcome, and the way in which it arrives at it, with independent results and clinical expert opinions.

Patients/materials and methods

The method of Holt et al. [1] was used to study the knee function of 22 osteoarthritic (OA) and 20 normal (NL) subjects during level walking over one gait cycle (GC). Using the DS method [2,3], each subject was automatically classified to one of two groups (OA or NL knee function) based on the set of input variables collated during the knee function clinical trial (kinematic and kinetic time series, anthropometric data and temporal gait parameters). As a measure of clinical relevance, the variable ranking method of Jones et al. [3] was used to investigate the contribution that each input variable makes to the overall classification of the subject.

Table 1. A description of the 10 most important knee function variables v_i

v_1	Vertical ground reaction force (GRF) (loading response–mid-stance)	N/kg
v_2	Cadence (strides per minute)	min^{-1}
v_3	Anterior–posterior GRF 1 (loading response–mid-stance and terminal stance–pre-swing)	N/kg
v_4	Flexion–extension (58–76% GC)	$^\circ$
v_5	Internal–external rotation (loading response to mid-swing)	$^\circ$
v_6	Abd-adduction 1 (stance phase)	$^\circ$
v_7	Stance phase as a percentage of the GC	% GC
v_8	Abd-adduction 2 (terminal swing)	$^\circ$
v_9	Body mass index (BMI)	kg/m^2
v_{10}	Anterior–posterior GRF 2 (late-pre-swing)	N/kg

Results

The 10 most important knee function variables identified by the DS classifier are given in Table 1.

Discussion

In terms of the above variables (v_1–v_{10}), a number of clinical observations are discussed. Subjects with OA knee function frequently walk with an antalgic gait pattern since it is a natural response to reduce the load (force) through the knee (v_1, v_3, v_{10}). Reducing the cadence and increasing the % stance phase (v_2, v_7) increases the double support phase which is a pain reduction mechanism. Due to joint deformity and soft tissue contracture, the OA knee rotation becomes restricted (v_4, v_5, v_6, v_8). An increase in BMI (v_9) leads to an increase in joint loading, which can result in knee OA. Therefore it is significant that the variables identified by the DS classifier are those that are anticipated to be clinically important in distinguishing OA and NL knee function.

References

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P1.22: The reliability and precision of three methods for measuring tibial torsion

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Summary

Three techniques for estimating tibial torsion were evaluated using a repeated-measures study design.

Conclusions

Reliability, as measured by intraclass correlations (ICC) was moderate-to-good for all methods. Precision, as measured by inter-rater differences, was poor. Other methods for measuring tibial torsion should be developed.

Introduction

Tibial torsion anomalies are common in Cerebral Palsy, Myelomeningocele, and other movement disorders. Pathological tibial torsion is frequently corrected via derotational osteotomy. A reliable and precise means for measuring tibial torsion is therefore needed to help guide surgical decisions. Tibial torsion is usually measured using one of three physical exam techniques: Thigh Foot Angle (TFA), Second Toe Test (STT), or Bi-malleolar Axis Angle (BMA) [Bleck]. The reliability and precision of these techniques has not been widely studied.

Patients, materials and methods

The study received approval from the Institutional Review Board, and all subjects gave voluntary consent. A convenience sample of 80 subjects was selected from the population being seen for evaluation of gait disorders at the Gillette Children's Specialty Healthcare Center for Gait and Motion Analysis. Each subject had her/his tibial torsion assessed by two of five different physical therapists in the laboratory. Assessment included each of the three measures (TFA, STT, and BMA). The therapist pairings were randomized to give equal distributions of all possible therapist pairs. The order of measurements was not controlled. Reliability of the measures was assessed using Intra-class correlation (ICC). Precision was assessed by the inter-rater deviation, $\pi = |x_1 - x_2|$, where π is the precision and x_1, x_2 the tibial torsions obtained by therapist 1 and 2. Mean precision and a 90% confidence interval (5th–95th percentile) were computed.

Results

The reliability and precision of each tibial torsion measurement was computed (Table 1). The wide inter-observer variability is evident in each of the three measurements (Fig. 1).

Discussion

The ICC and mean precision suggest a clear ranking of the methods TFA → STT → BMA. The ICC of the TFA (0.72) implies good reliability, whereas the precision data (30–35° range) clearly show that none of the physical exam based measures can give accurate guidance to orthopaedists who are considering derotational osteotomies. These results make clear the need for better means of assessing tibial torsion. One option is to define a tibial torsion in *biomechanical* terms by measuring the angle between functional knee and ankle axes. These can be determined precisely using any number of modern analytical methods [2,3]. This work is currently ongoing.

Table 1. Reliability and precision

	TFA	STT	BMA
Reliability (ICC)	0.72	0.65	0.59
Mean precision (°)	8.9	9.3	10.2
90% CI (°)	32	31	35

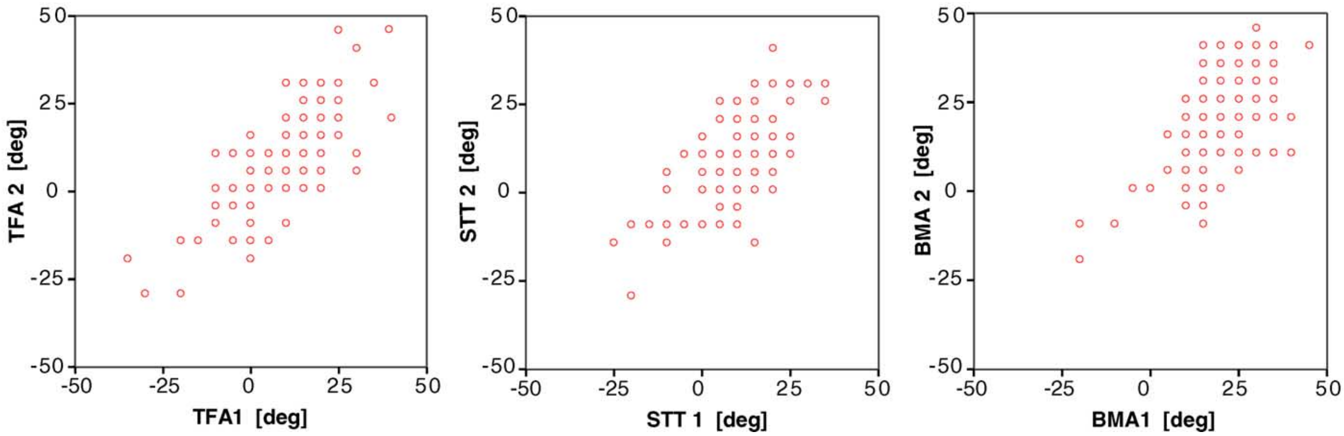

Fig. 1. Inter-rater precision. The tibial torsion measurements for the two raters show the measurements' imprecision. The relatively high ICC values are somewhat misleading due to the wide between-subject variation. None of the measures exhibits an acceptable precision.

References

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P1.23: Estimation of the tibio-femoral translation: preliminary results concerning marker placement

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Summary

Skin movement artifacts due to changes in joint angles and/or muscle contractions are a common problem in gait analysis. This study introduces the problematic for defining the anterior–posterior position of the tibia relative to the femur. Furthermore, a biomechanical model for calculating the anterior–posterior tibia translation (APT) relative to the femur is introduced. Comparing passive and active knee flexions–extensions, muscle activation induced a numerical APT of up to 8 mm, if we assume that in healthy subjects such muscle activation may induce only a minimal tibia translation compared to the passive movement. The amount of this error depended on the knee angle and the structure of the knee of each subject (increased variability between subjects).

Conclusions

The definition of the knee axis using one marker on the lateral epicondyle needs to be reconsidered when accurate measurements are required. The accuracy of the APT measurement may be improved for specific knee joint angles and knee structures by placing additional markers distally to the femur.

Introduction

The usage of markers applied on the skin to determine the position of bones is often inaccurate, due to skin motion, especially when the joint angles are varying and/or the muscles contract. Due to this drawback, biomechanical models have failed to define accurately enough the APT relative to the femur [1]. The purpose of the study was to measure the anteriorèposterior displacement relative to the tibia of the marker which is commonly used to gait analysis for the definition of the knee axis [2]. In this sense, the calculated displacement is a measure of the APT relative to the femur, in combination with the presence of skin motion artifacts.

Patients/materials and methods

Four healthy volunteers (age: 28.1 ± 2.0 years, weight: 78.6 ± 14.7 kg, height: 184 ± 8.7 cm) with no lower extremity injury history were measured for both sides. A 9-camera VICON system was used to capture the trajectories of the markers. The tibia–femoral translation was defined as the vertical distance between the marker placed on the lateral epicondyle during standing and the plane defined by the two malleoli and the tuberosity. The knee angle was calculated using the plug-in-gait model. A series of passive and active knee flexion–extensions were performed unilaterally in sitting position with the foot hanging freely. Mean values ± S.E.M. were calculated for intervals of 20° of knee flexion.

Results

As shown in Fig. 1, the calculated APT was differentiated during active knee extension compared to the passive. Muscle activation moved the lateral epicondyle marker posterior for knee angles from 20 to 60° and anterior when the knee was flexed up to 100°. These differences were variable between the subjects but were not over 8 mm (Fig. 1B).

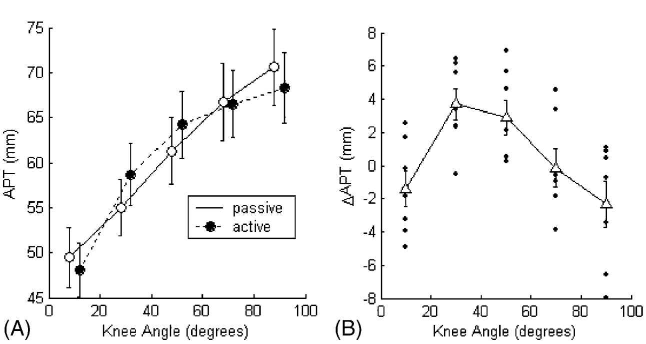

Fig. 1. Results concerning the marker placed on the lateral epicondyle while standing. (A) Mean (±S.E.M.) APT for active and passive knee flexions–extensions. (B) Mean (±S.E.M.) difference between the active and passive movement APT for different knee joint angles. Filled points represent individual subject measurements.

Discussion

The lateral epicondyle while standing is often used as landmark for the definition of the knee axis. While flexing the knee, the vertical distance between the lateral epicondyle marker and the plane defined by the tibia markers increased (Fig. 1A). This increase may be attributed partly to the skin movement and the roll-back movement of the femur. However, changes on the APT due to muscle activation is more likely to be limited and therefore the differences shown between active and passive situation could be mainly attributed to skin motion artifacts. It is suggested that the validity for measuring the APT of the tibia relative to the femur may be increased for specific knee joint angles applying additional marker(s) distally to the femur (medial and lateral).

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P1.24: New quantitative assessment of the effectiveness of treatment based on gait analysis

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Summary

In this study, we purpose a quantitative index based on kinematic gait analysis in order to evaluate the positive and negative individual response to a therapeutic intervention.

Conclusions

When the effectiveness of the treatment is estimated in children with cerebral palsy (CP), a certain variability of the responses can be found. Surely, this reflects the variability and the heterogeneity of clinical expression of this syndrome. In fact the effects of the treatment are diversified and thanks to the analysis of a sufficiently large number of elements of the gait cycle it is possible to quantify objectively how much and in which phases the single patient's gait is effectively improved.

Introduction

Gait analysis is customary in clinical practice in order to assess the effectiveness of treatments in children with CP. Nonetheless there is still a generalized demand of methods giving an appropriate description of joint kinematic and supplying also valid outcome measures for the quantitative assessment of different treatment. Botulinum toxin (BTX/A) is a relatively new treatment modality for the management of spasticity in chidren with CP that has been extensively researched during the last years [1]. Nevertheless few studies report individual profiles of efficacy and the risk of excessive correction induced by the therapy.

Patients/materials and methods

Twenty-one children with CP were subjected to BTX/A inoculation at the gastrocnemius, soleus and tibialis posterior, isolately or in combined manner. Among them seven had Diplegia, seven had Hemiplegia and seven had Double-Hemiplegia and all them were treated monolaterally. A control group of 10 healthy children matched by age was also recruited for comparison purposes. Kinematic data acquisition was carried out, according to Davis's protocol, in the Clinical Gait Laboratory of Stella Maris Scientific Institute using an optoelectronic motion analyser (ELITE, BTS Italy) with eight infrared-cameras sampling at 100 Hz. Kinematic data were analysed for both lower limbs (treated and not treated) on a minimum of five complete step cycles for every subject. The following parameters of the gait were estimated on the sagittal plane before treatment and 4 months after: Alignment of the Ankle and the Knee at the Initial Contact, at 10% of the gait cycle, in Mid-Stance, at toe-off and in Mid Swing. In order to assess the effectiveness of the treatment we calculated a percentage index of gain (IG) that expresses the distance between the condition pre-treatment and post-treatment when referred to the normal condition calculated from the sample of the control group. According to IG values the results were classified taking in account: No Response, Improvement (light to good), Worsening (light to severe) or Excessive Correction (light to severe).

Results

In our sample the main advantages of treatment with BTX/A were obtained at the ankle level in treated limbs during the phases of Initial Contact and Mid-Stance. Nevertheless some subjects showed an excessive correction, especially during the phase of Loading Response, relative to increased ankle dorsiflexion. At the knee level IG values are reduced, compared to the results obtained at ankle level. Benefits were obtained also for the untreated limb even if the number of No Response tends to increase both at ankle and knee level. In a limited number of subjects a light to severe Worsening was observed during specific phases of gait cycle.

Discussion

As well as considering positive benefits and evidence for the effects of treatment it is important to underline the individual negative results and complications due to the treatment. In this study we purpose an index (IG) that allows a fine discrimination of advantages and disadvantages of the therapeutic intervention in children with CP through the gait analysis.

Reference

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P1.25: Experimental noise in helical angle calculated from a marker setup

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Summary

This study describes how measurement noise in retro-reflective markers affects the calculations of a helical rotation angle (θ).

Conclusions

The results indicate a pure linear relationship between input and output errors, with a proportional constant of 1/2 for nonzero rotations. This is due to the algorithm, which gets close to singular for zero rotations.

Introduction

Whiplash-associated disorders (WAD) are common diagnosis after neck trauma, caused by sudden acceleration and deceleration forces acting on the head and neck, most typically rear-end or side-impact car accidents [1]. Woltring et al. [2] introduced the instantaneous helical axis method (IHA) to describe motion characteristics during slow head movements on a subject suffering from WAD and a control subject, showing the potential of IHA when constructing neck models. In two previous studies, we have shown that a resilient backpropagation network is able to classify a subject into a WAD or control group only using movement patterns as input [3,4]. In these two studies, two clusters of markers (attached to head and shoulder respectively) were used for calculating the helical angle between head and shoulders.

The aim was to study how white gaussian noise, added to simulated markers on a rigid body, affects the calculated helical angle for the marker set used in our previous studies [3,4].

Patients/materials and methods

A commercial available system consisting of four cameras was used for marker measurements. A reading of the measurement noise was obtained by calculating the Euclidean distance between two markers, located on the edge of a calibrated wand, in each time frame. The standard deviation; σ; of the distances calculated was then used as measurement of noise (i.e., precision).

A rigid body defined by three marker positions (collected in our earlier studies [3,4]) was used as a reference position. The rigid body was then rotated around the *z*-axis (i.e., planar movement). The first position was used as reference position while the second was disturbed with colored noise; $\varepsilon \in N(0;\sigma)$ in the *x*-, *y*- and *z*-co-ordinate. Thousand disturbed rigid bodies were constructed. Finally, θ was calculated (using method [5]) for every disturbed rigid body using the same reference position. This procedure was repeated for different rotations around the *z*-axis (i.e., within the *x*–*y* plane).

Results

The standard deviation of the measurement noise was estimated to 1 mm when using marker data from 600 frames inside the measurement volume. Fig. 1 shows the results from simulating different degrees of measurement error and how it affects the error in θ.

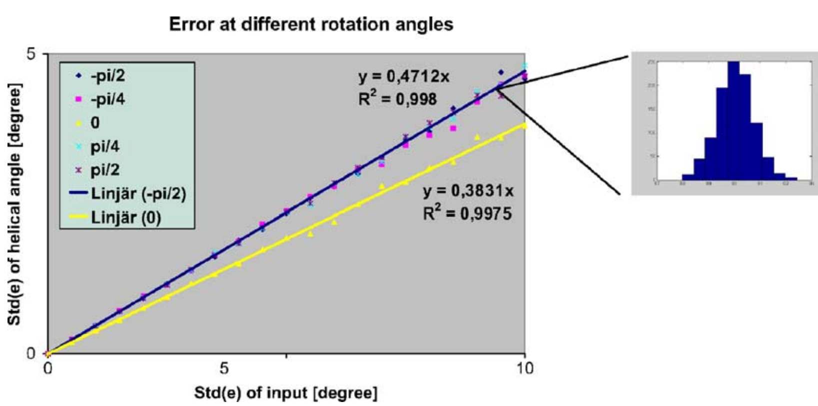

Fig. 1. Illustrates how different measurement errors affect the error in θ.

Discussion

In order to get a reliable measurement system it is important to know how measurement errors affect the final result. The results indicate a pure linear relationship between input and output errors. Also, a deviation is shown for a zero rotation (i.e., pure translation). This is due to the algorithm [5], which gets close to singular for zero rotations.

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P1.26: A new protocol for gait analysis in children

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Summary

A novel protocol is proposed for gait analysis, aimed at combining anatomical rigor and simplicity of the experimental and analytical procedures. Anatomical-based definitions, direct skin marker placement, simple algorithms for hip joint centre estimation, and a shorter calibration procedure were pursued. Twenty markers and six anatomical landmark calibrations enabled reconstruction of segment and joint anatomical frames of pelvis and lower limbs according to ISB standard definitions. Intra-subject, inter-operator and inter-subject variability was assessed. Encouraging results from the preliminary application of the protocol are reported.

Conclusions

The new protocol is suitable for gait analysis of children, where data collection must be not troubling and distressing and measurements must be completely 3D and anatomically-based. The protocol should facilitate also the community for data communication among different laboratories and even among motion systems.

Introduction

Human movement analysis still suffers of the weakness of the few currently used protocols for motion data collection and reduction. Reliable comparisons within and among subjects and precise clinical functional assessment require anatomical based definitions of the references and therefore careful identification and tracking of several anatomical landmarks. But when children are analysed, particularly those suffering of cerebral palsy, the marker-set and other associated measurement procedures must be minimised to limit duration of subject preparation and of data collection. Traditional gait analysis protocols are limited either by the reliability and repeatability of the measurements [1] or by the time consuming experimental procedures [2]. A novel protocol is here proposed for the analysis of pelvis and lower limb motion obtained as a compromise between these two opposite necessities.

Patients/materials and methods

Gait was assessed using a motion analysis system (Vicon Motion Sistems, eight cameras, Mcam2 1000 Hz) and two force plates (Kistler Instrument AG, Switzerland). One cm diameter passive markers were stuck in correspondence of the anterior and posterior superior iliac spines, most external prominence of the greater trochanter, lateral epicondyle, external apex of the head of the fibula, prominence of the tibial tuberosity, external apex of the lateral malleolus, lower ridge of the calcaneus posterior surface, dorsal aspect of the first and fifth metatarsal heads. The medial epicondyles the external apex of the medial malleoli and the head of the second metatarsals were calibrated [2]. Hip joint centre was assumed at a proportional position with respect to the superior iliac spines [3]. Anatomical frames were defined as in [4]. Ten normal children (aged from 4 to 10 years) were analysed over 10 trials. In one of these, five operators performed the data collection procedure.

Results

The average time for a single analysis was 20 min. Joint rotations and moments for the control population were found in general agreement with corresponding reports from these authors and from standard reference literature. The minimum and maximum mean values over the walking cycle of all angle standard deviations were respectively 1.0 (pelvic tilt) and 4.8 (knee flexion).

Discussion

The design of new gait analysis protocols should be according to the maximum reliability in the definition of co-ordinate references, for a better physiological and clinical interpretation. On the other hand, time necessary for patient preparation and data collection together with experimental apparatus encumbrance are critical issues, particularly for gait analysis in children. The proposed novel protocol seems to have achieved a good compromise between these two extremes. The number of markers is only a little larger than tradition protocols, but these are all well traceable also in very small children and, in preliminary analyses performed, also in CP children. The location of these markers needs only carefulness on bony prominence palpation and identification. This is likely to simplify operator training and to reduce inter-operator variability, as preliminary observed in this study. The anatomical calibration is limited to only six landmarks, though a much larger number can be obtained in case of special analyses. Finally, foot to shank motion is fully 3D.

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P1.27: A modular protocol for the analysis of movement in children

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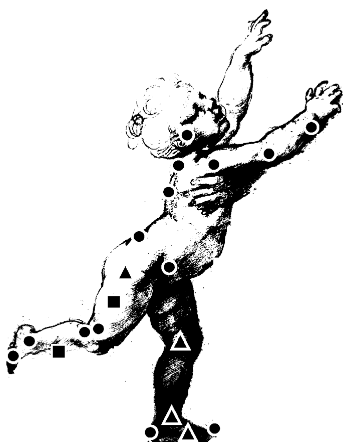
Introduction

The creation of a new Laboratory for the Analysis of Movement in Children (L.A.M.B.) at the Institute of Human Physiology I, University of Milan, was the opportunity of conceiving a new protocol for the acquisition of kinematic data, to be specifically applied in the pediatric age. The main points considered were: (a) inclusion of the advantages of the available anatomical approach [1], calibration approach [2] and functional approach [3]; (b) minimization of the operational constraints possibly related to the anthropometrical dimensions of the young subjects and the frequently low experimental compliance thereof; (c) reliable application of second level, pathophysiological approach to the analysis of movement (e.g. detection of dynamic spasticity) in disabled children [4].

Methods and results

The protocol was applied using an optoelectronic system (Smart, E-Motion, Italy) with 6 tv-cameras arranged as a hexagon. Markers' setup was adapted to the range of children's body size by adopting three progressively more complex double-side configurations (small, medium, large). The configuration "large" is represented in the figurine (each marker shown once). Circles indicate anatomical markers, squares technical markers and triangles calibrated anatomical landmarks. The anatomical markers of the HAT are zigomatic process of the temporal bone, C7 and T10 vertebral spinae, scapular acromion, lateral humeral epicondyle, distal ulnar tuberosity. The anatomical markers of the locomotor system are PSIS midpoint, ASIS, greater trochanter, medial and lateral femoral condyles, fibula head, medial and lateral malleoli, 1st and 5th metatarsal heads, distal insertion of the Achilles tendon, dorsal aspect of the 1st toe. The body is modelized as a complex of 16 segments, 7 of which belong to the locomotor system (pelvis, thighs, shanks and feet). The latter are identified by at least three points each (the third point on the thigh is the estimated pelvis-based hip joint centre) allowing quantification of 6-*d* of kinematics. Mathematical models independent from the absolute reference frame enable reconstruction of calibrated points, identification of pelvis frame and estimation of the hip joint center [1], identification of lower limb frame and joints' centres [5] computation of joint angles [6], joint dynamics, muscle geometry, COM kinematics [7] and energetics.



Discussion

The L.A.M.B. protocol, which has been tested by a laboratory activity spanning more than 1 year, revealed good operational feasibility. The marker set-up with no external fixtures (wands, plates) reduces subject encumbrance, while complying with requirements for a full 3D kinematic assessment. The consistent set of identifiable bony landmarks limits marker placement and skin motion artifact risk and, depending on the configuration, curtails or avoids anthropometric measurements. The anatomical calibration applied to eight points further shortens the preparation phase. The use of mathematical models independent from the absolute reference frame enables analysis of (loco)motor movements occurring in any direction, thereby allowing the use of ground-fixed force plates by the most convenient orientation. The detailed characterisation of foot–leg segments geometry allows utilization of more accurate muscle models for computation of distal muscle kinematics. The application of the protocol to adult subjects with positive results has confirmed the advantages of the discussed features.

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P1.28: Body segment kinematics estimated through inertial sensing

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Summary

A method is proposed and validated for estimating accurately 3D body segment kinematics from mini inertial motion sensors.

Conclusions

A calibration through a few single functional axis rotations delivers an accurate and reliable estimation, which appears also to facilitate a more intuitive interpretation than a bony landmark calibration in video based methods.

Introduction

Inertial sensing offers accurate estimation of 3D orientation, velocities and acceleration without artificial reference. This would allow for more freedom for the patient and clinician in parts of clinical motion analysis. There will be no visibility problems, no limited measurement volumes and no special demands on the examination room. However to be able to use these sensors accurately the kinematic data of the sensor module has to be translated to the kinematics of the body segment. Because of the nature of the data of inertial sensors for this translation dedicated calibration methods have to be designed and validated. This paper proposes and validates one such method for the trunk and discusses its use for arms and legs.

Patients/materials and methods

The calibration is performed based on a few recordings of controlled trunk posture where one axis of the body segment is known in the global coordinate frame in which the kinematics of the sensor module are expressed and/or controlled rotations around a single body segment axis. Typical suitable postures are the ones in which one axis of the body segment coordinate frame is assumed to be parallel to gravity. Typical suitable motions involve single axis rotation of a body segment around one of its segment coordinate frame axes. In validation experiments for nine healthy subjects simultaneous recording were performed with the Amber inertial sensing modules and with a video based reference method Vicon. Kinematics were assessed from 3 trunk segments ('thorax', 'low back' and 'sacrum'). For the Amber method 10 different versions of the segment calibration were applied. For the video based reference system a state of the art bony landmarks calibration method was applied. Nine healthy subjects (age: 25 ± 4 years, weight: 80 ± 4 kg, length: 185 ± 5 cm) participated in the experiment. Three tasks were performed and led to separately recordings:

1. Standing motionless in natural upright posture for 5 s. Perform trunk flexion in sagital plane (around *x*-axis) repeated five times. Then again standing motionless in a natural upright posture for 5 s. This task was repeated five times.
2. The same with lateroflexion (around axis).
3. The same with twist around the vertical (around *y*-axis).

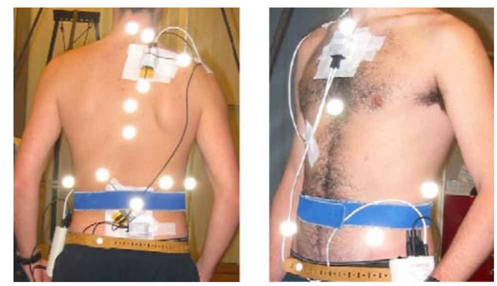

Fig. 1. Experimental setup. Vicon markers are placed on bony landmarks and additional marker trees are placed oni the inertial sensor modules.

Set-up: Sensor module angular velocities and accelerations were directly derived from gyroscope and accelerometer signals. Sensor module 3D orientation was estimated applying a Kalman filter.

Results

The accuracies with which the gravity axes could be determined (<1°) is higher for the gravity axes than for the rotation axes (<3°).

De best repeatability was found with methods 1 and 2; mean of 1.8 (S.D. ±1.3) and 0.9° (S.D. ±1.1) for the thorax sternum and 2.1° (S.D. ±1.5) and 1.6° (S.D. ±1.9) for the thorax back.

For the comparison of the Amber and reference methods, only methods 1 and 2 are taken into account. The mean values for structural difference over the eight subjects for the different methods and segments are varying between 10 and 30° (Table 1). The maximum standard deviation is 12.5°. This difference is around 10° smaller for thorax sternum then for the thorax back.

Discussion

Remarkable is the large structural difference between the Amber segment calibration method and the reference bony land marks method, while both are similarly accurate and reliable. First results of further tests suggest that similar differences are found when both calibration methods are performed on Vicon cluster marker data. This implies that the difference is not caused by the use of inertial sensing but only by the way of calibrating. For Amber only the segment calibration can be used. For video based set-ups both can be used and it may be argued that the segment calibration method also here would to be preferred, because it results in a body segment axes frame of which the axes are closer to the axes of functional rotation, which would allow for a more intuitive interpretation, especially in clinical assessment.

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Friday, 24th September

Session 4 (oral): 9:10 to 10:22

Miscellaneous

S4.1: Foot motion of treated congenital talipes Equinovarus—a comparison to the sound side

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Summary

Nine children with unilateral surgically treated clubfoot deformities have been examined usin a multi-segment foot model. In every patient clinical changes could be identified and quantitatively determined in sagittal, transverse and frontal plane.

Conclusions

Functional assessment is until today based on clinical findings and questionnaires. The determination of kinematic data of the foot segments within gait allows a more detailed understanding of the underlying biomechanics and is the prerequisite for a better and more specific treatment planning.

Introduction

The surgical management of congenital club feet remains a challenge for the surgeon. Restrictions of foot functions can only be derived indirectly based on static measurements. Recommendations for further treatments are based mainly on indirect observation. Recent dynamic investigations show an indication for restricted function of surgically treated club feet [2]. Nevertheless, a more detailed assessment of foot function seemed nessessary. The aim of this study is to objectively and quantitatively describe the gait function of surgically treated CTEV with a multi-segment footmodel in stance as well as swing phase.

Patients/materials and methods

Clinical and 3D gait analysis data were assessed for nine patients (five females, four males, mean age of 10.7 years, range: 3–13 years) with previous surgical treatment in unilateral CTEV. All patients showed noticeable changes in the foot shape. The last surgical treatment had been carried out at the mean age of 4.5 years (range: 1–13); the follow-up examination was performed 6.2 years after surgery. Six children were treated with a dorsomedial realease and Achilles tendon lengthening, three children received a dorsomedial release only. In eight children an additional pantalar release or a repeated dorsomedial release was nessessary. For the model, a set of 17 markers placed on the skin was used to monitor foot motion as described in [1]. Data capturing was performed with a 9-camera VICON612 system. Eight strides were captured on a 7 m walkway asking the patient to walk at a self selected speed. For analysis, the kinematic data of all three planes which describe the typical aspects of pathologic deformity in CTEVs were analysed and the data of the affected side was compared to the sound side.

Results

In eight out of nine children an increased cavus in the complete gait cycle was found, seen in the data as a decreased medial arch angle. Furthermore, increased subtalar inversion could be found also in eight patients throughout the gait cycle with no significant reduction in ROM. Seven patients showed a reduced maximum dorsiflexion in swing. In six children we found an internally aligned forefoot relative to the gait direction which is either the result of an internal ankle rotation or a pronounced forefoot adduction. The other three children showed an increased forefoot abduction which coincided with an internal foot orientation.

Discussion

We could corroborate the findings of Theologis et al. [2] of decreased ankle dorsiflexion whereas an increased forefoot adduction could not be found in all cases. In the transverse plane we could get new insight in the dynamic positioning of the foot segments. The observed intoeing gait which is reported clinically appears as a common feature also in the motion analysis of the club foot which can mainly be attributed to the orientation of the forefoot relative to the gait direction. However, there appears little direct correlation solely to internal ankle rotation or forefoot adduction. It is rather the combination of both parameters which leads to a resulting internally oriented forefoot.

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S4.2: Understanding standing posture using muscle driven forward simulation

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Summary

This paper describes the use of muscle driven forward simulation techniques in the study of normal standing. Crouching down and standing up were also studied and compared with measured data sets in order to validate the model response.

Conclusions

A musculoskeletal model, with a dynamic foot-floor interface, using muscle driven forward simulation, can be used to study the control of standing posture. The optimisation algorithms used are able, by modulating the excitation pattern of the 22 muscles, to stabilise the joints during standing and control joint movement during crouching down and standing up.

Introduction

Using forward simulation it is possible to study the relationship between muscle excitation, muscle force and the resultant movement of the musculoskeletal system. Many studies have analysed standing using different measurement techniques but these techniques do not allow such a causal relationship to be established. Using forward simulation to study standing posture has the potential to increase our understanding of the underlying neuro-physiological control system.

Patients/materials and methods

A seven segment musculoskeletal model was defined using SIMM, including 22 muscle-tendon actuators. The foot-floor interface was set up using six spring-damper contact points for each foot. Forward simulation was performed using Dynamics Pipeline and SDFast, with a standard Hill model to convert the muscle excitation profile into force. Optimisation routines (Optimus, LMS) were used to modulate the muscle excitation profiles in order to produce the target joint trajectories. Optimisation was carried out over steps of 0.1 s. To limit the number of variables required for the optimisation, symmetrical activation patterns were assumed. The target trajectories were taken from data collected on a control subject performing the prescribed movements.

Results

A stable standing posture was achieved with good control at each of the joints (including a 3 DOF hip joint). Stability was maintained for 3 s (300 simulation steps), showing modulation of the muscle excitation levels and movement in the centre of pressure of the ground reaction force under the feet. Dynamic stability was also achieved during crouching down (2.5 s) and standing up (2 s) manoeuvres. Fig. 1 shows the simulated joint angles (in grey) compared with the target trajectories (in black).

Discussion

The method described here allows the causal relationship between muscle excitation and postural control to be explored. The spring-damper interface effectively allows the centre of pressure to move in response to changes in segment position and muscle excitation. For the three postures studied a satisfactory match of the model response to the target trajectories was achieved by modifying the excitation patterns of the muscles. The observed discrepancies between the predicted excitation patterns of the muscles and recorded EMG signals could only be resolved by using additional neurophysiological control modules. This is a potential future development.

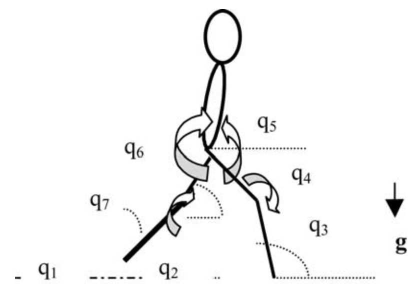

Fig. 1. Seven DOF model.

S4.3: Multibody gait modeling and simulation with preview objectives

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Summary

Some multibody walking models including legs, tights and upper-body have been developed with various objectives of preview symmetry at mid-stance position and configuration at the end of the swing phase. Continuous gait motion simulation and a steady symmetric limit cycle can be achieved for a large number of steps. Applications addressed to normal gait cases are also foreseen for cases presenting disabilities.

Conclusion

This method of generating controlled gait motion with preview objectives seems promising. This approach can be applied to models of great complexity including arms and feet, and can be extended to three dimensional gait motions needed for many normal and deficient gait simulations. The limit cycles obtained for some simulated normal and deficient gait cases offer some potential application in the field of stability and clinical gait analysis

Method

A model of rigid bodies, such as shown on Fig. 1, can be mathematically described by a system of seven nonlinear second order differential equations. Impulsive external forces and torque as well as gravity forces are applied to the model, each body having its own mass and inertia. While the nonlinear equations can be numerically integrated using a controlled Runge-Kutta algorithm, a polynomial solution for the linearised system in the form of $V_i = C_{i1} + C_{i2}t + C_{i3}t^2 + C_{i3}t^3$ may also be developed for each body. These last solutions depend of course on the initial generalized coordinates and velocities. When objective values, such as conditions for symmetry at mid stance and others at the end of the swing phase are specified, these polynomials form a set of algebraic equations whose solution specify the required initial velocities. The integration of the equations of motion over a very short time interval at toe-off, yields another set of algebraic equations relating these initial velocities to the impulsive forces and torque needed to achieve this objective.

The specific time for mid-stance to occur, becomes a gait velocity control parameter. A programme can be developed to provide a step to step simulation and animation.

Results

A continuous gait motion may be obtained and visualised with a dedicated animation program and the gait quality can be readily observed from such animations. A limit cycle involving primarily the leg variables is quickly attained after a normally short transient period. The propulsion impulses are seen to vary somewhat from step to step to account for the variation of step angular velocity needed at toe-off. The stability of the system can be appreciated from the steadiness the limit cycles when parameters variations or perturbation impulses, such as tripping impulses for example, are purposely introduced during the gait cycle. Results are presented in the form of simulations and limit cycles for a variety of normal model cases. For the purpose of illustrating the capability of this method, some results are also shown for a few models having geometrical or physical parameters differing from leg to leg. A time delay may also be introduced and impulsive torque of limited amplitude can be specified. Thus applications are foreseen for many clinical cases with physical deficiencies.

Discussion

A good gait is a symmetric gait, as had often been said. For models intended for deficient cases, the research of gait symmetry, even if not perfectly satisfied, will yield most likely a better gait, but the question is opened. The limit cycles and phase diagrams are indicative of the level of stability present in the gait motion, as for example, when a parameter or variable perturbation suddenly occurs.

Acknowledgements
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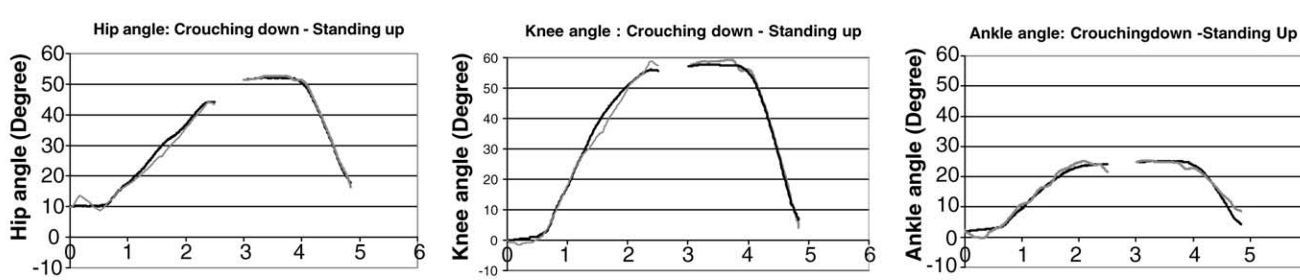

Fig. 1.

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S4.4: Cognitive perturbation makes stance more stable!!

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Introduction

Regulation of posture involves sensory as well as cognitive processes. Postural sway measurements during dual task conditions have been used to examine the impact of cognitive task on posture control. Researchers have evaluated postural sway by using a force platform to measure displacements of the Centre of Pressure (COP). Attempts to interpret stabilogram, a plot of time varying coordinates of the COP, from a motor control perspective have not been successful.

Collins and DeLuca [1] introduced a new method for analyzing COP trajectories known as stabilogram diffusion analysis. This analysis generates a function that summarises the mean square COP displacement as a function of the time interval between COP comparisons (Fig. 1). The analysis generates three sets of six parameters. The parameters are long and short term diffusion coefficients, long and short term scaling exponents and critical point coordinates. Diffusion coefficients are calculated from the slopes of the resultant linear-linear plots, scaling exponents are calculated from the slopes of the resultant log–log plots, and the critical point coordinates approximate the transition region that separates the short term and long term regions. The sets are for medio-lateral, antero-posterior planar displacements. The two parts of the plot suggest two different control regimes namely, a short term open loop control and a longer term closed loop control.

Method

Ten able bodied, healthy subjects participated in the study. Their age ranged from 21 to 49 years. During trials the subjects were asked to stand, barefoot, in an upright position in a standardised stance, as quiet as possible, on a force platform that measured the time varying displacements of the COP. Each trial lasted for 30 s. Four different test conditions were randomly tested, namely eyes open, eyes closed and a cognitive task with eyes open and with eyes closed. The cognitive task consisted of Paced Auditory Serial Addition Task (PASAT). This task demands a lot of focused attention. For each condition 2 series of 10 trials were conducted. The data was analysed according to the method described by Collins & DeLuca. Statistical analysis, ICC calculations were carried out using SPSS v11.5 to study the reliability of findings obtained for various test conditions.

Results

ICC for majority of parameters for all test conditions represented fair to excellent reliability. The parameters for planar displacements were studied in detail for trends. With cognitive perturbation diffusion coefficients, for short as well as long term, lowered in all subjects with eyes open as well as eyes closed. There was no discernible difference in short term scaling exponents on cognitive perturbation but long term scaling exponents were lower in all. The critical point coordinates were similar for all four test conditions.

Discussion

Open loop control mechanisms, when interpreted physiologically, indicate inherent stability of the body and closed loop control mechanisms indicate the efficacy of the feedback mechanisms and the corrective actions. Cognitive perturbation requiring high level of attention such as PASAT brings the automaticity of stance control in to play. Lowering of D and H with cognitive perturbation indicates that the stance becomes more stable and the closed loop mechanisms work more efficiently. The findings are in contrast to a previously reported study [2]. Perhaps in healthy subjects the automaticity at sub-cortical level works more efficiently when one is busy with a complex cognitive task. These findings are in accordance to a previous study reported in the literature about the effect of complexity of cognitive task on postural sway [3].

Conclusions

Cognitive perturbation using a complex task makes stance more stable in healthy adults.

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S4.5: Evaluation of standing balance using a body fixed kinematic sensor

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Summary

A new methodology using 3D accelerometers and 2D gyroscopes was proposed to assess body sway during standing in elderly people. The system allowed to estimate body sway with eyes open and closed, and provided objective outcomes related to clinical structured evaluation.

Conclusions

The multi-band frequency decomposition of horizontal acceleration allowed to discriminate balance control sway components from other movements. The root mean square value of this component showed significant correlation with a measure of fear of falling (Fall Efficacy Scale, FES). The system can be used in different environments (home, hospital), and requires a single module attached on the sacrum.

Introduction

In elderly persons, balance improvement or deterioration can be of interest in the clinical setting. However, there is a lack of a low cost, reliable and simple ambulatory system usable in different environments. The aim of this study was to assess balance with a single kinematic sensor module which can be used easily by a clinician at hospital or office. Objective outcomes related to body sway during standing were extracted and compared to clinical evaluations.

Patients/materials and methods

Sixteen elderly persons (mean age 79.7 years, range 69–87) were asked to carry a kinematic sensor composed of a 3D accelerometer and a 2D gyroscope. The kinematic sensor was attached to the lower back, near the sacral area. Patient's trunk accelerations in the anterior–posterior (AP) and medio-lateral (ML) directions were extracted during 30 s in quiet standing under two conditions: eyes opened (EO) and eyes closed (EC). The absolute trunk angles in AP and ML directions were calculated based on integration of the gyroscope signals. This allowed to estimate the actual horizontal accelerations and to remove the gravity component from the raw acceleration data. To evaluate the balance control, the acceleration signals were decomposed into three frequency bands, using Wavelet Transform: low frequency band (0–0.21 Hz) representing slow movement of the trunk, medium frequency band (0.21–1.71 Hz) related to the body sway, and high frequency band including movement artifacts. For each conditions, the root mean square (RMS), as well as the range of acceleration (ROA) in both AP and ML directions were estimated. A non-parametric rank-sum test was used to find significant difference under EO and EC conditions. In addition, Tinetti's Fall Efficacy Scale (FES) and Performance Oriented Mobility Assessment (POMA) clinical scores were obtained to assess the fear of falling and fall risk for each patient.

Results

Multi-band frequency decomposition removed successfully the slow as well as jerky movements from the acceleration patterns. In addition, both RMS and ROA parameters enabled discriminating between the balance control under EO and EC conditions ($P < 0.001$). Interestingly, we observed a relatively high negative correlation between each parameters extracted under EC condition in medium frequency and the FES score ($r = -0.5$, $P < 0.05$). This correlation was higher for ML direction ($r = -0.7$, $P < 0.005$). In contrast, there wasn't any significant correlation between these parameters and FES under EO condition ($r = 0.3$, $P = 0.3$). Finally, no significant correlation was found between these parameters and Tinetti's POMA score (including gait and balance scores).

Discussion

Our results demonstrate that a single kinematic sensor attached to the sacrum provides valid information on balance control in elderly people. The differential correlation between the magnitude of horizontal acceleration and the clinical scores supports the hypothesis that fear of falling and fall risk might not be related to the same kinematic parameters. In the future, this system might make possible to perform bedside evaluation of balance control and of its relationship with fear of falling and fall risk in elderly people.

S4.6: Emg analysis during elementary arm motions and during pitching

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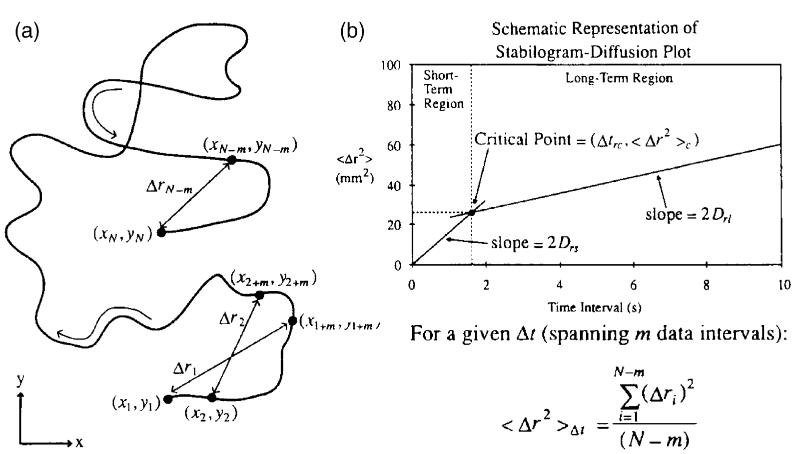

Fig. 1.

Summary

In order to clarify if different arm motions and sport activities influence the activity of shoulder muscles, eight shoulder muscles were examined using surface electromyography (EMG) in 25 subjects. The results obtained from the muscles of upper extremities of throwers were compared with those of recreational athletes. The better neuromuscular control of throwers caused more profitable muscle activity during elementary arm motion. Differences during pitching are more significant.

Conclusions

By analyzing EMG curves of all movements we can determine that muscle activity occurred simultaneously in muscles producing the movement and in antagonistic muscles stabilizing the joints with nearly equal amplitude. This indicates that coordination due to muscle contraction plays a significant role in stabilizing the shoulder joint. In the control group the m. biceps brachii, the m. triceps brachii, and the m. deltoideus also play an important role, while in javelin throwers the role of the rotator cuff muscles are more intensive in ensuring proper stability. With this knowledge, rehabilitation programs tailored to injured throwers' needs can be developed.

Introduction

Both normal and pathological muscle functions have been examined by electromyography. EMG has been used to quantify muscle activity patterns during shoulder rehabilitation protocols, sports activity, all-day work, and overhead sports activities [1,2]. There are no reports on the muscle activity patterns of the rotator cuff muscles and the shoulder synergist during overhead throw at javelin throwers. The purposes of this study were to define the sequence of muscular activity patterns in selected shoulder girdle muscles during elementary motion and during overhead throw and to analyze the learned characteristics of overhead throw.

Materials and methods

The study was carried out on nine javelin throwers (21.2 ± 3.1 years, 185.3 ± 12.1 cm, 79.1 ± 4.1 kg) and on 16 healthy subjects (22.1 ± 1.1 years, 182.9 ± 23.9 cm, 72.1 ± 3.4 kg). Surface EMG electrodes were attached to m. pectrolalis maior, m. infraspinatus, m. deltoideus anterior, middle and posterior parts, m. supraspinatus with m. trapesius, m. biceps brachii, and m. triceps brachii. The investigated movements included pulling in the saggital plane; pushing in the saggital plane; elevation in the coronal plane; slow and maximal speed overhead throw. Muscle-activity is characterized by EMG envelope-curve in time-function. The activity recorded during the investigated movement was normalized by the maximum voluntary contraction (MVC) achieved during all the five movements instead of reference voluntary contraction (RVC).

Results

Significant differences can be observed between the two groups in the MVC% of the middle and posterior deltoid, the m. supraspinatus and m. infraspinatus during pulling, of the posterior deltoid and m. supraspinatus during pushing, of the posterior head of m. deltoideus during elevation and during maximum speed overhead thrower. In the control group, a time dislocation (13.12%) can be observed between the maximum activities of the different muscles in the same phase of movements compared to the javelin throwers, where the difference is a minimal 10.63% if we consider the total time of a pitching to be 100%. The difference is not significant.

Discussion

By analyzing EMG curves of all movements we can determine a difference in ensuring the stability of the shoulder. In javelin throwers the time difference between the activity maximum of the agonist and antagonist muscles is minimal, while in the control subjects the time difference is broader; however, the difference between the groups is not significant. This can be well observed during maximum speed pitching. This suggests that the different neuromuscular control and proprioception of the javelin throwers caused different muscle coordination during throwing. As a consequence of the research, we may suppose that elementary movements are combined of several motion types; amateurs add considerable rotation to all movements.

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Session 5 (oral): 10:52 to 12:52
Cerebral Palsy

S5.1: Changes in joint kinetics in children with diplegic cerebral palsy

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Summary

We examined changes in knee, hip and ankle kinetics of patients at two consecutive gait analyses. These children had a diagnosis of Spastic Diplegic Cerebral Palsy (SDCP) and were independent ambulators. They had not had surgical intervention or Botulinum toxin injections before the 1st analysis or between analyses. We found that those children presenting with minimum knee flexion in single support of less than 20° at the first analysis remained stable, i.e. their minimum knee flexion and their mean joint extensor moments during single support did not change significantly. In contrast, the group who presented with greater than 20° of knee flexion at the first analysis had positive mean knee extensor moments and developed greater levels of knee flexion and larger knee extensor moments by the second analysis.

Conclusion

Our results indicate that the natural history of children with SDCP who present with knee flexion of greater than 20° is one of increasing knee flexion and exposure of the knee extensors to greater loads.

Introduction

In cross-sectional studies, increased knee flexion in the stance phase of gait in children with SDCP has been found to be associated with an increased and prolonged knee extensor moment [1]. Knee flexion has also been shown to increase the forces acting through the knee extensors dramatically [2]. A longitudinal analysis of lower limb joint kinetics in children with SDCP may improve our understanding of the development of crouch gait. This study examines the changes in minimum knee flexion and the internal extensor moments of the joints of the lower limb from two consecutive gait analyses in a group of children with SDCP. We hypothesised that children with knee flexion greater than 20° would fall further into crouch and expose their knee extensor musculature to greater loads.

Patients/materials and methods

We reviewed kinematic and kinetic data obtained from two consecutive gait analyses (Vicon 370 six-camera system, three AMTI force plates) of 17 children (34 limbs) with SDCP, aged 4–16 years (mean: 8.5 years). The interval between analyses ranged from 7 months to 2 years (mean: 1 year). All these children were independent ambulators and had not undergone surgery prior to, or between, analyses. The following variables were computed over the single support interval using Event Analyser (Vaquita, UK): minimum knee flexion; mean ankle extensor moment; mean knee extensor moment and mean hip extensor moment.

Results

We found significant increases in minimum knee flexion ($P < 0.05$) and mean knee extensor moments ($P < 0.05$) between analyses for those children who presented with greater than 20° of knee flexion at the first analysis (six limbs). The changes in knee flexion and knee extensor moment were highly and significantly correlated ($r^2 = 0.7632$; $P < 0.05$). We did not find significant differences in the mean hip extensor or ankle moments between the two analyses for this group. There were no significant changes in the group of children who presented at their first analysis with minimum knee flexion of less than 20°.

Discussion

Previously, we have found that increasing knee flexion in children with SDCP loads the knee extensors preferentially [1]. In this small longitudinal study, we have shown that children with increased levels of knee flexion tend to develop greater levels of crouch and greater knee extensor moments. We believe that increased levels of knee flexion in children with SDCP cannot be maintained because of deleterious changes in the quadriceps secondary to the increased loading of these muscles and the underlying neurological condition of these patients.

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S5.2: The importance of additional strength-training in the post-operative treatment of children with cerebral palsy

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Summary

The rehabilitation period after surgery is important concerning the duration and quality of recovery. In a randomized, prospective study a group of 40 children with cerebral palsy (CP) was divided in two groups to determine the effect of strength training 6 and 12 months after the operation. Functional parameters with Gross Motor Function Measurement (GMFM) as well as kinematic data of 3D gait analyses were assessed to investigate gait quality improvement.

Conclusions

Functional strength training in addition to regular physiotherapy does not affect spasticity. However, it is still unclear whether the gained muscle strength, which is diminished by surgery, helps the patients to improve the functional outcome and shortens the rehabilitation process.

Introduction

The commonly prescribed post-operative physical therapy for children with CP does not currently include functional strength conditioning. However, several studies have been formulated and published, which examine the effects of short-term strength training on functional ability, walking efficiency and crouch gait in non-operated spastic diplegics [1–3]. The use of functional strength training as an additional post-operative rehabilitation tool has not been investigated so far. The purpose of this study is to compare the effects of functional strength training in addition to conventional post-operative physical therapy and to determine the relationship between strength gain and functional improvement.

Patients/materials and methods

Forty spastic diplegia patients with CP (assisted or unassisted walkers) in the age of 6–16 years have been examined. Prior to surgery (Pre-Op), the patients underwent clinical examination, 3D gait analysis, Biodex (isometric and isokinetic knee flexors–extensors strength test), oxygen consumption testing and GMFM. Half of the patients (randomized) received functional strength training of the flexor and extensor muscles of the lower limb additional to regular physiotherapy (Strength Training Group: STG), whereas the other half received physiotherapy only (Control Group: CG). The patients and their parents have been instructed during the hospital stay to perform the strength training independently at home, at least three to four times a week. Six months after surgery (Post-Op6) the patients underwent clinical examination and muscle strength test, in addition to digital video recording. Twelve months after surgery (Post-Op12) the complete set of examinations was performed again. The measurements of strength and functional outcomes are used to compare the two groups of surgically treated spastic diplegics.

Results

Generally, the experience was that the rehabilitation phase after soft-tissue and bony surgery was longer than originally estimated, especially when looking at the patients' muscle strength. Comparing the strength tests Pre-Op and Post-Op6, the STG showed a smaller decrease in the knee flexor moments relative to the CG. However, the strength level Post-Op12 did not show any differences between the groups. Additionally, the strength gain between the Pre-Op and the Post-Op12 was significantly correlated with the training frequency (training units/week). The 3D gait analysis which was performed only at Pre-Op and Post-Op12 showed a significant improvement between the tests in the majority of the kinematic parameters as well as in the overall normalcy index [4] for almost all of the 40 patients. However, the improvements in the STG were not significantly greater than in the CG.

Discussion

The presented study is to our knowledge the first long-term study of the effects of strength training in the post-surgical rehabilitation process of patients with CP. Despite the motivation problem to attend this strength training additionally to the daily activities, the extra strength training was well tolerated, continuously performed for a 9-month period and as other authors [5], we could not find any signs for increased spasticity due to strength training. Following the concept of the study, the strength training was kept as uniform as possible for all patients to keep the STG homogenous. However, the strong and individual effects of the operation impose large functional differences within each group. This implies that the differences between the groups can probably only be singled out as an effect of strength training in larger and more homogenous groups, which are difficult to obtain in a single-center study.

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S5.3: Stride to stride variability in young adults, children and children with cerebral palsy

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Summary

In this study we purpose the use of a quantitative index for assessing the repeatability of kinematic variables during gait and we studied the application of the index to developmental and clinical issues. The index (IP), that is extracted using a data-driven approach, quantifies the deviations from the dominant pattern of the joint and, physically, it reflects the percentage of the total energy contained in the dominant singular value.

Conclusions

Adults have stable gait patterns with small amount of energy lost in fluctuations around the dominant trace. In children the gait is less stabilized especially at ankle level and the reduction is even more dramatic when considering the affected side of hemiplegic children where a large amount of energy is lost in corrective movements.

Introduction

A fundamental hallmark of human condition is the ability to perform bipedal walking despite the highly complex sequence of neural and biomechanical events that have to take place for walking to occur. In terms of observational characteristics, the gait of healthy adults is characterised by smooth, regular and repeating movements which occur with consistency, adaptability and spatiotemporal precision. It is known that, in developmental age, the primary gait variables will change as an effect of both the maturation of central nervous system and the musculoskeletal growth [1]. Beside spatiotemporal parameters even kinematic traces undergo to an evolutionary process that progressively leads the joint kinematics to the stable patterns that are reported for adults. From a dynamic-system perspective it may be stated that the "system" develops a stable attractor that enables the dominant pattern to emerge [2]. In this context the investigation of the repeatability of joint kinematic—not in terms of singles data points but in terms gait-cycle-curves-offers valuable information for both developmental and clinical issues.

Patients/materials and methods

Five adult subjects (AG) (mean age 21.6 ± 0.9 years) five children (CG) (6.6 ± 0.9 years) and an age-matched group of five hemiplegic children (HG) (6.4 ± 1.3 years) were recruited for this study after giving the informed consent. Neither neurological disorders nor orthopaedic impairments were reported for the AG and CG groups whereas for the HG group the diagnosis of hemiplegia was supported by neurological examination and neuroimaging. Gait data were acquired using a motion analysis system (Elite BTS, Milan) equipped with eight infrared camera operating at 100 fps. Ten complete gait cycles were acquired for each participant and for each leg. Angular displacement together with angular velocity and acceleration were calculated and time-normalized for ankle and knee joints. Singular value decomposition pattern analysis was applied to kinematic variables and an index of repeatability was calculated for accounting the degree of the between-trials variability of the kinematic traces in each subject.

Results

The AG group showed highly stereotyped kinematic traces both in terms of angular displacement, velocity and acceleration with no statistically significant differences (SSD) between the left and the right leg. The repeatability of kinematic traces in the CG group was considerably lower even if the irrelevance with respect of the limb is preserved. Conversely, SSD ($P < 0.01$) were evident when comparing the impaired and the "unimpaired" limb in the HG group. The repeatability at knee level was significantly higher ($P < 0.01$) with respect to the ankle joint and this finding holds even in the CG and HG groups. Numerical values of the IP were highly consistent in the AG group whereas the variances increases when considering the CG and HG groups. When comparing the two groups of children we found SSD between the affected side of the HG group and the CG group whereas the unaffected limb showed no SSD in the same comparison. Post-hoc analysis (Tukey's HSD $P < 0.01$) showed that the IP of the AG group was significantly higher with respect both to the CG and the HG groups.

Discussion

In this study we purpose the study of kinematic traces regarding at them as curves emerging from a functional action rather than a collection of independent data-points. The IP showed the ability to discriminate and assess both the subtle differences of pattern stability that is typical of developmental age and the abrupt changes in gait patterns introduced by the pathologic condition.

References

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S5.4: EMG patterns in various stereotyped walking patterns in cerebral palsy

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Summary

In this retrospective study EMG patterns during gait of five main muscles of 70 legs in 43 patients with CP were analyzed. Patterns were compared after grouping the deteriorated gait into four basic patterns, based on foot contact and knee angle. Except for the medial gastrocnemicus, no differences between groups were found.

Conclusion

Although walking disorders in CP show a variety of postural and kinematical patterns, implying a variety in muscle load, these phenomena show no correlations with a typical muscular coordination pattern.

Introduction

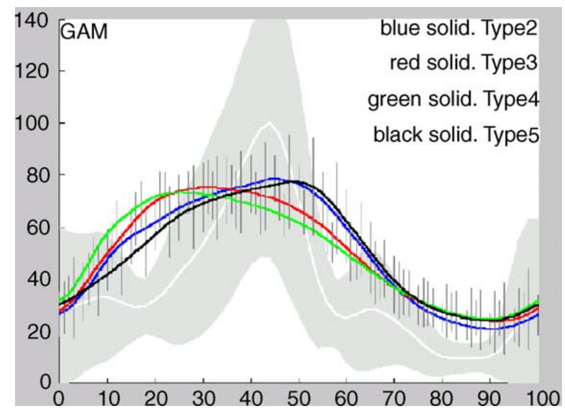
Improvement in gait is a frequent treatment goal in children with CP. Advancements in movement analysis methodologies in the last decennia has contributed to the understanding of gait pathologies and is recognized as a valuable tool to assist clinical decision making. Several authors have suggested a classification of deviant gait patterns in CP into stereotyped groups. The general denominator of these classification is that they are based on the posture during midstance, which are very different from a mechanical point of view. Since the mechanics of the skeleton are counterbalanced by the muscles, which provide force by contraction, it is likely that deviant walking patterns will be the result of a deviant muscle coordination. The muscle coordination can be, with some restrictions, derived form the EMG, resulting in EMG patterns during gait [1]. The aim of this study was to investigate whether deviant muscle contraction patterns are strongly coupled to pathological walking types.

Patients/materials and methods

Forty-three patients with Cerebral Palsy that were measured at the gait lab of our department were selected. All patients were between 4 and 12 years of age with no history of treatment on muscular performance, and were waking with no walking aids. Diplegic patients were measured on both legs and hemiplegic patients on their affected side, resulting in 70 legs for analyses. Gait assessment consisted of a routine biplanar video recording and simultaneous EMG recording of Tibialis anterior, Gastrocnemius Medialis, Rectus Femorus, Semitendinosis, and Vastus Lateralis. EMG envelopes were averaged over at least seven strides. From the video recording the walking pattern was stereotyped by its posture during midstance, based on knee angle (flexed or hyper extended) and foot position (foot flat or forefoot contact only), into four groups. Before group averages per muscle were made, the EMG envelope ensembles were normalized to their mean activity level.

Results

Classifying walking patterns was successful in 64 legs, with at least 12 legs in each of the four groups. M. Gastrocnemius (see figure) was the only muscle that showed a difference, i.e. increased activity in midstance for the two walking types that included forefoot walking. In all other muscles the EMG envelope ensembles were only marginally different, with no statistical differences. In comparison to normal EMG profiles (gray area in figure) all muscles showed differences.



Discussion

In contrast to what we expected the muscle coordination patterns as measured by EMG were quite uniform for the walking of our population of CP children, regardless of their walking patterns. The relatively increased EMG activity in midstance in gastrocnemius for forefoot walkers is coincident with the greater amount of ankle plantar flexion needed for these walking types. Similar responses in EMG of the vastus lateralis in knee-flexed walking types could not be observed. However, it must be stressed that our method uses EMG profiles. Inferring net joint moments from EMG activation, does not comply with the dependency of this relation on muscle length which is very different for the various walking types. Moreover the method of normalization, though standard in EMG envelope processing [1], will obscure any differences between subjects with regard to their absolute mechanical muscle performance. Finally, net joint moments are also taken up by the passive structures of the muscles, which are considerable in case of muscle shortening, which is frequently present in this population. Research should focus at the relative contribution of passive and active forces from the muscles in CP gait.

Reference

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S5.5: Gait classification in hemiplegic cerebral palsy based on EMG

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Summary

Normal electromyography (EMG) for gait in healthy children was quantified. Visual classification of raw EMG patterns showed reasonable repeatability between independent assessors. A classification of EMG activity was proposed for hemiplegia. Abnormal activity was found in the non-hemi side of CP, particularly in the gastrocnemius.

Conclusions

EMG may be used to classify gait patterns, and distinguish normal from abnormal activity. Work is ongoing to further improve repeatability in classifying EMG. This system, in combination with other gait data, may provide useful information for classification of hemiplegia in CP.

Introduction

Classification of gait patterns in cerebral palsy (CP) is a complicated task. The most commonly accepted method currently available is that proposed by Winters et al. [1]. This is useful for classifying physical manifestations of the syndrome, but gives little information about the underlying pathology. EMG is the best approximation of primary deficits in neurology, since it is the most direct measure of it, and therefore has potential to help guide treatment in CP. However a simple yet objective criteria for assessing EMG is difficult to define. There is ongoing debate about the intra/inter assessor reliability of gait data in general. This study aims to assess the repeatability of pattern identification in EMG, and to develop a classification system for hemiplegic CP based on EMG.

Patients/materials and methods

Thirty-nine children with hemiplegic cerebral palsy and 15 healthy children had surface EMG electrodes placed on gastrocnemius (G) and tibialis anterior (TA) muscles on both legs. Subjects were asked to walk at a comfortable pace. One representative trial from each subject was selected (which included three gait cycles). All G traces from the healthy children were averaged together, and a normal "on/off" time interval was established (Fig. 1). This was repeated for the TA muscle. The order of the 54 raw EMG graphs with normal bars was randomised, and then reviewed independently by two assessors who had agreed a classification scheme based on pilot work. A third independent assessor, less familiar with interpreting EMG data then reviewed the same graphs. Categories for G included: (1) normal, (2) mildly premature, and (3) premature activity; and for TA: (1) normal timing and biphasic, (2) normal timing but monophasic, (3) reduced second burst, (4) absent second burst, and (5) continuous activity. Any graphs which were classified as "inconsistent" were excluded from the study. Lower body 3D kinematics were also collected (Vicon 612) and the sagittal plane graphs were independently typed by two assessors according to the Winters classification system [1].

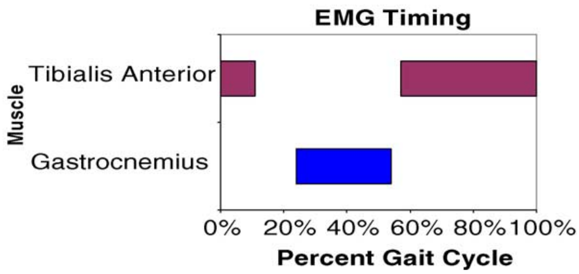

Fig. 1. Normal timing of gastrocnemius and tibialis anterior ($N = 15$).

Results

In G analysis, distinction between groups 1 and 2 was less repeatable than other comparisons, similarly for groups 3 and 4 in TA analysis. Table 1 shows results these categories combined. There was 100% agreement for healthy subjects between the first two assessors, and 89–95% for CP subjects. This is reduced when all three assessors are considered together. Interestingly, G was premature in the non-hemi side of CP patients in 50% of cases while TA only had abnormal activity in 8% of cases. Two independent assessors agreed on Winters' classification of patients in 55% of cases.

Table 1. Agreement between three independent assessors for categorising EMG patterns in healthy and CP subjects ($N = 54$)

	G hemi side (%)	TA hemi side (%)	G non-hemi side (%)	TA non-hemi side (%)	g healthy (%)	TA healthy (%)
First two assessors	89	95	92	89	100	100
All three assessors	89	67	78	87	90	100

Discussion

There have been some attempts to define on/off timing of EMG with automated methods. While this provides objectivity, it has limitations in the presence of signal artifact and maximum signal intensity. Arguably, visual inspection of raw signal can be more informative, but is also more reliant on experience, which was corroborated by these results. Based on the results achieved, it is possible to classify G activity in hemiplegia into two distinct groups, and TA into four groups. Repeatability results are comparable to other aspects of gait data. Further improvement in objectivity and repeatability of classification is expected with the reduced number of categories, and having a reference set of normal raw EMG patterns for comparison when classifying graphs. There was no correlation between type of hemiplegia and EMG patterns noted.

Reference

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S5.6: Factors associated with pelvic retraction during gait in cerebral palsy

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Summary and conclusion

Static and dynamic measures thought to be associated with pelvic retraction were investigated in patients with cerebral palsy. Gait laboratory data of 233 patients with cerebral palsy were studied retrospectively. Two groups were selected; those who demonstrated pelvic retraction during gait >6.85° and those with <4.83°. Of 233 patients, 37.77% showed pelvic retraction of >6.85°. While differences were seen between hemiplegic and diplegic subjects, static and dynamic tightness of the gastro-soleus and internal rotation of the lower limb were the most significant features associated with pelvic retraction. This study suggests that pelvic retraction is multifactorial in origin and secondary to both static clinical measures as well as dynamic features during gait.

Introduction

Pelvic retraction during gait is common in children with cerebral palsy and can lead to cosmetic and functional concerns due to an asymmetric gait pattern. Studies have shown that pelvic retraction is associated with internal rotation [1,2] and it is thought that static or dynamic tightness of the gastro-soleus may contribute to this gait pattern. The purpose of this study was to compare the measurement of both static and dynamic variables in two groups of patients: those with and without excessive pelvic retraction during gait.

Methodology

Excessive pelvic retraction during gait was defined as >6.85° (average value) based on a previous study of normal subjects (mean + 2 S.D., $n = 59$, age range 5–32 years). Two hundred thirty-three patients with cerebral palsy (diplegia: 53.65%, hemiplegia: 46.35%, age range 4–39) with no previous surgical history and who had undergone gait analysis using the CODA mpx30 system from 1998 to 2004 were reviewed. Two distinct groups were selected: those with pelvic retraction of >6.85° and those with <4.83° (mean + 1 S.D. from normal study). Each group was further subdivided into patients with hemiplegia or diplegia. Measures of eight clinical variables and eight gait variables thought to contribute to this gait pattern were compared in the two groups for hemiplegia and diplegia.

Results

Of 233 patients, 88(37.77%) patients walked with pelvic retraction >6.85°. One hundred one (43.35%) patients had pelvic retraction <4.83°. Using two-tailed *t*-tests, the *P*-values for each variable and group were calculated and are shown in the tables below. Significance level was set at $P < 0.05$.

Static measures	Hemiplegic	Diplegic	Dynamic measures	Hemiplegic	Diplegic
TA-knee extended	$P = 0.01$*	$P = 0.02$*	Mean hip rotation	$P = 0.002$*	$P < 0.001$*
TA-knee flexed	$P = 0.02$*	$P = 0.13$	Mean knee rotation	$P = 0.51$	$P = 0.39$
Popliteal angle	$P = 0.26$	$P = 0.33$	Mean ankle rotation	$P = 0.005$*	$P = 0.95$
Hip flexion contracture	$P = 0.40$	$P = 0.01$*	Mean foot progression	$P = 0.80$	$P = 0.60$
Femoral anteversion	$P = 0.66$	$P < 0.001$*	Max hip extension	$P = 0.011$*	$P < 0.001$*
Tibial torsion	$P = 0.98$	$P = 0.67$	Max knee flexion	$P = 0.18$	$P = 0.57$
External rotation	$P = 0.47$	$P = 0.02$*	Max knee extension	$P = 0.40$	$P = 0.009$*
Rectus tightness	$P < 0.001$*	$P = 0.46$	Max ankle dorsiflexion	$P = 0.009$*	$P = 0.27$

* $P < 0.05$

Discussion

Factors contributing to excessive pelvic retraction were examined in children with cerebral palsy. Causes of such a gait pattern are multifactorial and there are important differences between patients with diplegia and hemiplegia. Static and dynamic tightness of the gastro-soleus and rectus tightness are the most significant features in hemiplegics while internal rotation of the hip and hip flexor tightness were the most significant factors in diplegics with a pelvic retraction gait. Further study is needed to determine if these factors are causal or compensatory.

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S5.7: The ability of gait analysis to inform treatment decisions in children with spastic diplegia

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Summary

Treatment decisions based on three-dimensional gait analysis in a group of 20 children with spastic diplegic cerebral palsy were assessed by a repeat gait analysis at a mean interval of 14.7 months. Those children in whom multi-level surgery had been recommended but not yet performed showed a deterioration in their mobility and in their kinematics, while those children in whom surgical intervention was not initially thought to be indicated remained stable or improved.

Conclusions

Three-dimensional gait analysis can discriminate between children with spastic diplegia who have a deteriorating mobility and those who are stable, allowing prediction of future mobility and the formulation of appropriate treatment recommendations.

Introduction

Three-dimensional gait analysis (3DGA) is used commonly in children with spastic diplegic cerebral palsy (CP) to plan appropriate multi-level surgical intervention and to assess the outcome following surgery. The ability of gait analysis to discriminate between children with CP with progressive deformity and deteriorating mobility and those who are stable has not previously been assessed.

Patients/materials and methods

Two groups of children with CP who were referred to our laboratory for 3DGA were reviewed. The treatment group consisted of 10 children (mean age 9.9 years) in whom multi-level surgical intervention was recommended but not immediately performed because of family or administrative reasons, and who had a repeat gait analysis before surgical intervention at a mean interval of 13.1 months from the initial analysis. The control group consisted of 10 children (mean age 8.2 years) in whom an exercise program was recommended, and who had a repeat gait analysis at a mean of 16.3 months. The gait analyses were performed using the Vicon 370 motion analysis system (Helen Hayes marker set, Vicon Clinical manager) and surface electromyography, and all of the treatment recommendations were made by the same team.

Results

On the second gait analysis the treatment group overall had a reduction in mobility, with a significant increase in minimum hip flexion ($P < 0.001$) and minimum knee flexion ($P < 0.001$) in stance. The control group overall remained stable, although there was a significant change in their minimum knee flexion in stance ($P < 0.05$), and in their popliteal angles ($P < 0.02$). One child in the control group had gastrocnemius recessions recommended following her second analysis, but exercise was recommended again in the remainder. Eight of the children in the treatment group have since undergone multi-level surgery.

There was no significant difference between the mean age at the initial analysis or the mean interval between gait analyses in both groups. There was a significant difference in the mean popliteal angle ($P < 0.01$), minimum hip flexion in stance ($P < 0.01$), and minimum knee flexion in stance ($P < 0.01$) between both groups on the initial analysis. There was no significant difference between mean ankle passive range or maximum ankle dorsiflexion in stance between both groups at the initial analysis, and these parameters did not show any significant changes between analyses in either the treatment or control group.

Discussion

This study suggests that clinical gait analysis can be used successfully to differentiate those children with CP with a deteriorating mobility who would benefit from surgical intervention and those with a stable pattern of mobility who can be managed nonoperatively. The factors which appear to predict deterioration, namely increased popliteal angle, minimum hip flexion and minimum knee flexion in stance, suggest that increasing knee flexion rather than equinus should be seen as a cause for concern and a focus for early intervention in children with CP. The deterioration seen between gait analyses in the treatment group raises concerns about the longterm outcome following surgical intervention in those children with CP who present with a deteriorating level of mobility. The results also emphasise the importance of defining appropriate controls if the effect of any operative or nonoperative intervention in children with CP is to be assessed.

Table 1. Errors in hip joint location (MRI method) in mm associated with each dimension (where x is anterior/posterior direction, y the inferior/superior direction and z the medial/lateral direction) and absolute distance error (Δd) for 20 hips expressed as mean with standard deviation in parentheses

	Δx	Δy	Δz	Δd
US	−9.4 (6.8)	−2.7 (9.6)	1.4 (6.6)	15.4 (5.7)
Bell	−0.5 (10.3)	−15.7 (5.4)	3.4 (6.6)	19.9 (5.7)
Davis	−6.0 (8.5)	8.9 (5.8)	13.6 (8.7)	20.0 (8.9)

Technology

S5.8: Validation of a 3D ultrasound technique for locating the centre of the hip joint

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Summary

A 3D ultrasound technique was used to estimate the position of the hip joint centre (HJC) in 10 adults. When positions were compared to measurements made from MRI scans the technique was found to be more accurate than the regression models commonly used.

Conclusion

3D ultrasound may be considered a feasible method for locating the HJC in adults. In children with pathology where the prediction of HJC using regression equations is known to produce greater errors, the ultrasound technique may be used to provide accurate subject specific measurements.

Introduction

Many models of human movement depend on accurate estimation of joint centres and joint axes of rotation. Methods that have been used to locate the hip joint centre within a pelvic reference frame include the use of regression equations [1,2], functional methods [3] and more recently optimisation techniques. Measurements of hip joint location made from magnetic resonance images (MRI) of the femoral head and pelvic girdle can be considered as the Gold Standard. This paper aims to validate a 3D ultrasound technique against MRI measurements and to compare the accuracy of the ultrasound technique with outputs from regression equations.

Patients/materials and methods

A 3D ultrasound technique [4] was used to measure the location of the centre of the femoral head (nominal HJC) in 10 young adults (eight male, mean age: 24 years, range: 20–32 years). These results were compared to positions obtained from MRI (the Gold Standard) and from two common anthropometric models (Bell [1] and Davis [2]).

Results

Using the 3D ultrasound technique we were able to predict the position of the hip joint to within 15.4 mm of the true value on average making it more accurate than the regression models ($P = 0.02$ for Bell, $P = 0.11$ for Davis) (see Table 1). In y- and z-directions the ultrasound showed no bias when compared to the positions measured from MRI. In the x-direction (anterior–posterior) a bias of 10 mm was found. Ultrasound precision did not differ significantly from that for the regression models.

Discussion

The ultrasound technique showed nearly 5 mm of improvement in the absolute error when compared to the regression models. However HJC position in the x-direction had significant bias: the hip was found to be on average 10 mm anterior to the position measured by MRI. We believe that this is due to the difficulty in estimating by eye the centre of the femoral head from the arc which is visible in the ultrasound images. This could be improved by fitting a circle to the arc; by making a complete reconstruction of the local anatomy under ultrasound and estimating the centre of a partial spherical surface or by selecting the most suitable image of the femoral head while conducting the examination.

The regression models used here are based on data from adults. Jenkins [5] has shown that errors associated with these models increase in children and increase further in children with cerebral palsy (CP). The absolute errors associated with the ultrasound technique are not expected to be any greater in these groups. We suggest that using ultrasound to make subject specific measurements may result in improvements in gait analysis data.

References

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[4] Fry NR, et al. Gait Posture 2003;17(2):119–24.
[5] Jenkins S. Personal communication, 2002.

S5.9: Gait with a new carbon spring orthosis in children with plantarflexor weakness

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Summary

A gait analysis study was performed to compare orthoses with a carbon fibre spring to habitually-worn orthoses in children with plantarflexor weakness. Ankle kinematics and kinetics and temporal–spatial parameters are shown for one subject. Some evidence of improved gait function was determined, both objectively and subjectively.

Conclusions

In a presented subject, gait patterns and plantarflexor moment were similar with both orthoses, but the spring orthoses showed the added benefit of providing increased power generation at the ankle and improved temporal–spatial parameters. Most subjects preferred the spring orthoses to their habitual ones.

Introduction

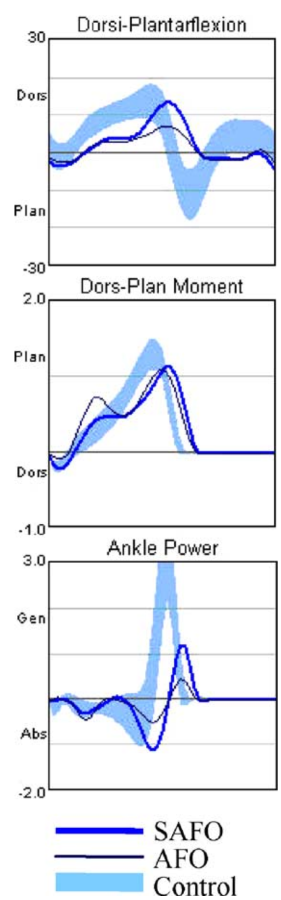
The roles of the plantarflexor muscles during gait are to stabilize the ankle and control tibial advancement during stance. The plantarflexors also act during heel rise to reduce vertical centre of mass excursions [1]. The plantarflexor muscles are a major source of power generation in terminal stance and contribute to forward propulsion [2]. Children with motor disorders such as myelomeningocele (MMC) and arthrogryposis often lack plantarflexor muscle strength. Orthoses are commonly used to compensate for this weakness. In the past decade a German orthotics company has been developing an orthosis based on design principles from carbon fibre prosthetic feet. The 'spring orthosis' was designed to compensate for plantarflexor weakness and the inability to push-off by storing energy during tibial advancement and returning it during terminal stance [3]. The aim of this pilot study was to investigate whether a difference could be seen in gait efficacy between spring orthoses and standard orthoses.

Patients and methods

Eight children, of which six with lumbo-sacral MMC, one with arthrogryposis and one with an orthopaedic syndrome (median age 9.0, range 6.2–15.2) years, were included in a gait study. Six children used ankle–foot–orthoses (AFOs) and two children used knee–foot–ankle orthoses with unrestricted sagittal knee motion. All children had been prescribed spring orthoses by their clinicians and had used them routinely for 2–3 weeks before gait evaluation. They were also instructed to use the former orthoses occasionally. All children underwent 3D gait analysis (Vicon Motion Systems) using a 6-camera system while wearing both orthosis types. Gait kinematics, kinetics and temporal–spatial parameters were compared. Results from 23 healthy children (5–14 years) were used for comparison.

Results

Results are shown for one subject, a 15.5-year-old female with MMC and complete plantarflexion paresis with her AFOs with overlapping foot and shank sections, and her spring ankle–foot–orthoses (SAFOs). An average of 3 left and 3 right gait cycles was computed in each orthosis and used for comparison. In this subject, the SAFOs allowed more tibial advancement than the AFOs with nearly-fixed ankle joints. This resulted in a normal degree of dorsiflexion during mid- to late stance. Peak plantarflexion moment was similar in magnitude for both orthoses. The SAFOs showed a tendency for greater ankle power generation in terminal stance. This subject walked 9% more uickly (1.08 m/s versus 0.99 m/s) and took 9% longer strides (1.22 m versus 1.12 m) in SAFOs while walking at similar self-chosen cadences (107 steps/min versus 106 steps/min).



Discussion

The observed gait patterns with the two different orthosis types were overall very similar. The standard orthoses were designed to provide plantarflexion moment and some power generation from the slightly flexible thermoplastic soles. The spring orthoses showed no compromised stability but appear to have the benefit of providing increased power generation at the ankle during terminal stance and improved temporal–spatial parameters. All subjects reported positive experiences with the spring orthoses and preferred them over their old orthoses. A study with gait analysis and a subjective questionnaire is underway.

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S5.10: 3D motion analysis and synthesis from inertial gyroscopes and image data

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Summary

A new method using miniature gyroscopes with synchronized video cameras is proposed. Combining gyroscopic signals in the sagittal plane and 3D information from the cameras lets us recover leg motion not only in the sagittal plane but also in the frontal one.

Conclusions

We proposed a new approach for 3D tracking applicable in gait analysis. The approach takes advantage of both markerless stereo imaging and miniature body-mounted sensors. We show that this fusion significantly improves tracking stability and robustness, over that of either modality alone.

Introduction

Markerless and high-speed tracking of human movements during gait is a very complex task. Current optical motion analysis systems are very expensive, require wearing reflective markers by the subject, the measurements are restricted to a laboratory environment, and the markers are easily obscured from vision. In this study we presented an inexpensive and easy-to-use solution by integrating body-mounted sensors and vision tracking technologies. Our system is based on combining the output of a very limited number of inertial gyroscopes with inexpensive and commercially available synchronized cameras. Our philosophy is to combine the respective strengths of body-mounted sensors [1] and image-based technologies [2]. The former is robust but impractical to attach enough sensors for capturing all degrees of freedom of human motion. The latter provides more aspects of motion, yet it is usually less reliable due to obscuring body segments from vision resulting in incomplete data. Our ultimate goal is to allow the measurement of changes in the biomechanics of the prosthesis by noting the effect of these changes on clinical findings and day-living patient activity.

Patients/materials and methods

We tested two patients with posterior-stabilized total knee arthroplasty. The patients performed specific activities such as walking at different speeds and climbing stairs while five gyroscopes were mounted respectively on their shanks, thighs and trunk, and in parallel being filmed by two synchronized video cameras. For a given time step, the system extracts clouds of 3D points from our synchronized input video sequences using a correlation-based approach. The tracking process adjusts the model's joints angles (thigh, shank) by minimizing the objective function with respect to the joint angles relative to that frame in order to superpose the 3D model on the cloud. This modified posture serves as the initialization for the next one. For the legs we update this position with the prediction given by the integration of the gyroscopes signal.

Results

As shown in the figure, the motion parameters in the sagittal plane is recovered using a few sensors whose output is refined to include frontal motion by taking into account the 3D information derived from the video sequences. More specifically, the kinematic data allows robust motion recovery in the sagittal plane, while using imagery allows us to refine the description by incorporating motions in the frontal plane, which is just as significant for diagnostic purposes.

Discussion

We have shown that combining gyroscopes with cameras allows us to model patient's motion in more details than either modality alone. In its final form, the system we are developing will produce synthetic 3D animations that clearly represent the patient's condition and help the physician diagnose and treat it. We expect this to foster progress because there are currently no truly effective, automated and easy-to-use tools for functional assessment of patients with locomotion disability and for the outcome of orthopedic replacement surgery.

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Session 6 (oral) 14:30 to 15:30
Prosthetics

S6.1: The effects of shoe's instep on foot and knee dynamics during walking in patients with a tibio-talar arthrodesis

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Summary

In patients to whom a tibio-talar arthrodesis was performed in neutral sagittal position, various shoe's instep were tested to approximate the foot and knee sagittal kinematics and kinetics of control subjects walking with their usual shoes. The optimal shoe configuration in the arthrodesis group was a total shoe instep of 26 mm including a rocker bar.

Conclusion

Based on these results it may be proposed to the patients to whom a tibio-talar arthrodesis was performed in neutral sagittal position to choose and test first commercially available shoes with an instep of about 25 mm including a metatarsal rocker. Further studies are needed to appreciate the long-term effect of footwear design on the development of foot osteoarthritis.

Introduction

Degenerative osteoarthritis in subtalar and midtarsal joints occurring after tibio-talar arthrodesis are likely related to biomechanical factors [2]. In normal gait, heel off occurs during the third rocker as the fulcrum has moved to the metatarsal heads. Thus at heel off, the ground reaction force (GRF) is located close to the metatarsal heads [4]. When the tibio-talar joint is blocked, walking barefoot the anterior tilting of the tibia during midstance is enabled by an early heel off. We reported [1] in patients with an ankle arthrodesis that walking with their usual shoes compared to barefoot delayed significantly the heel off but at heel off the GRF was still too posterior from the metatarsal heads compared to control values what exerted abnormal stress on the midfoot. In addition, the maximal foot/tibia dorsiflexion during stance which was unchanged compared to barefoot condition and very close to the forced dorsiflexion value, probably generated local stress. The goal of the study was to improve or correct those anomalies by modifying the shoe design. The instep (anterior slope) of the shoes was significantly greater in patients (16 ± 5 mm) than in control subjects (10 ± 7 mm, $P < 0.05$). We hypothesized that increasing more the shoe's instep would delay the heel off and shift forward the GRF at heel off closer to normal values. In addition increasing the shoe instep was expected to decrease the maximal foot/tibia dorsiflexion in order to decrease local stress. On the other hand, walking with high heeled shoes was reported to alter knee sagittal dynamics [3]. The use of a metatarsal rocker bar which rocks the foot during stance was also tested.

Materials and methods

In the same series previously reported [1], a three-dimensional gait analysis was performed on nine patients with ankle arthrodesis fused in the neutral position and on 10 control subjects. Four conditions of walking at self-selected speeds were reported: walking with the usual shoes (S), with the same shoes the instep of which was increased either by 1 cm (S + 1, S + 1b (including a rocker bar)) or by 2 cm (S + 2).

Results

In the arthrodesis group at similar spatiotemporal parameters, increasing the shoe instep by 1 or 2 cm significantly delayed heel off (66 ± 7% (mean ± S.D.) to 68 ± 4% of stance phase) compared to the S condition (55 ± 8%, $P < 0.01$) thus at heel off the GRF was significantly closer to the metatarsal heads (79 ± 14% to 83 ± 11% of the ankle-second metatarsal head distance) compared to the S condition (67 ± 11%, $P < 0.01$) with similar values compared to the control subjects S condition (84 ± 8%). In the arthrodesis group, the maximal foot/tibia dorsiflexion was low and did not differ between barefoot and S conditions ($5 \pm 3^\circ$ versus $5 \pm 3^\circ$, respectively) but decreased significantly although slightly by using modified shoes ($2 \pm 2^\circ$ to $4 \pm 3^\circ$, $P < 0.05$ compared to S condition). Increasing the shoe instep by 1 cm was more comfortable than by 2 cm because of imbalanced feeling in the latter condition. In addition, the use of a metatarsal rocker bar which accelerated the GRF progression allowed similar sagittal knee kinetics as in control subjects. However the slight knee kinetics alteration in the other modified shoe conditions in the arthrodesis group had no significant importance.

Discussion

Thus the optimal condition of shoe configuration in the arthrodesis group was the S + 1b condition with a total shoe instep of 26 mm including a rocker bar. To benefit the effect of the shoe instep on the gait pattern the patient must have a sufficient range of foot plantar flexion to allow the foot to comfortably flatten on the ground during early stance. Further adaptation of the shoe configuration to individually find the best comfort of walking must be proposed.

References

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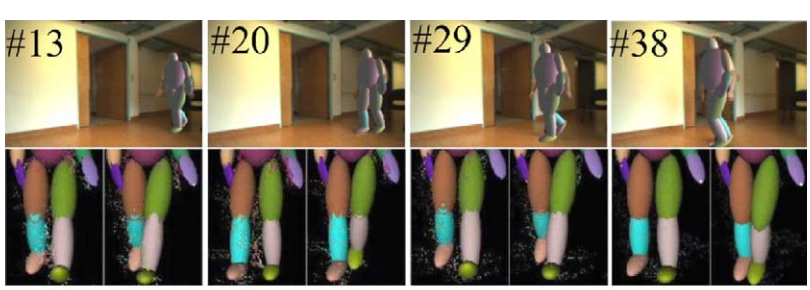

Fig. 1. First row: several frames of a walking sequence with the projected 3D model; second row: for each frame, frontal view of the limbs before (b) and after (a) using the 3D information. Note the frontal motion clearly visible in the (a) frames.

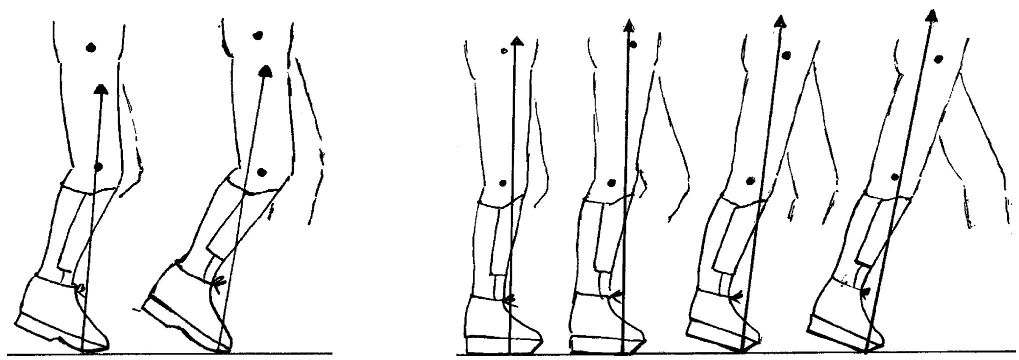

Fig. 1A and B.

S6.2: The point of 'point-loading rockers' in ankle–foot orthosis footwear combinations used with children with cerebral palsy, spina bifida and other conditions

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Summary and conclusion

When tuning an AFO-Footwear Combination (AFOFC) a 'point-loading rocker' (PLR) on the footwear can facilitate the kinematics and kinetics of terminal stance (TST). The position of successful PLRs and the accompanying toe spring angles (TSA) of AFOFCs were measured. When using a PLR a good starting point would be to position it at approximately 78% along the length of the footwear and move it backwards or forwards as required. A stiff deep sole and heel is required and one that provides a toe spring angle of 30° would also be a good starting point.

Introduction

The footwear that is worn with an AFO is integral in determining the overall biomechanical control provided so they have been described as an AFO-Footwear Combination. AFOFCs can be used to manipulate the kinematic and kinetic features of gait. One aspect of sagittal tuning of an AFOFC is to align the ground reaction force (GRF) for midstance (MST), by setting the Shank Angle to Floor/Vertical (SAF/V) of the AFOFC [3]. Another is to align the GRF for terminal stance (TST) by adjusting the design of the footwear. GRF alignment, anterior to the knee and posterior to the hip, in TST of normal barefoot gait is achieved by combination of maintenance of a relatively fixed ankle in appropriate dorsiflexion and use of metatarsal phalangeal joint (MTPJ) extension, third rocker, in order to produce appropriate inclination of the shank relative to the vertical. In some pathological gaits excessive inclination of the shank in TST prevents this GRF alignment and stability of TST is lost. An AFO can be designed to correct this. However, inappropriate accompanying footwear can reduce the chance of success as despite a fixed ankle and MTPJs in the AFO the profile of the sole of the footwear may allow the shank to incline excessively, with consequent lose of GRF alignment (Fig. 1A). A stiff sole and a sole profile that will not allow the heel to lift until the point of application (PoA) of the GRF reaches a PLR together with an appropriate 'toe spring angle' (TSA) allows the footwear to control the shank kinematics in MST and TST. In addition the use of a PLR arrests the forward movement of the PoA of the GRF, which facilitates alignment of the GRF behind the hip joint and production hip extension moments in TST [1] (Fig. 1B).

Method

Twelve children who were independently ambulant and who required solid AFOFCs that modified the kinematics and kinetics of MST and TST had their prescriptions tuned on the ORLAU transportable Video Vector Generator Gait Laboratory. The angle of the ankle in the AFO, the SAF/V and other prescription details including the position of the PLR and TSA of the 23 wholly or partially successful PLRs were recorded

Results

The PLRs were located at a mean of 78% of the length of footwear (S.D. 5.09; range 70–88%). The mean of the toe spring angles was 33° (S.D. 8.11, range 18–50°).

Discussion

The MTPJs, which provide third rocker in gait, are located at 72% along the length of the foot. In order to accommodate an AFO designed to fix the ankle and MTPJs a larger boot than required by the foot alone was needed. The PLRs were located at 70–88% along the length of the footwear, so were placed ahead of the MTPJs. Once the MTPJs are fixed in an AFO the PLR simulates third rocker. In MST the forward positioning of the PLR creates a stable sole profile, which allows control of shank kinematics for MST tuning. The position of the PLR dictates when the heel can lift. If the PLR is placed too far back the heel will lift too early with subsequent excessive shank inclination and loss of optimum vector alignment. If it is placed too far forward the heel will lift too late and the child will walk on their toes to avoid this. In TST the toe spring angle must be sufficient to prevent the distal end of the sole reaching the ground. This enables the PoA to remain harnessed at the point of the rocker throughout TST for facilitation of hip extension moments. Deep heels and soles are required to create appropriate TSAs and this increases the stiffness of the sole which is helpful. The success of PLRs seems to rely on: the selection of an appropriate angle of the ankle in the AFO for gastrocnemius; optimal design of AFO to resist ankle dorsiflexion and MTPJ extension; selection of optimum SAF/V by MST tuning; use of a boot to firmly secure the AFO to the footwear; a stiff non-compressible sole material; sufficient joint range and muscle length and tone at the hip and knee to allow extension of these joints at the angular velocity of thigh of the child's gait; appropriate foot progression angles. Kinetic tuning is necessary to be confident that TST tuning of AFOFCs.has been successful.

References

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S6.3: The effect of ankle–foot orthosis on walking ability in chronic stroke patients; a randomised controlled trial

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Introduction

Regaining mobility is a major goal during the rehabilitation of stroke patients. To support this process, often an ankle–foot orthosis (AFO) is prescribed. Although AFOs are thought to have beneficial effects on functional walking ability, results reported in literature are scarce and inconsistent. In a systematic review Leung and Moseley [1] reported a dominance of positive studies suggesting improvement of walking speed. The significance of these changes on daily functioning (clinical relevance) and implications for the wider population however remain unresolved. The aim of this study was to investigate the clinically relevant effect of an AFO on mobility in chronic stroke patients.

Methods

Twenty chronic stroke-patients, wearing an AFO for at least 6 months, were included. Mobility was operationalised as comfortable walking speed, scores on the 'Timed Up & Go' (TUG) test and stairs test. Patients were measured with and without their AFO. The sequence of tasks was randomised. Additionally, subjective impressions considering self-confidence and difficulty of the tasks were scored. Clinically relevant differences based on literature were defined for walking speed (0.20 m/s) [2], the TUG-test (10 s) [3] and the stairs-test (15 s). Gathered data were statistically analysed using a paired *t*-test.

Results

The mean difference in favour of the AFO in walking speed was 0.048 m/s (95% CI: 0.0085–0.087), in the TUG-test 3.56 s (95% CI: 2.38–4.76) and in the stairs-test 8.59 s (95% CI: 3.07–14.12). Sixty-five percent of the patients experienced less difficulty and 70% of the patients felt more self-confident while wearing the AFO.

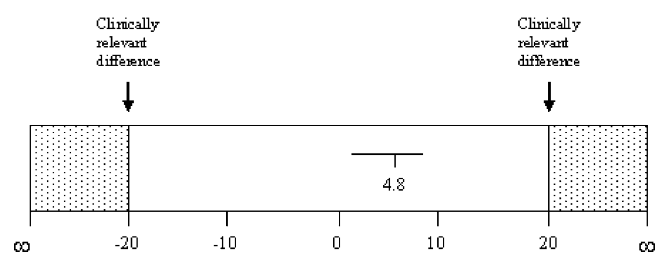

Fig. 1. Typical example: walking speed (m/s), mean difference and 95% CI.

Discussion

Results show that the effect of an AFO on walking ability and subjective impressions are statistically significant. Compared to the a priori defined values however, these differences are too small to be considered clinically relevant, which is in agreement with earlier findings of Beckerman et al [4].

The subjective impressions obtained with the questions about difficulty and self-confidence are clearly in favour of the AFO and judged as clinically relevant. This is comparable to the findings in the study of Tyson [5].

Conclusions

The effect of an AFO on mobility is statistically significant, but differences are too small to be clinically relevant. The effect on self-confidence suggests that other factors might play an important role in the motivation to use an AFO.

References

[1] Leung J, Moseley A. Impact of ankle–foot–orthoses on gait and leg muscle activity in adults with hemiplegia: systematic literature review. Physiotherapy 2003;89:39–55.
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S6.4: Effect of the socket ischiatic support on gait patterns of AK amputees

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Introduction

The gait patterns of subject with above-knee amputation and using a prosthesis with ischiatic support appear to be quite normal and only an expert can visually detect the prosthesis if it is not disclosed. Most of the studies of the AK amputees' gait have focused on the prosthetic knee and ankle kinematics and dynamics and on the assessment of asymmetry between lower limbs [1]. No detailed study, to the authors' knowledge, exists on the specific role played by the ischiatic support of the socket: it is generally assumed that the ischiatic support provides load bearing during the prosthesis ground contact phases.

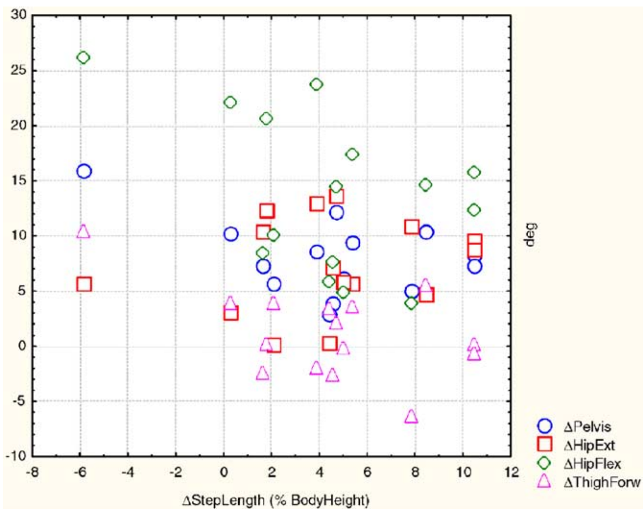
In the present study, the authors investigate the ischiatic support role by focusing on the pelvis geometry and on the kinematic limitation of hip extension caused by the ischiatic support. This kinematic constraint determine a relevant asymmetry of the locomotor system which the subject compensates by modifying the kinematics of other body segments: particularly the pelvis and the lumbar region of the spine.

Materials and methods

The gait patterns of 12 subjects (11 males and 1 female, mean age 30.5 spanning from 19 to 54 years) with unilateral transfemoral amputation and using prosthesis with ischiatic support (three subject were admitted with two prosthesis each) were assessed in the Movement Analysis Lab at the Bioengineering Centre of the Don Gnocchi Hospital (Milan, Italy). Acquired data have been elaborated [2] and the differences between prosthetic and sound limb were considered for the following variables: anterior step length, pelvis tilt and hip extension at controlateral heel strike, hip flexion at ipsilateral heel strike.

Results

The results are plotted reporting the step length difference on the *X*-axis versus the remaining difference variables on the *Y*-axis.



Discussion and conclusion

The presented results showed that 11 subjects have a common kinematic pattern: a reduced anterior step length of the sound limb determined by reduced prosthetic side hip extension (primarily due to the ischiatic constraint) only partially compensated by larger pelvis tilt and sound hip flexion. No general effect is due to thighs' inclination, which shows values about zero, confirming that a visual inspection cannot detect any asymmetries. The only subject showing longer prosthetic step appears to apply the same patterns, but producing an over-compensation thus resulting in longer step length, moreover he is characterised by the largest thigh inclination asymmetry.

In conclusion, the experimental data have shown how the intrinsic constraint due to the ischiatic bearing leads the subjects to adopt an asymmetric strategy, particularly involving larger pelvis tilt motion. Future analyses must verify if the often reported lumbar pain by amputee subject could be, at least partially, attributed to the larger pelvis tilt induced by the ischiatic bearing constraint and, in this case, this would strongly require for a technological development of the load bearing mechanism in AK prostheses: possibly a "smart" ischiatic bearings.

References

[1] Rietman JS, et al. Prosthetic Sand Orthotics Int 2002;26:50–7 [review].
[2] Frigo C, et al. Med Biol Eng Comput 1998;36:179–85.

S6.5: Does the floor reaction ankle-foot orthoses improves the hip, knee and ankle kinematic during the stance phase in the cerebral palsy gait?

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Summary

The efficiencies of the floor reaction ankle-foot orthoses in children with cerebral palsy were appraised using three-dimensional gait analysis. The efficiency was noticed in the children with moderate and excessive flexion of the knee in the stance phase and it was not observed in limitation less than 15°.

Conclusion

The FRAFO when indicated to improve the extension of the knees in the support it was effective. It makes necessary future studies for best to understand the biomechanics of this type of orthoses in children with just limited extension less than 15°. If it is better to use it or not.

Introduction

The floor reaction ankle-foot orthoses (FRAFO) is common prescribed in the attempt of decreasing knee flexion during the stance phase in the cerebral palsy (CP) gait. There is insufficient information on this orthoses described in the literature.

Purpose

The purpose of this study was to determine the effect clinically prescribed floor reaction ankle-foot orthoses have on kinematic parameter of the hip, knee and ankle in stance phase of the gait cycle, as compared with barefoot walking in children with cerebral palsy.

Methodology

A retrospective chart review of data collected between 1996 and 2004 in our motion analysis laboratory was performed. A retrospective chart review 2200 patients revealed 71 patients (142 limbs) mean age 12.2 ± 3.9 who had diagnosis of diplegia, no contractures in hip and knee flexion. All were wearing clinically prescribed hinged FRAFO undergoing a three dimensional gait analysis. In line with our standard clinical practice, data for both conditions (brace and barefoot walking) were collected in the same day by the same examiner. We divided the patients in three groups: Group I Limited extension (pick of knee extension less than 15°); Group II moderate limited extension (pick of knee extension between 15 and 30°) and Group III Crouch (pick of knee extension instance more than 30°).

Were extracted the maximum values of hip and knee extension and ankle dorsiflexion during the stance phase with and without FRAFO for each group.

Table 1. Mean values and standard deviations of the pick of hip, knee extension and ankle dorsiflexion after statistical analysis

	N	Hip kinematic	Knee kinematic	Ankle kinematic
Group I	71	41.2 ± 19.9 ($P > 0.05$)	37.6 ± 11.4 ($P = 0.0002$)*	4.2 ± 7.6 ($P < 0.01$)**
Group II	57	19 ± 20.7 ($P > 0.05$)	15.7 ± 10.2 ($P = 0.0001$)*	11.5 ± 9.0 ($P < 0.05$)**
Group III	14	17.7 ± 14.8 ($P > 0.05$)	6.1 ± 9.4 ($P > 0.05$)	9.5 ± 6.5 ($P > 0.05$)

* $P \le 0.0001$. ** $P < 0.05$.

Results

Statistical analyses (*t*-test) indicated the parameters pick of knee extension and ankle dorsiflexion was significant in Groups I and II and not change in Group III. The pick of hip extension was not significant in all three groups. Total data can be analyzed in Table 1.

Discussion

There are not clinical studies that check the effectiveness of FRAFO in patients with CP. It is possible that the FRAFO limits the ankle dorsiflexion in the single support and consequently improve the knee extension. Harrington [1] refers that it increases the knee extension moment in this instant.

Reference

[1] Harrington ED, Lin RS, Gage JR. Orthotics Prosthetics 1984;37(4):34–42.

Poster Session 2: 15:30 to 17:00
Cerebral Palsy

P2.1: Validity of a 1-min walk test for children with cerebral palsy (CP)

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Summary

The concurrent validity of a 1-min walk test at a child's maximum walking speed was assessed in children with bilateral CP. Distance covered during the walk was compared to gross motor function as assessed by the GMFM.

Conclusions

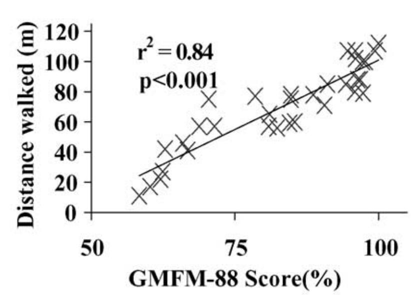
A strong correlation between the walking test and gross motor function demonstrated its ability to predict functional ability in children with CP. Its cost-effectiveness and user friendliness makes it a potentially useful tool in the clinical setting. Further study needs to address its reliability and ability to detect change over time.

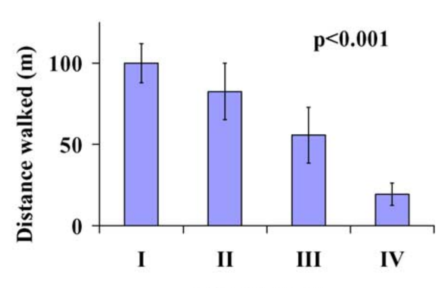
Introduction

Walking tests have become increasingly popular as an outcome measure for testing patients with a disability. Walking times vary between 2 and 6 min and are usually carried out at self-selected walking speeds. While previous studies in children with CP have shown a strong correlation between walking speed over a limited distance and functional ability [1,2], no studies have assessed the ability of longer walking distances to predict functional ability in this population.

Patients/materials and methods

Thirty-eight children with bilateral CP attending a regional orthopaedic service gave consent to participate in the study. Of these, 34 (10 females, 24 males; age range 4–16 years; mean age 11 years) were able to complete both tests. Three of the children were classified in Gross Motor Function Classification System (GMFCS)[3] level I, 17 in level II, 10 in level III and four in level IV.





Figs. 1 and 2.

The same assessor carried out both tests. The 1-min walk test was carried out on an oval 20 m level track. Following a 5-min rest children were asked to walk as fast as possible around the track for 1 min. Distance was calculated using markings on the track. The GMFM assessment was then carried out.

Results

A one-sample Kolmogorov–Smirnov test was used to establish that data followed a normal distribution. Simple linear regression and Pearson's correlation coefficient demonstrated a significant relationship ($r = 0.92$) between the GMFM-88 score and distance covered during the 1-min walk test (Fig. 1).

A one-way ANOVA also showed a significant decrease in the distance walked with increasing GMFCS level (Fig. 2). Post hoc analysis (using the Scheffe test) revealed significant differences between levels II and III ($P = 0.003$) and levels III and IV ($P = 0.008$). There was no significant difference between levels I and II ($P = 0.42$).

Discussion

The strong correlation obtained between distance walked during a fast 1-min walk and the GMFM score suggest that the 1-min walk test may be a good predictor of functional ability in children with bilateral CP.

References

[1] Damiano DL, Abel MF. Dev Med Child Neurol 1996;38:389–96.
[2] Drouin LM, et al. Dev Med Child Neurol 1996;38:1007–19.
[3] Palisano R, et al. Dev Med Child Neurol 1997;39:214–23.

P2.2: Functional electrical stimulation (FES) for children with cerebral palsy

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Summary

The present study reports on the orthotic effect of FES to either the dorsiflexors or knee extensors of 14 children with diplegic and hemiplegic cerebral palsy. Dorsiflexion in swing and the foot floor contact pattern were significantly improved with FES to the dorsiflexors compared to no FES. Knee extension improved when FES was applied to the knee extensors but this effect was not significant.

Conclusions

FES to the dorsiflexors has a significant direct 'orthotic' effects on gait kinematics. However, it is important to investigate the long term therapeutic effects and practical issues with regard to FES for young children.

Introduction

Functional electrical stimulation (FES) has been applied as a treatment option for children with cerebral palsy since the early 1980s [1]. At present, the most common way of using FES is to stimulate the ankle dorsiflexors during the swing phase [2]. The aim of this study was to investigate the direct 'orthotic effect' and the long-term 'therapeutic effect' of FES to either the dorsiflexors or knee extensors in children with cerebral palsy. This abstract will focus on the orthotic effects on the gait characteristics.

Patients/materials and methods

Fourteen diplegic ($n = 6$) and hemiplegic ($n = 8$) children (mean age 8, range 5–13 years old) participated in this study. For 10 children, the target muscle group were the dorsiflexors, for four the knee extensors. Each child was randomly allocated to either the control group or the experimental group. The 3D kinematics of all children were recorded during three visits to the gait lab. After their first visit, the children in the experimental group received therapeutic electrical stimulation of gradual increasing intensity at 30 Hz to the target muscle for 2 weeks to condition the muscle and let the child get used to the sensation of electrical stimulation. During, the second gait analysis, 2 weeks after the first, all children in the study received FES to the target muscle group. After the second visit the children in the experimental group used the stimulator for 8 weeks, after which all children came for gait analysis the third time and the tests of the second visit were repeated.

Results

The orthotic effects of FES to the dorsiflexors for both the children in the control and experimental group in the first and second FES session are shown in Table 1.

Table 1. Mean (standard deviation) of the gait characteristics ($n = 10$)

	First FES session		Second FES session	
	FES off	FES on	FES off	FES on
Foot-floor angle	−4.7 (9.4)	−1.6 (9.5)*	−5.7 (10.2)	−1.4 (8.9)*
Peak dorsiflexion swing	−7.0 (6.5)	−5.0 (6.0)#	−7.1 (7.7)	−3.6 (6.1)*
Knee flexion angle at initial contact	18.3 (7.2)	17.3 (8.0)	19.1 (8.5)	16.3 (8.8)
Walking speed (m/s)	1.02 (0.12)	0.95 (0.10)#	1.02 (0.11)	0.98 (0.11)*

Positive foot-floor angle means heel contact, negative dorsiflexion angle means plantar flexion.

Significant difference between FES off and FES on $P < 0.05$.

* Significant difference, $P < 0.01$.

FES to the knee extensors of four children reduced the average knee peak extension from 18.8 to 16.3° of flexion at the first FES session and from 20.1 to 16.6° at the second FES session but these improvements were not statistically significant.

Discussion

FES to the dorsiflexors in children with cerebral palsy results in a statistically significant improved foot floor contact pattern without increased knee flexion at initial contact but with a reduction in walking speed. When deciding on the clinical effectiveness of FES, one should also investigate the long-term 'therapeutic' effects on gait and passive range of movement and the practical issues of using FES for young children with cerebral palsy comparison between the control and experimental group will allow us to investigate the therapeutic effects.

References

[1] Gracanin, et al. Int J Rehabil Med 1984;6:25–30.
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P2.3: Intrinsic and extrinsic constraints during reaching and grasping in children with hemiplegic cerebral palsy

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Summary

Children with hemiplegic cerebral palsy have a number of problems when reaching and grasping. Previous studies have used kinematic analysis to examine hand functions in children with hemiplegic cerebral palsy [1] focusing on descriptions of reaching and grasping movement when the hands move unimanually and comparing this bimanual movements. Of particular interest was the hands coupling during the bimanual movement with the hemiplegic side being influenced by the movement of the less involved limb. This paper examines the influence of extrinsic constraints on intrinsic constraints during unimanual and bimanual reaching and grasping with the orientation of the table on which the children are reaching perturbed.

Conclusions

As in previous studies [1] there is evidence of temporal, postural, and spatial coupling. There is strong evidence of temporal coupling that is generally as a result of both hands adjusting their movement during the bimanual condition to a common timing. Changes in posture result in a less rigid movement on the hemiplegic side and less extension and splaying of the digits. Sloping the board towards the subjects appears to have resulted in similar temporal coupling to sloping the board away but greater postural coupling. Placing the cube in an elevated position may have afforded subjects more opportunity to concentrate on posture and grasping the cube, as the cube was more in line with the trajectory commonly employed on the hemiplegic side. It would appear that sloping the table away from the subjects (lowering the position of the target object) has afforded subjects using a lower trajectory.

Introduction

Explanations of motor development have taken a step forward through the application of ideas from proponents of dynamic systems, here movement involves the final product or whole being the active cooperation of many parts, and contains multiple subsystems all contributing in a unique manner [3]. The potential for some of these ideas have been initially explored in the context of reaching and grasping in children with hemiplegic cerebral palsy [1]. Such children have to overcome intrinsic constraints where the neural properties directly provide a direct link to the type of movement observed. External constraints such as task demands and contextual influences have only recently been investigated [2].

Methods

Nine children aged 5–12 participated in the study. The children performed two tasks involving reaching and grasping a cube unimanually and then bimanually. The cube was placed on a table with the top sloping 4° away from the child in experiment 1, and sloping 4° towards the child in experiment 2. Kinematic (3D) and video data were collected and analysed.

Results

Kinematic data and video data are presented including velocity profiles, inter and intra limb correlations and displacement profiles. Video analysis provided information on, posture of the hand, trajectory of the reach and corrections made during the reach. Comparisons are made within and across subjects with the focus on the movement pattern of the wrists and third digits.

Discussion

The data presented in these experiments support some of the principals of a dynamic systems approach to motor control studies. The dynamical approach provides tools to describe and characterise observed movement patterns in context and the transitions and invariance's among them. Coordination becomes the consequence of the constantly evolving processes of self-organisation, sometimes temporarily assembled and flexible while at other times more permanent in nature. Recently solving the degrees of freedom problem in reaching has also been approached from a cost containment approach and the data discussed in these experiments presents evidence that the performer deals with costs in a variety of contexts, in a variety of ways.

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P2.4: Self-dependent and aided walk of cerebral palsy (CP) children — a case study

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Summary

Walking skills of three CP children are presented in this paper. They represent different abilities of walking: child 1/MJ walked independently, 6/SM needed somebody supporting him with two hands and 13/WP walked using support of an assistive mobility device. It is shown that the kinematics parameters do not help to categorize the locomotion of these three different walking abilities. However, the kinematics parameters can help to set the diagnosis and suggest for the physiotherapists the exercises-program needed.

Conclusions

The basic kinematics parameters indicate the individual differences in locomotion of CP children. However, they do not distinguish them in terms of self-dependent or aided walks. In suche a case using patterns is irrational to some extend. The deficiency in walking could have a functional and/or structural base. Some of the trials of pathological walking along with the medical check can be helpful in establishing the physiotherapy program.

Introduction

Cerebral Palsy (CP) is a developmental disorder of motor, psycho and emotional function. In case of locomotion the following walks can be distinguished: the self-dependent walk, the walk with human support and with an assistive mobility device. The aim of this study was to analyze walking abilities of the three children mentioned, with the help of basic kinematic parameters.

Patients and method

There were three children with different walking disabilities investigated. Child 1/MJ — 9-year-old girl, with infantile cerebral palsy, spastic diplegia, flexion contracture of the knee joint, irreducible joint contracture, left-sided scoliosis, independent paraparetic a gait with flexed of knees and foot rotation; 6/SM — 9-year-old boy, with infantile cerebral palsy, spastic quadriplegia, diminished active movability of upper and lower extremities, do not walk independently, walks supported; 13/WP — 11-year-old boy, with infantile cerebral palsy, spastic diplegia, flexion contracture of the knee joint and talocrural joint, plantar foot flexion (after operation), walking on tiptoes with assistive mobility devices.

Two video cameras were used to record the left and right side of the body in sagittal plane while walking along the path. Four to six strides were recorded and analyzed. To calculate the kinematic parameters the SIMI MOTION was used.

Results

In the study, different walking skills were analysed, described by these parameters: stride velocity, times of walking-cycle (moving- and supportingphase) and changes in the knee joint angle during the support phase. Two of the tested children were walking slowly: 0.62 m/s (1/JM) and, 0.65 m/s (13/WP) and one very slowly 0.23 m/s (6/SM). Stride lengths: 0.68 m (1/JM), 0.51 m (6/SM) and 0.79 m (13/WP) as well as velocities were relatively small, compared to the patterns found in literature for healthy children [1,2]. The support phase in child 6/SM lasts 84% of the cycle. Child 1/MJ was showing asymmetry in time of support (68% of right leg to 61% of left leg). The changes in the knee joint angle during support phase are shown in Fig. 1. Child 1/JM did not bent knee joint of the right leg in mid support phase. Right and left knee of the child 6/SM were flexed about 50° during the whole support phase. The knee angles of child 13/WP were almost normal during foot strike and mid support, but the left knee was flexed in toe-off phase.

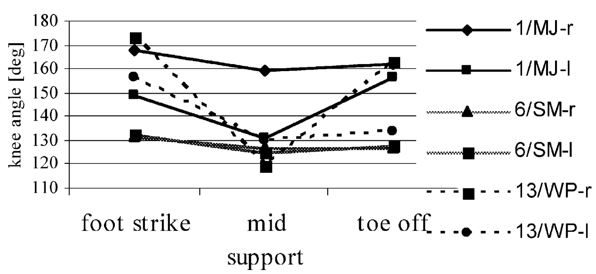

Fig. 1. Changes in knee joint angle during support phase of the right (r) and left (l) leg.

Discussion

The walking skills of the child 1/MJ can be assesed positively, and better than child 13/WP. The worst records were achieved in case of child 6/SM. Kinematics parameters are not enough and do not provide necessary information for assesing CP children's walking abilities. It is important information, if a child needs any support when walking. The kinematics parameters provide very accurate information concerning walk as: low velocity, short stride lenghts. They can be used in knee angles analysis.

Acknowledgement

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P2.5: The functional walking test for CP chidren

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Summary

We would like to describe our modification of the functional walking test originally described in *Gait* & *Posture* by Kelly et al. in 1997. It is reckoned as a reliable and accurate test for testing motor skills of the CP children. Because of lack of standards of trials we decided to modify some trials in our own modification. We used this modification to examine 19 healthy children aged 1, 3–7 years and 24 CP children*. Data three of them are the material of this paper.

Conclusions

Our modification of functional walking test seems to be good test for examining CP children. Extension of points scale gave more possibilities of estimation.

It is based on simple movements like: kneeling, standing, walking which are natural stages of little children motor development.

We suggest however broaden surveys and measure the strength of leg muscles by dynamometer.

We used this test to estimate the level of motor skills of the children qualified to our examinations and we observe changes in locomotion in successive studies. Little healthy children aged two and less are examined too. We want to establish natural sequences of healthy children locomotion development as a background for older children with Cerebral Palsy.

Introduction

Running investigations of motor functions of the CP children is very difficult because of problems refers to organization, procedure and applicability. On the other hand it is very important for estimation progress in motor skills during therapy. The laboratory methods uses in examinations are not useful in hospitals or physiotherapists activity. So the tests based on simple and elementary movements are better solution in such circumstances. We would like to present our modification of functional walking test we use in examinations of CP children.

Patients/materials and methods

We slightly modified original functional walking test constructed in Central Remedial Clinic in 1986 (Jenkinson 1986, behind: [1]). It was verified in 1997 by Kelly and co-workers as a reliable and accurate for CP children. Our test contains four skills such as: kneeling (some trials of kneeling from side to side, back and standing from kneeling), one leg independent standing (one or both legs), walking on incline (going up and down, rotating) and stairs walking. Speed of walking on 5 m distance and endurance (1 min walking) were measured additionally. Our modification relates extending points scale (originally scale was between 0 and 1 pt., we added 0.5 if child makes trial with assistance of therapist). Besides we gave up the trial of walking a beam, because of lack of standard description. We examined nineteen healthy children aged 1.3–7 years and 24 CP children aged 2–9 years. Data three of them (one healthy and two CP children) were the material of this paper.

Results

The trials included in test let us estimate basic motor skills of examined children such as kneeling, balance and walking. We defined the level of their motor skills what is base for our next investigations. However our experience suggests measurement of leg muscles strength too. Examinations of little, healthy children enable comparison to natural sequences of locomotion development. We found that healthy 5 years old children can do all the trials and we can estimate their level of motor skills as a 100%. CP children aged 7.5 years with diagnosis of a four limbs paresis had less than 40% of healthy children motor skills level.

Discussion

There are some tests intended to studies children with Cerebral Palsy. One of them is GMFM or GMFCS. They are similar to functional walking test, but there are too many trials. The possibilities of using that tests are rather limited. Besides that tests are commercial. It causes some medical centers ca not afford to buy them. It seems the test briefly presented in this abstract should be good solution in examinations children with Cerebral Palsy.

Acknowledgement

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P2.6: Functional movement possibilities of interceptive actions in children with spastic hemiparetic cerebral palsy

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Summary

Children with spastic hemiparetic Cerebral Palsy (CP) perform interceptive actions towards static targets with adapted movement strategies, especially when using the impaired hand. However, in tasks where there is motion between the child and the object to be intercepted (intercepting a ball while walking), a few kinematic variables are the same as the non-impaired hand.

Conclusions

Longer movement times and more trunk involvement seemed common adaptations when children with spastic hemiparetic CP reached for an object. However, these strategies did not always occur when the task required different coupling of visual information and movement, like intercepting a ball while walking, which resulted in equal movement times.

Introduction

The coupling of a movement with relevant visual information is necessary for the performance of interceptive actions and enables us to adapt our response within our own functional movement possibilities. For example, interceptive actions such as reaching for a moving ball requires the co-ordination of many degrees of freedom (DF) available within the motor apparatus such as the shoulder, elbow, wrist and trunk, such that they move fluently and efficiently (i.e. sequencing of body segments). Particularly at the initial stages of skill acquisition, this can be achieved by free(z)ing the DF in the body so that the motor apparatus are more controllable [1]. Although children with CP show a different movement behavior because of their motor impairment, this can be seen as an example of adapting to their own action capabilities and organizing the DF into a more controllable unit(s) [2,3]. This research investigated the functional movement possibilities of children with spastic hemiparetic CP when intercepting objects in different task contexts.

Patients/materials and methods

Ten children (5–11 years) with spastic hemiparetic CP participated in this research. They were all able to walk without walking aids. Children were required to reach and grasp a stationary object while standing (1) and while walking (2), and to reach and grasp an approaching object while standing (3). A 3D motion analysis system (CODA) recorded and calculated the kinematics of the hand, arm and trunk.

Results

Preliminary results showed that when the children performed the reaching movements with the impaired hand, the movement goal was attained with a decreased involvement of the elbow and shoulder joint and an increased trunk involvement. They also showed an increased variability of hand trajectories. Movement time when reaching with the impaired compared to non-impaired hand was increased in the two standing conditions (1 and 3) but stayed the same in the walking condition (2).

Discussion

The findings may exemplify an adaptive movement strategy. To avoid the increased stretch reflexes that are characteristic of spasticity, motion of the elbow and shoulder joints was limited, leaving the (relatively unaffected) trunk to play a major role in successful task completion. The body tries to find solutions within its own action capabilities when reaching for objects, indicating that it should be recognized in what context an interception is performed, as this could lead to different movement behaviour.

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Energy Consumption

P2.7: The mechanical energy cost of toddler gait

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Summary

Mechanical energy expenditure was investigated in children who are just learning to walk and compared with adult mechanical energy expenditure during walking. We considered the shape and magnitude of the kinetic and potential energy fluctuations of the center of mass (COM) and calculated recovery values (R) to determine whether toddlers already make use of the energy saving inverted

pendulum (IP) mechanism. External, internal and total mechanical work was evaluated over a range of speeds.

Conclusions

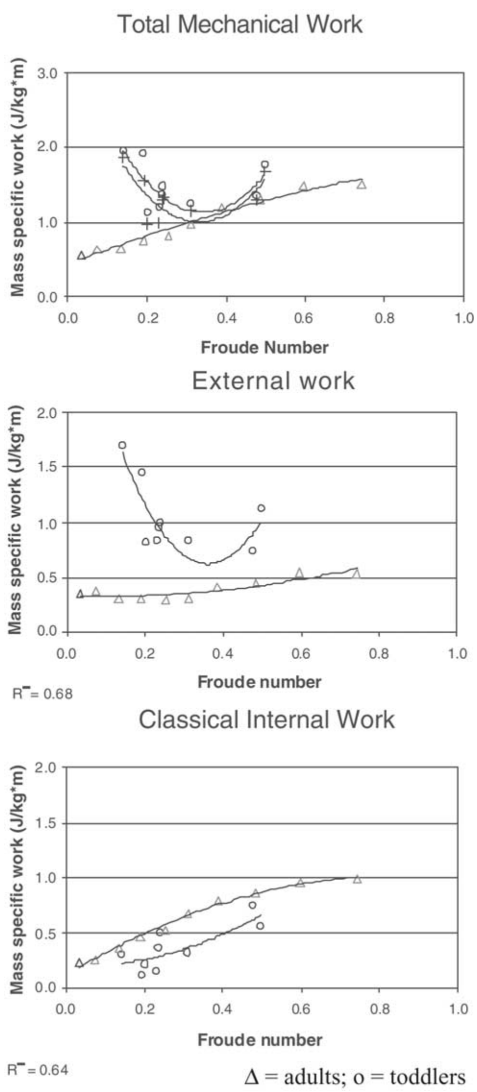
Mass specific work per unit distance is larger in toddlers compared to adults when walking at the same speed, even if their small size is taken into account. In toddlers, external mechanical work is the major contributing factor of total mechanical work. Despite the fact that the IP mechanism is observed to a certain degree, it is not completely mastered yet. Because of their tossing gait and slow walking speed, energy exchange is imperfect. Consequently, more work has to be performed by the muscles to lift and accelerate the COM against gravity. Apart from external work performed on the COM, internal work is performed, primarily to swing each limb forward during walking, which increases linearly with speed. If their small stature is taken into account, toddlers perform less internal work compared to adults.

Introduction

During walking metabolic energy is consumed, even if the average walking speed is constant and there is no net change in height of the body. At each step energy has to be put into the system again, firstly to lift and accelerate the COM against gravity (external work) and secondly to move the body segments relative to the COM (internal work). To minimize external mechanical work, adults make use of an imperfect IP mechanism of energy exchange, allowing recovery of as much as 70% of the required energy (1). Recently Schepens (2) showed that children aged between 3 and 11 years old, due to their small stature, consume more energy per unit body mass to walk at a given speed than adults do. Is this also the case in toddlers who are just learning to walk? They are even smaller and show markedly different body proportions compared to adults. Balance problems and immature control of movement are compromising factors that make their gait pattern different from mature walking (3). Considering the toddler as a mechanical system, the observed kinematic and kinetic differences could result in different energy and power requirements of the system.

Patients/materials and methods

Nine healthy children aged between 12 and 18 months participated in this study. Their walking experience ranged from 2 weeks to 6 months. Ground reaction forces and full body kinematics were recorded. The amount of external and internal work was calculated and evaluated over a range of speeds. To find out whether toddlers make used of the IP mechanism of energy exchange the time profiles of kinetic and potential energy were considered and percentages of recovered energy were calculated.



Results/Discussion

First, we determined whether the IP mechanism of energy exchange was present in toddlers. It seems new walkers partially make use of this energy saving mechanism, however it is less efficient. The reduced recovery values (*R* equals 40% at optimal speeds in toddlers compared to 70% in adults) can be explained by their low self selected walking speed in combination with their tossing gait (large vertical oscillations of the body) and by the observation that during as much as 25–50% of the gait cycle kinetic and potential energy are oscillating in phase.

The second step was to calculate positive external mechanical work. Since the inverted pendulum mechanism is less efficient in toddlers, more mass-specific positive work has to be performed to lift and accelerate the COM than when walking at the same speed than adults, even when differences in body size are taken into account.

The amount of positive internal work necessary to move the body segments relative to the COM was the third parameter we calculated. In toddlers it is largely determined by the kinetic energy of the lower limb. Compared to adults, toddlers have to perform less mass-specific work per unit distance to accelerate the body segments since the upper body is kept relatively stiff during walking and there is no arm swing.

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P2.8: Measurement reproducibility of metabolic walking parameters in adults with a poliomyelitis history

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Summary

Measurement reproducibility of metabolic walking parameters was evaluated in both a clinical and a healthy population using a high-technology gas-analysis system, the VmaxST.

Conclusion

A good reproducibility for all walking parameters was found, with the best results for the healthy subjects. The parameter ‘energy cost’ and the gross condition contained the least amount of variability.

Introduction

It is generally accepted that energy cost of walking in adults with movement disorders, either related to musculoskeletal pathology or to neuromuscular pathology, is elevated [1]. Energy cost of walking can be estimated from high-technology portable gas-analysis systems that measure both oxygen-uptake and carbon dioxide production. Out of those walking energy can be calculated, thereby taking into account the relative contributions of carbohydrates and lipids. In order to detect significant changes in walking energy, it is of paramount importance that the reproducibility of these measurements is established. To our knowledge, this study is the first to assess measurement reproducibility of metabolic walking parameters with a high-technology gas-analysis system in a clinical population.

Methods

Assessment of reproducibility was made in a group of patients with a musculoskeletal pathology (i.e. poliomyelitis). Fourteen post-polio adults (age: 36–67, body mass: 53–95 kg) and 14 matched control subjects (age: 31–63, body mass: 53–94 kg) volunteered to participate in the study. The study protocol consisted of two blocks: 10 min of resting in a comfortable chair followed by 5 min of walking at a self-selected walking pace. For walking, an oval track of 50 m was used and walking speed was measured per round. Gas-exchange was measured using the portable VmaxST system (SensorMedics, The Netherlands) for which technical validity was established [2]. Both the resting-test and the walking-test were completed four times on four different days, at the same time of the day, and under similar conditions. Reproducibility assessment comprised: (1) walking speed, (2) gross and net energy consumption, (3) gross and net energy cost. The standard error of measurement (S.E.M. = $\sqrt{((\text{VARoccasion} + \text{VARsubject} \times \text{occasion})/4)}$, and the smallest detectable change (SDC = 1.96 × S.E.M. × $\sqrt{2}$) were used to express measurement reproducibility.

Results

Table 1. Reproducibility indexes: S.E.M. and SDC for post-polio patients (P) and controls (C), respectively

Parameter	Gross condition				Net condition			
	S.E.M. P (%)	S.E.M. C (%)	SDC P (%)	SDC C (%)	S.E.M. P (%)	S.E.M. C (%)	SDC P (%)	SDC C (%)
Speed (m/min)	2.2	0.9	6.1	2.6				
Econs (J/kg min)	2.7	1.2	7.5	3.2	3.3	1.4	9.1	3.9
Ecost (J/kg min)	1.7	1.2	4.6	3.3	2.5	1.4	7.0	3.8

Econs = energy consumption, Ecost = energy cost.

Discussion

The main result was that reproducibility of all walking parameters, based on our protocol, was very good in both groups: S.E.M. values were low ($\leq$3.3%) and the smallest detectable changes were not larger than 9.1%, where changes up to 10% are regarded as clinically insignificant [3] The best results were found for the healthy subjects. The parameter ‘energy cost’ appears to be less variable than ‘energy consumption’. This is in agreement with findings of Plasschaert et al. [4]. Their results showed that oxygen consumption was the least repeatable parameter because it contains more *within*-subject variability. This arises from differences in walking speed between days. A comparison of conditions showed the gross condition as the more repeatable condition. The increased variability in the net condition is due to differences in resting values between days. In conclusion, a smallest detectable change of 4.6% for gross energy cost was found for polio patients, which makes metabolic assessment of walking a very sensitive tool to evaluate walking performance in the individual subject

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P2.9: Exercise and glycemic control in type I diabetes adolescent girls

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Summary

The purpose of this longitudinal study was to investigate the effect of various intensive exercise programs on blood glucose (BG), lactate (La) and glycosylated hemoglobin (HbA1C) levels in type I diabetes adolescent girls.

Twenty-seven adolescent girls (age 13–17) with type I diabetes participated in this study. Each girl did running and walking exercises on two separate occasions: 6 min Cooper test and intermittent running/walking test. Between the tests, adolescent girls trained according to their routine specific running and walking programs, which lasted 2 months.

Six minutes Cooper test significantly influenced on adolescent girls with I type of diabetes mellitus post BG (10.6 mmol/l versus 6.3 mmol/l) and La (6.8 mmol/l versus 5.0 mmol/l) levels while in this girls post intermittent running/walking test (20 m skittles run for 30 s + walked 15 s). BG (5.9 mmol/l versus 6.5 mmol/l) and La (5.1 mmol/l versus 6.5 mmol/l) levels differed no significantly in comparison with the pretraining values. The positive correlation between post exercise BG and La concentrations were found at all adolescent girls ($r = 0.708$ and 0.862 post Cooper test and post running/walking test). This correlation seemed independent of training induced changes in 6 min Cooper test results.

The mechanism, linked post exercises BG, La and HbA1C concentrations after the running/walking training exercises program, which lasted 2 months, remains obscure.

Conclusions

Our study revealed that running and walking trainings, which lasted 2 months, induced significant changes in the post 6 min Cooper test BG and La results in comparison with the pretraining values.

Results of intermittent running/walking control test after 2 months training was associated with reduced post-exercise BG and La concentration.

The results of HbA1C after 2 months exercise training program is efficacious for the adolescent girls with I type of diabetes mellitus to reduce their HbA1C level and assist with their diabetes management.

Training induced correlation between BG and La is probably due to the influence of training on hormonal regulation of glucose and lactate production without insulin.

Patients/materials and methods

Twenty-seven adolescent girls (age 13–17) with type I diabetes participated in this study. The mean duration of diabetes mellitus was 5.1 ± 2.0 years. The longitudinal exercises program consisted of running and walking trainings, which lasted 2 months.

Blood glucose (BG) and lactate (La) was measured enzymatically using commercial kits (Boehringer–Mannheim, Germany). Glycosylated hemoglobin (HbA1C) was determinated using commercial kits DS1 Glycomat (Wiener and Roberts, 1998). Heart rate was recorded throughout all the tests using Polar Sport Tester (Finland). BG was assessed prior to the tests, immediately after each exercise session and after 20 min recovery. HbA1C was determined before the training and walking trainings started and after all exercise program, id est. after 2 months.

The first session consisted of 6 min Cooper and Ruffie control tests followed by three randomly assigned testing days. The successive session consisted of intermittent running/walking test.

Results and discussion

The results indicated that 6 min Cooper test produced significantly higher ($P < 0.01$) BG and La, than intermittent running/walking test, while BG and La was significantly greater after running than after walking test. There was a trend at walking exercises moderately reduce BG while intermittent running exercises moderately increased BG.

The results of HbA1C in type I diabetes adolescent girls before the running and walking program were higher (8.6 ± 0.87; $n = 27$) and lower post 2 months training course (7.7% ± 0.88; $n = 20$). Therefore, we conclude that our proposal of 2 months exercise training program is efficacious for the type I diabetes adolescent girls to reduce their hemoglobin level and assist with their diabetes management.

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Foot

P2.10: Influence of age, gender and body-mass-index on 3-day foot shape in children

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Summary

With a 3D foot scanner in a bipedal upright position, the feet of 1996 children, aged 3–10, were measured. Basic foot measures in last development were taken. All foot measures were analyzed per shoe size in terms of relative frequency (both genders), gender and BMI. BMI influenced all foot measures, gender seemed to have no influence at this age. Only a maximum of 50% of all feet per shoe size was represented by each single foot measure.

Conclusion

There must be different specifications (at least two widths) per shoe last to optimize the shoe fitting for as many children as possible. All foot measures have to be considered (not only ball circumference, as in the past) in the development of well fitting lasts.

Introduction

Extensive studies on children's feet in the 1960s (1) led to the formation of guidelines (AK 64) to develop and produce lasts for children's shoes, which are still effective today. Measurements done in the early 1990s (4) showed an increase in foot sizes per age, whereas basic measures, such as foot width as well as the relation of foot width to ball circumference (40%), stayed constant. Deficiencies in these studies were mainly the non standardized measurements (3D foot measures by hand) and insufficient foot measures (2D plantar measures). It is still unclear whether there is an influence of age, gender, height and weight on the relevant 3D foot measures (foot shape) to develop well fitting lasts for children's shoes.

The goal of this study was to verify current 3D foot measures in children's feet with a valid and reliable measuring device to find out whether age, gender, height and weight influence these measures.

Patients/materials and methods

The feet of 1996 children, aged 3–10, were measured with a 3D foot scanner (pedus, human solutions, resolution < 1.5 mm) in a bipedal upright position. Relevant foot measures [2,3] in last development, such as foot length (FL), foot width (FW), toe circumference (TC), ball circumference (BC), waist circumference (WC), instep circumference (IC) and heel circumference (HC), were taken as well as the children's age, gender, height and weight. The BMI was chosen to clarify a possible influence of height and weight on the 3D measures. All foot measures were analyzed per shoe size in terms of relative frequency (both genders), gender and BMI. Statistics were based on descriptive analysis (e.g. cross-tables), as well as on Pearson's correlation coefficient [2].

Results

Most foot measures (FW, TC, BC, WC, IC) showed high correlations (0.8–0.9) to foot length. Foot length increased consistently (no growth spurt) with age. Furthermore, BMI influenced all foot measures, e.g. children with a lower BMI (<16 kg/m^2) showed smaller values (more narrow feet) for all foot measures than children with a higher BMI (>16 kg/m^2). Gender seemed to have no influence on 3D foot shape. The relation of foot width to ball circumference was about 38% for all foot sizes (not 40% as assumed). Only a maximum of 50% of all feet per shoe size was represented by each single foot measure.

Discussion

It can be concluded that there must be different specifications (widths) per shoe last to optimize the fitting for more than 50% of the children, and to take BMI results into account. The minimum demand per last must be two width specifications for each shoe size, whereas all foot measures have to be considered (not only ball circumference, as in the past). Gender does not play any role in last creation in these age groups.

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P2.11: Influence of movement type on plantar pressure distribution patterns

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Summary

Leisure runners ran/walked on a treadmill while plantar pressure distribution parameters were assessed. Results suggest that walking – compared to running at the same speed – increases loading in the rearfoot and toe areas.

Conclusions

Differences in foot strike and knee flexion angles could be responsible for the observed differences in plantar pressure patterns. Up to now we are still unsure whether the increase in loading should be seen more as a different kind of input signal into the neuro-muscular system rather than as an increase in stress for the human body.

Introduction

Commonly, pressure and force measurements are used to quantify dynamic loading of the musculoskeletal system. When comparing different velocities of locomotion (while maintaining the same type of locomotion, e.g. running), one can observe increasing vertical forces as the velocities increase [1,3]. It is still unclear whether there is a difference in vertical loading during fast paced walking compared to running at the same speed. The goal of this study was to investigate the influence of movement type (e.g. walking versus running) and locomotion velocity on plantar pressure patterns in order to gain information about basic kinetic characteristics of different types of locomotion. This could affect construction essentials of specific walking shoes, as well as the importance of performing proper walking technique in recreational sports.

Patients/materials and methods

Twelve pain free subjects (age: 27 ± 6.8; weight: 69.3 kg ± 11.6; height: 176.7 cm ± 9.5) were included in the study. Measurement conditions were defined as walking and running at different speeds (walking 5 and 7 km/h, running 7 and 12 km/h) on a treadmill (HP Cosmos). Both walking and running trials were performed barefoot as well as shod (wearing a neutral running shoe). Plantar pressures were assessed using an in-shoe Novel® Pedar mobile system (50 Hz). Maximum force (Fmax) as well as maximum pressures (Pmax) were calculated in up to 10 anatomical foot areas (4SD/PRC masks) using the Novel® Software package.

Results

During walking (5, 7 km/h) Fmax as well as Pmax were significantly ($P < 0.01$) increased in heel and forefoot areas compared to running (7, 12 km/h). This could be observed for both footwear conditions (barefoot & shod).

Discussion

Increased plantar pressures during walking could be caused by the different foot strike modalities (increased dorsiflection angle of the foot in combination with decreased knee flexion angle, DE WIT 2000). Additionally, one can assume differences in muscular activity causing the pressure increase, mainly during impact phase in the heel area. Kinematic measurement methods, as well as measurement of muscular activity have to be added to clearly identify relationships between the plantar pressure data and the subjects' movement and muscular activity patterns. We assume that the observed increase in loading during walking is connected to the fact that walking at higher speeds tends to become increasingly uneconomical [4]. Incorrect walking techniques seem to be able to cause higher loading in specific foot areas compared to running at the same speed. On the one hand, these results suggest taking a specific look at the design of walking shoes. On the other hand, recent tendencies in biomechanical research suggest looking at forces as input signals into the neuro-muscular system which the body is able to adapt to. From this point of view higher loading in fast paced walking is not necessarily something that has to be avoided by all means and could be a constitutional characteristic of this type of human locomotion.

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P2.12: Longitudinal follow-up of gait patterns by dynamic plantar pressure measurements

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Summary

The objectives of this study were to evaluate how foot pressure distribution and velocity of roll-off change during growth. Four groups of normal children and adults were compared to look for typical changes in patterns.

Conclusions

The foot pressure pattern still develops after the age of 6. We notice some differences in plantar pressure distribution and velocity of roll-off into adolescence. Total contact time of stance phase and duration of midstance continues to increase into adolescence. On the forefoot we notice a lateral shift in loading pattern with increasing age.

Introduction

During growth foot function as well as foot morphology changes, which causes a varation in gait pattern in normal children compared to normal adults. Dynamic plantar pressure measurements give us the opportunity to study the changes in pressure distribution and temporal aspects of the foot. There is still no strict clarity about the maturity of foot pressure pattern. Some authors suggest that the major structural musculoskeletal changes have been completed by the age of 6, so that the foot pressure pattern is mature [1]. But others indicate that the development of the gait pattern continues into adolescence [3].

Patients/materials and methods

Thirty-two healthy subjects of both sexes, aged 3–28 years, were included in this study. They were divided in four groups: group A ($n = 5$, mean age 5.2 ± 2.26 years), group B ($n = 9$, mean age 9.7 ± 2.45 years), group C ($n = 9$, mean age 16.7 ± 0.48 years), group D ($n = 8$, mean age 24.8 ± 4.93 years). Each subject underwent full gait analysis as well as foot pressure measurements for both feet. A footscan pressure plate (Rsscan International, 0.5 m × 0.4 m, 4096 sensors (4 cm^{-2}), 350 Hz) was mounted in the middle of a 10 m long pathway. Three valid left and right trials were collected at self-selected speed. One well-experienced observer localised eight anatomical regions on the footprints (medial and lateral hindfoot, metatarsal I–V and hallux). Total contact time of the stance phase was calculated. Foot roll-off was divided into three phases: loading response, midstance and propulsion. Temporal data for each anatomical region were calculated for each trial, bilaterally and were averaged per subject. The 3D kinematic data were registrated using a eight-camera VICON motion system. The current study mainly focused on ankle and foot kinematics. Differences between all groups were evaluated by Wilcoxon Signed Rank test.

Results and discussion

We observed changes in velocity of roll-off and plantar pressure characteristics between the different groups. Total contact time of the stance phase increased with increasing age. Significant increase was recognized between groups A and C ($P = 0.0027$), groups B and C ($P = 0.0017$) and groups B and D ($P = 0.0021$). A mild significant evolution between groups A and C ($P = 0.05$) was found for the pressure distribution on the hindfoot, indicating an obvious loading on the medial part of the hindfoot in the youngest group compared to group C, where the loading occurs more laterally. Furthermore, the results revealed a trend in pressure distribution on the forefoot, the loading was more laterally with increasing age. In group A the metatarsal heads were almost equally loaded but primarily on the medial and central side (M1–2–3–4). In the older groups there was a clear peak at M2. This change in loading pattern is caused by the development of the medial longitudinal arch and the absence of pes planovalgus after the age of 6. Finally, we noted a trend for increased duration of midstance phase with age. This parameter was found to be related to the second rocker of the 3D ankle kinematics. We noticed a relation between the duration of the midstance phase, calculated by the dynamic plantar pressure system, and the velocity of ankle dorsiflexion during midstance, processed by the 3D motion analysis system. This kinematic data showed us an increased velocity of ankle dorsiflexion with increasing age. The results revealed also a longer propulsion phase in the youngest group in relation to the older groups. We can conclude that the gait pattern is not mature by the age of 6, this was confirmed by the 3D ankle kinematics.

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Modelling

P2.13: The mathematical modelling of human movement
Jolanta Pauk

Summary

An experimental approach for identifying subject parameters was developed and tested on healthy subjects and subjects with spina bifida. Differences between model's coefficients in the groups are investigated.

Conclusions

The method reveals a promising monitoring tool for functional evaluation of gait improvement. It could be used for planning rehabilitation or surgical treatment, in order to improve walking in affected patients.

Introduction

Human walking is an example of a well-learned fundamental movement pattern that, in normal situations is performed with a great deal of coefficiency and consistency. In the paper will be presented a new quantitative method to analyse and assessment of human gait. The goals of quantitative analysis of human gait in clinical settings vary depending on the limitations and needs of each patient. Rehabilitation of injuries may require limited quanitative analysis and gait training, while serious problems require extensive quanitative gait analysis, rehab and gait training. Gait quanitative analysis in physical therapy is essentially to determine the cause of an observed gait abnormality.

Patients/materials and methods

The experiment was conducted on 20 normal subjects and 34 patients with spina bifida in Centro di Bioingegneeria in Milan. Anthropometrical parameters (body weight, body height, thigh, shank, foot length, pelvis width and height, diameter of the knee and of the ankle) were measured on each subject. Gait movement has been detected using passive markers placed on representative points of the subject. Proposed model describes the dynamical properties human movement. The model is based on analysis of power developed by muscle joints. The method has been used is based on regression function. Below is presented the method of identificationof human gait model.

$$\hat{Y}_n = \underline{U}_n \cdot \underline{a}, \quad \underline{U}_n = [u_1 u_2 \cdots u_k], a = [a_1 a_2 \cdots a_k], \quad N = 1, 2 \ldots, N \tag{1}$$

where N — sample size, Y_n — model's output, $\underline{a}$ — unknown parameters of gait, $\underline{U}_n$ — model's input.

Results

Lower performances were obtained for patients with spina bifida compared against control subjects.

Discussion

Model's identification in all joints of lower limbs does not give a lot of information about human walking. We only now that parameters for patients with spina bifida are higher than for patients with normal walking. That's why identification of human gait model was done for each joint of lower limbs in two phases of gait (stance and swing).

Table 1. Model's coefficients for normal subjects and patients with spina bifida

Joints	Coefficients	Normal	Spina bifida
Hip	a_1	0.844 ± 0.132	2.420 ± 0.553
	a_2	0.303 ± 0.070	−1.109 ± 0.328
	a_3	−0.169 ± 0.053	−0.668 ± 0.238
Knee	a_1	0.782 ± 0.102	2.385 ± 0.251
	a_2	0.369 ± 0.054	−1.094 ± 0.352
	a_3	−0.146 ± 0.055	0.677 ± 0.328
Ankle	a_1	0.724 ± 0.113	2.385 ± 0.553
	a_2	0.204 ± 0.0521	−1.166 ± 0.257
	a_3	−0.034 ± 0.004	−0.738 ± 0.155

Acknowledgement

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P2.14: Development of a lower extremity model for sport shoe research
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Summary

The purpose of this study was to develop a lower extremity model capable of providing important parameters for sport shoe research including conventional foot and ankle angles as well as kinetic data like knee and ankle joint moments which have become very important with regards to the prevention of overuse injuries like patellofemoral pain syndome (PFPS) [1].

Conclusions

Different footwear can now be evaluated regarding conventional stability parameters (e.g. γ- and β-angle) as well as knee and ankle joint moments with a single measurement procedure.

Introduction

The use of 3D motion analysis has become more and more important for biomechanical studies in the sport shoe research area. Nevertheless, models provided by the manufacturers are still mainly for clinical purposes (e.g. Plug-In Gait, Vicon, Oxford Metrics, Oxford, UK). Especially for the determination of foot and ankle kinematics in the frontal plane, there is a lack of models which can reliably detect small differences, as well as incorporate applicable marker placements which do not interfere with running movements. The knee has been shown to be a common site of injury for runners with PFPS being the most common of the injuries to this joint. Therefore it is of great interest for sport shoe research to combine the measurements of knee joint moments which are related to PFPS [1] with measurements of conventional kinematic data (e.g. γ- and β-angles) which are used to describe stability properties of running shoes.

Materials and methods

The model was programmed in Bodybuilder and can be used with Workstation (Vicon, Oxford Metrics, Oxford, UK). Reflective markers were placed on the pelvis, upper leg, lower leg, rearfoot and forefoot (3 per segment). The knee joint center was determined as the middle between the medial and lateral epicondyles. The medial epicondyle marker was removed for the dynamic trials and the offset from the lateral epicondyle collected during the static trial was used to recalculate its position. The zero position of the foot was determined by three markers on the rearfoot setting up a coordinate system aligned with the floor, so that the γ-angle was zero in "neutral-0-position". Due to the separation of the foot in two segments, the possibility to describe torsionability around the longitudinal foot axis and forefoot flexion was obtained.

Kinematic data were collected using a six-camera Vicon System (200 Hz) and a high speed video system (HCC-1000) from posterior (230 Hz). Kinetic data were collected using a Kistler force plate (1000Hz). Subjects were four runners (age: 35 years; height: 173 cm; mass: 66 kg) with an average weekly running distance of 46 km. A standard running shoe (adidas® Unity) was used for the running trials at a velocity of 3.6 ± 0.2 m s^{-1}. For each subject five valid trials were collected. To investigate reliability all markers were removed and put on again by the same examiner for another five valid trials. Three-dimensional knee joint moments were calculated using an inverse dynamics approach and normalized to bodyweight. Selected values of angle and moment curves were determined and averaged for each condition.

Results

The comparison between Vicon data (V1, V2) and high speed video analysis (HCC) shows the expected results considering the mistakes of the 2D analysis due to abduction or adduction of the foot (displacement angle) especially during impact [2]. The two Vicon measurements (V1 versus V2) reveal a strong reliability for angles as well as for moments (Table 1). Moreover, the absolute values of the knee joint moments are comparable with data in the literature [1], [3].

Discussion

Foot eversion described by the new model corresponds very well with expectations from 2D measurements considering alignment problems of the longitudinal and transversal axis of the foot with the camera axis [2]. The determined knee joint moments show similar values as described in the literature in similar studies [1,3]. The reliability of the analysed data meets the requirements to judge differences in various footwear conditions.

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Table 1. Maximum knee joint moments and rearfoot angles of all subjects, positive: eversion, abduction resp.; negative: inversion, adduction resp.

	Subject 1			Subject 2			Subject 3			Subject 4		
	V1	V2	HCC	V1	V2	HCC	V1	V2	HCC	V1	V2	HCC
Impact angle (γ-angle) (°)	−7.2	−6.7	−10.1	−3.1	−3.4	−6.0	−6.4	−7.0	−7.8	−3.3	−2.4	−1.4
Displacement angle (impact) (°)	4.7	5.0		6.1	5.8		1.5	2.6		−1.3	−1.6	
Maximum eversion (γ-angle) (°)	3.3	3.4	3.1	1.8	2.2	2.0	−0.2	−1.0	−0.2	1.3	1.3	0.9
Displacement angle (stance) (°)	4.2	3.6		2.9	3.2		0.2	0.1		−1.8	−2.1	
POM (γ-angle) (°)	10.5	10.1	13.2	4.9	5.0	8.0	6.2	6.0	7.6	4.6	3.7	2.3
Knee ext. moment ($N\,m\,kg^{-1}$)	2.45	2.40		3.43	3.25		2.48	2.32		2.59	2.39	
Knee abd. moment ($N\,m\,kg^{-1}$)	0.40	0.36		1.15	1.24		1.76	1.76		1.00	0.95	
Knee rot. moment ($N\,m\,kg^{-1}$)	0.11	0.13		0.12	0.11		0.40	0.38		0.26	0.27	

Muscles

P2.15: Stabilising and driving function of muscle during exercises with inertial load

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Summary

The aim of the study was to estimate EMG differences for stabilising and driving function of muscles during motion with inertial type of load. Higher values of loads affected all muscles by increasing their driving function. Significant change of muscle activation for their function of stabilising was not identical. Knee joint structure, precisely position of thigh and shinbones, is protected by suitable muscle activity. Therefore higher values of EMG were recorded for flexor muscle during knee extension than extensor muscles during knee flexion.

Conclusions

Not ambiguous relation between mechanical and bioelectrical structure of analysed motions was obtained. Devices with inertial loads allowed competitors to obtain more external power during knee extension (8%), in relation to other type of loads. This effect existed with relationship to lower muscle activity during such motion (9%). Inversely trends at knee flexion were established

Introduction

Most of the information presented in literature is related to concentric muscle activity. External loads are usually controlled by isotonic [4] or isokinetic mechanisms [2]. Therefore the aim of the study was a comparison of mechanical and bioelectrical factors describing motion of knee joint during exercises with inertial loads.

Material and methods

Five male (aged — 22.4 ± 0.3 years; body weight — 74.4 ± 10 kg; body height — 178.4 ± 6 cm) students from the Academy of Physical Education took part in the research. All examined people were acknowledged with measurement form and agreed to join the research. During the measurement they sat in a position of 90° in hip and knee joints. They had to extend and flexed the knee joint with a maximal velocity. Three quantities of disc weights as a external torque were used: 30, 50 and 70 N m. Analogue signals of the muscle torque, the angle position in the knee joint and EMG (Bosco Muscle Lab) were synchronized (Spider–Hettinger Baldwin Messtechnik) with 2400 Hz sampling rate. EMG as the RAW signals was analogically frequency band-pass filtered in range of 20–500 Hz, amplified (differential amplifier, CMRR > 130 dB), analogue to digital converted (12 bit) and stored in PC memory. Ten ms areas for each smooth rectified EMG curve were integrated electronically as a function of time. Average and maximal values of EMG in time function were calculated. Disposable Ag/AgCl electrodes (Medicotest, model M-00-S, Olstykke, Denmark) were attached over belly of rectus femoris (RF), vastus lateralis (VL) and biceps femoris–caput longum (BF). Knee angle of 90° was established as a start position for the knee extension, 160° of full extension for the knee flexion. Maximal voluntary contraction (MVC) under static condition (three joint positions) and exercises with elastic bands were additionally made as reference condition.

Results

Forty Newtonmeter increase of external load leads to increase AEMG of knee extensors muscles (12%) and no change EMG of knee flexor muscle. If EMG for driving and stabilising function was related to their activity under condition with elastic bands load we noticed 9% higher EMG of muscles for knee extension and 10% lower for knee flexion. In additional reference to MVC contraction EMG of RF was lower for stabilising and higher for driving function (booth 20%), VL was higher (20%) for both types of function, BF did not change for driving but increased for stabilising function (40%). Differences of one and two joint muscles function caused describing differences. Similar conclusions were presented in Alkner et al. (2000) and Mastalerz et al. (2000) papers. Analysis of maximal EMG value and its time characteristics shows additional differences in stabilising and driving muscle function in relation to mechanical properties of motion.

Acknowledgements

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P2.16: EMG-patterns in running of children at different ages change with footwear

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Introduction

Although there already exist studies regarding differences in kinematic and kinetic running patterns of children at various stages of development [1], of children's kinematic and kinetic walking patterns with and without shoes [2] and of the EMG-activity during the learning process of walking [3], there is still a lack of knowledge on how children of different ages react to different running conditions. The aim of this study was to examine the changes in EMG-patterns between running with bare feet or shod in children of different ages.

Methods

Fifty-five children participated in this study. They were divided into four groups according to their age [age 4–5 years (eight females, sex males); 6–7 years (eight females, six males); 8–9 years (seven female, seven male); 10–11 years (six female, seven male)]. The children ran at two velocities (2 × height (m/s), 2.5 m/s) for each condition (barefoot and shod). The barefoot running was done on a soft surface (stiffness 94 kN/m). Five steps per condition and child were analysed. Surface EMG (1000 Hz)

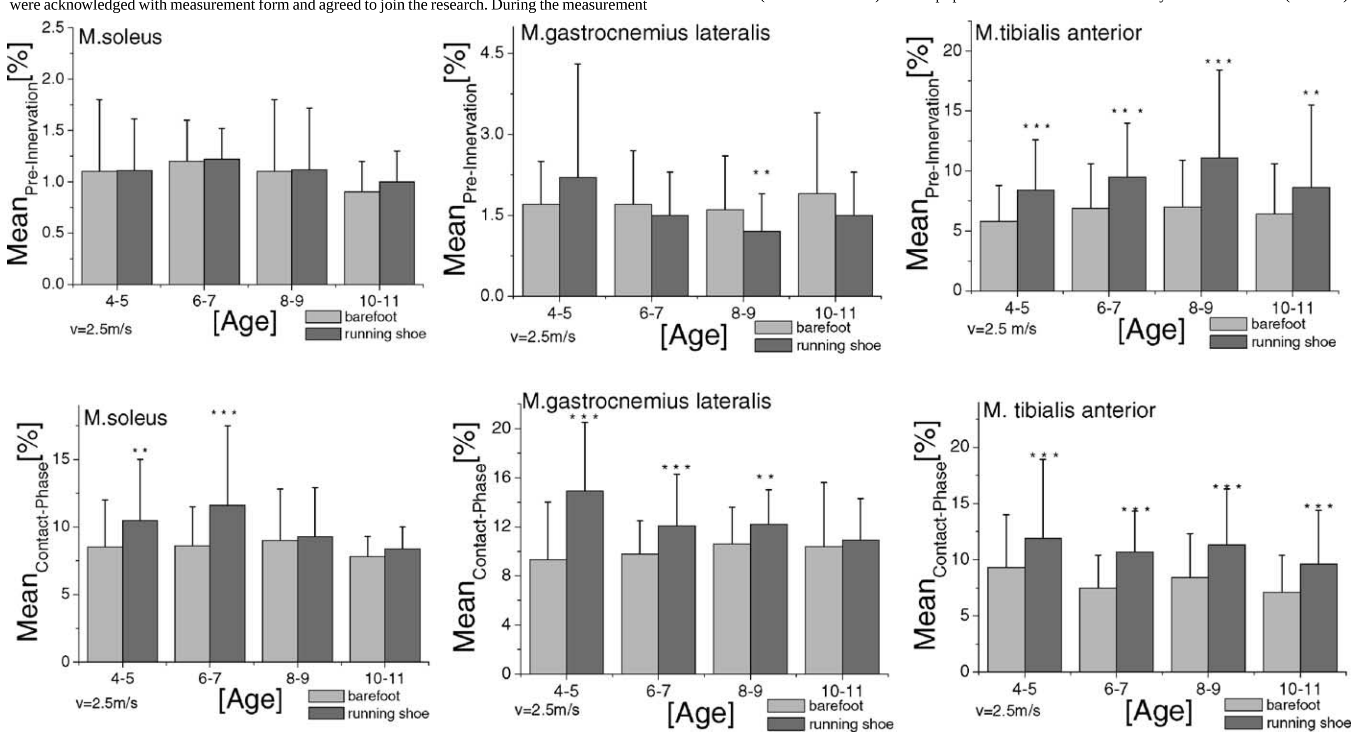

Fig. 1. Mean EMG-activation during the pre-innervation-phase and during the contact-phase. Statistically significant differences between barefoot and shod running: $^{*}P \leq 0.1$, $^{**}P \leq 0.05$, $^{***}P \leq 0.001$ [1]. Statistically significant difference $P \leq 0.05$ to group on (age 4–5).

of three muscles (M. gastrocnemius lateralis = GL, M. soleus = SO, M. tibialis anterior = TA) was measured. The mean EMG-amplitude during the pre-innervation-phase (75 ms, PP) and during the contact-phase (CP) were examined. The rectified and smoothed EMG-data were normalised to the maximum rectified and filtered EMG-data from the first trial running barefoot at velocity 2 × height. The CP was determined from GRF data (1000 Hz, trigger at 10 N).

Results

For all muscles except TA, the influence of shoes was higher during the CP than during the PP. While in TA the significantly higher activity during the PP in shod running was independent of age, statistically significant changes between both conditions in SO and GL differ at various stages of development. Fig. 1 shows that during the CP the EMG-activities in TA and GL were higher for shod running in the children aged 4–9 years. The activity of SO was only significantly higher for those children aged 4–7 years.

Discussion

The high activity of the TA during shod running was might be caused by a more extreme heelstrike at touch-down. The mass of the shoe causes also a higher activity in TA to control the plantarflexion in the late swing phase. The probably bigger lever arm of the reaction force to the joint axis in shod running leads to a higher activity of the triceps surae during the support phase. The results indicate, that the influence of shoes on the EMG-patterns of SO, GL and TA of running children is higher on younger children with age between 4 and 7 years than on older children aged 8–11 years.

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Orthopaedics

P2.17: Gait analysis pre- and post-operatively treated patient on patients with congenital neglected hip luxations

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Introduction

In post war period neglected hip luxations represent big medical and social problem. Operative treatment and postoperative rehabilitation are connected with different kind of difficulties.

Aim

To present the results of orthopedic and physical treatment children with high neglected congenital hip luxation.

Patients and methods

We evaluated 20 patients (18 female and 2 male) age 5–9 years. Follow up period is 2 years. We performed same operative treatment to all patients and it includes: cruent repossession, osteothomy of proximal femur, osteothomy of pelvis. Same rehabilitation program was conducted to all patients. We analyze:

1. heteroanamnesis data — level of satisfaction;
2. clinical examination — we evaluate muscle trophy, level abduction, addiuction, flexion, extension, inner- and outer rotation, circumduction, Trendeleburg and Duschenn sign;
3. X-ray diagnostic analyze: AC index, femoral head position, level of necrosis if exist 2 years after surgery;
4. CT scan analyze of operated hip in three dimensions (2 years after surgery).

Score and Hip Score: We use modified Gait score adopted to our possibilities.

Results:
Level of satisfaction:

- Completely satisfied (10 points).
- Partially satisfied (five points).
- Low grade of satisfaction (three points).
- Unsatisfied (two points).

Objective results: Based of our modified score (maximum 50 points):

1st group: 41–50 points.
2nd group: 31–40 points.
3rd group: 21–30 points.
4th group: 0–20 points.

Conclusion

Significant problems of neglected congenital hip luxation 4 years after war in Bosnia and Herzegovina have faced orthopedic and physiatrists institutions with great deal of problems. Level of satisfaction as well as used score for gait where additional reason to implement Hip screening program in Bosnia and Herzegovina.

P2.18: A 2–4-year follow up study of the active, sagittal, hip excursion used during a portfolio of functional activities by total hip arthroplasty (THA) patients

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Summary

A cohort study of active, sagittal, hip excursion measured with electrogoniometry during a portfolio of eight functional activities in 50 osteoarthritic (OA) subjects 2–4 years following THA.

Conclusions

OA of the hip and subsequent joint arthroplasty leads to significant and continued restriction of the active, sagittal, range of motion of the hip joint in a selection of functional activities up to 2–4 years following surgery.

Introduction

Total joint replacement is established as a valuable procedure for the management of patients with disabling osteoarthritis [1]. A number of studies of the effects of joint arthroplasty have confirmed that the removal of pain leads to improved quality of life and greater general mobility [1,2]. Studies by our research group have indicated that the range of motion used by subjects following arthroplasty may remain limited and may be associated with reduced quality of life [3–5]. Few studies have considered the medium term functional outcome in arthroplasty.

Patients/materials and methods

This study therefore investigated the active flexion–extension excursion of the hip measured using electro-goniometry (Biometrics Ltd.) during a portfolio of eight functional activities (gait, in and out of a standard chair, in and out of a low chair, tying shoe laces, up stairs and down stairs) in a cohort of 50 THA patients with osteoarthritis 2–4 years after surgery and a group of 25 age and gender matched control subjects. Data was recorded during each functional activity using electrogoniometers and a lightweight datalogger while the subject performed a curcuit of activities around the local orthopaedic hospital. Subsequently the data was downloaded and a cycle of each activity analysed in Excel for Windows to give the maximum, minimum and change in joint angle (excursion) used by each subject in each activity. The affected hip of the THA patients was compared to the dominant hip of the normal subjects.

Results

In all eight functional activities the THA patients showed a decreased excursion with an average decrease in hip excursion of 10.1°, ranging from 16° when sitting down to a low chair to 4° during stair descent. In seven of the eight functional activities the data were normally distributed and hence significant differences were tested for using an independent *t*-test (with or without equal variance assumed). In ascending stairs the data was non-normal and hence a Mann–Whitney *U*-test was used. *P*-levels for all eight tests were set at $P = 0.05$. In all eight functional tasks the differences proved significant and in six of the eight the differences would have proved significant at the $P = 0.001$ level.

Discussion

From the results it is clear that while THA may successfully remove pain and restores general mobility, the active excursion of the hip remains limited and abnormal 2–4 years after surgery and leads to a reduction in functional ability. The consequences of these limitations to the joint itself, the other lower limb and back joints and to quality of life of the patients are unclear but would appear worthy of further consideration.

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P2.19: Gait analysis in patients with arthrogryposis multiplex congenita (AMC)

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Summary

This retrospective study was aimed at identifying common gait deviations in patients with arthrogryposis multiplex congenita (AMC) by using instrumented 3D gait analysis.

Conclusions

Compared to healthy gait, all patients walked with an increased pelvic tilt, increased hip flexion, and a lack of ankle power generation at push-off. Variations in the movement curves were higher at the knee and ankle level. 3D gait analysis data showed that, despite differences in treatment and surgery among a small group of AMC patients, similarities in gait deviation were seen.

Introduction

AMC is a symptom complex of congenital joint contractures associated mainly with neurogenic (>90%) but also myopathic (<10%) disorders [1]. About half of the patients are affected on all four extremities, 43% only on the lower limbs and 11% only on the upper extremities. The distal joints are involved more frequently than the proximal ones [2]. The main treatment of patients with AMC is physiotherapy (PT), splinting, and orthopaedic surgery [3]. This retrospective study was aimed at identification of common gait deviations in patients with AMC by using instrumented 3D gait analysis.

Patients/materials and methods

Kinematic and kinetic data of five patients (four males, one female) with AMC (age: 8–21 years) were taken out of the gait laboratory database. These were all patients with AMC referred to the gaitlab over the last 4 years. Clinically all patients had multiple surgeries at the lower extremities. One patient was provided with stiff ankle foot–orthoses and one used orthopaedic shoes. All patients had two PT sessions per week with the main focus to maintain joint flexibility, muscle strengthening, and prevent further development of joint contractures. Instrumented 3D gait analysis was performed with a VICON 370 system with six cameras and two KISTLER force plates. For data collection all patients walked barefoot and independently at a self-selected speed. The lower body motion was determined based on the model reported by Kadaba et al. [4] and data were normalised to percentage of gait cycle. For each patient, data from three trials were averaged and the means and standard deviations were calculated. The data of the patients were compared to a mean data-set of 20 healthy adults.

Results

The sagittal plane gait analysis data showed for all five patients increased mean pelvic tilt (AMC: 24.2 ± 7.6°; healthy: 13.1 ± 6.2°) and they walked with increased peak hip flexion (AMC: 58.1 ± 8.4°; healthy: 40.6 ± 4.2°). No hip extension was reached (AMC: 16.5 ± 10.8°; healthy: −4.7 ± 4.8°). Hip range of motion (ROM) tended to be only slightly reduced (41.7 ± 8.9°) compared to normal (45.2 ± 4.5°). Knee flexion ROM was decreased in the AMC patients (AMC: 42.3 ± 18.9°; healthy: 54.5 ± 4.6°) due to a reduced peak flexion during swing (AMC: 55.2 ± 15.7°; healthy: 61.3 ± 3.8°) and increased flexion during midstance (AMC: 12.9 ± 15.6°; healthy: 6.8 ± 5.4°). The patients showed reduced dorsiflexion movement during swing phase compared to normal with the feet held in an equinus position. All five patients demonstrated a lack of power generation during push-off (AMC: 1.0 ± 0.62 W/kg; healthy: 3.0 ± 0.8 W/kg).

Discussion

Despite a variety of deformities, joint contractures, and different surgeries among the five AMC patients, similarities could be observed in the gait analysis data, especially at the pelvis, hip, and ankle power. Literature shows that knee and ankle are involved most frequently in severe contractures which could explain the higher variations in the knee and ankle movement curves of this study. The power data showed that push-off was lacking in all five patients in contrast to healthy gait, where it is the major promoter of forward progression. Muscle weakness is typical for the disorder but seems to be most important at the ankle level. Four patients compensated for this lack by generating power at the hip, one patient compensated at the knee. Optimising gait maintenance of plantarflexor power and avoidance of impeding contractures seems to be the major goal of treatment and hence regular physiotherapy is indicated.

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P2.20: Functional analysis of gait after surgical reconstruction due to complex foot traumas

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Summary

A movement analysis (MA) study of patients submitted to surgical treatment after complex foot traumas is described in this paper. A 3D bilateral gait analysis is performed. It appears that some indications for planning rehabilitation treatment and for outcome evaluation can be given.

Conclusions

Some "disability signs", not all perceivable by clinical examination, characterize gait of subjects with traumas in different area of the foot (rearfoot, forefoot and dorsum). Results of this study put into evidence that absence or reduction of proprioceptive control, due to the trauma, produce abnormal loads on the plantar areas with poor sensibility, asymmetries between limbs and altered angular kinematics of ankle and knee (affected and unaffected) during gait.

Introduction

Complex traumas of the foot due crash injuries with extensive loss of skin needing for a complete tissues coverage. The preferred treatment is usually a surgical operation aimed at a morphological reconstruction and a functional recovery of the injured foot. The reconstructive surgery main objective is to restore the weight bearing capability, ambulation dynamics and anatomical shape. The age span of the subjects involved is very broad from childhood up to adult age. They are, in general, active subjects. Hence they ask for independence, autonomy and a good quality of life. They frequently claim ambulation reduced functionality, pain and fatigue. In fact substitution of specific skin and muscles with coverage tissues implies week or missing proprioception. Foot progression from stance to swing depends on normal ankle and foot joint mobility and on a correct proprioception. The consequences of reduced somatosensation on regulation of gait and posture have been investigated by inducing paraesthesia by means of ice immersion [1] or in subjects with diabetic neuropathy [2]. In general body segment movements and their control mechanism under reduced somato-sensory input are not completely described. This study is aimed at to characterise the functional ability of the subjects after reconstructive surgery by means of a 3D bilateral gait analysis. In particular lower limbs kinematics, plantar pressure distribution and ground reaction forces (GRF) are recorded and analysed.

Patients/materials and methods

Twenty subjects (mean age 31.74 ± 17.15 S.D.) affected by traumas at the dorsum, the calcaneal area and the forefoot have been tested up to now. Four of them are examined for a second time, 6 months after the first gait analysis test. During the second test for two of them, wearing special arch support during daily activity, two experimental sessions were performed: with and without support inside footwear. Control population is composed by 10 subjects matched for age. Each subject is asked to walk several times over the walkway wearing his/her shoes at his/her natural cadence. Shod condition is adopted to avoid discomfort. The following variables are recorded or calculated for evaluating subject locomotor behavior and revealing the presence of compensatory/corrective mechanism if any: 1-GRF (2 Bertec© force plates, $f_{acq} = 500$ Hz) for evaluating body weight acceptance and its transfer from one leg to the other; two-pressure distribution (*F*-Scan System, $f_{acq} = 150$ Hz) for examining the loads under the foot; three-linear and angular kinematics of ankle, knee and hip (ELITE Sistem, B|T|S, $f_{acq} = 100$ Hz, CAST protocol [3]); four-spatio/temporal parameters (stride, step, stance and double supports durations, speed of progression).

Results

All the subjects present some deviations from the "normal"; these affect different variables depending on the damaged foot area. Asymmetries on the load pressure distribution on the plantar area, on the duration of the stance and double support phase for subjects with traumas at the forefoot and rearfoot, respectively. The duration of the stance for the unaffected foot is generally longer than for the affected one. For "forefoot" group the double support phases are longer than for the normal population, while for the "rearfoot" group the final double support phase of the affected leg is longer than the initial one. This seems to reveal an uncertainty during the injured foot stance. For the affected foot CoP trajectory presents evident Medio-Lateral oscillations for the "dorsum" and "forefoot" groups, while CoP velocity is higher than the controlateral for forefoot and dorsum groups. Plantar-dorsiflexion ranges of the ankle are altered.

Discussion

Asymmetries and high plantar pressure on the foot during gait provide a quantitative description of the outcome and useful information for preventing ulcers. They correspond to compensatory mechanism appearing at the ankle kinematics. According to their recognition planning better surgical or rehabilitative treatment seems possible. The seriate of some subjects after surgical treatment reveals that recovery of the function can be some times and somehow gained, by means of rehabilitation programs and special arch support use.

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P2.21: Early effects of multi-level orthopaedic surgery on gait kinematics, muscle strength and motor function in children with cerebral palsy

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Summary

As part of a larger clinical trial, a study was undertaken to quantify changes in gait, motor function and lower limb muscle strength in children with spastic diplegic cerebral palsy (CP) 6 months after multi-level orthopaedic surgery.

Conclusions

This study confirmed the value of multi-level orthopaedic surgery in correcting complex musculoskeletal deformities in children with spastic diplegia. At the same time it quantified the early effect of surgery on muscle strength and motor function, showing a significant reduction, possibly more than is currently appreciated.

Introduction

The effects of multi-level orthopaedic surgery on muscle strength in CP remain unclear. It is known that lengthening a tendon reduces its force-generating capacity [1]. Although muscle-tendon lengthening has a positive biomechanical effect on joint alignment, the potential negative effect on muscle strength has not been well established in patients with CP.

Patients/materials and methods

A consecutive sample of 15 ambulant children (mean age 12.5 years, seven females + eight males) with a confirmed diagnosis of spastic diplegic CP, participated in the study. The local Research Ethics Committee approved the study and informed consent was obtained from the parent or guardian. All children had soft-tissue and bony procedures by the same Paediatric Orthopaedic Surgeon as part of their clinical management and underwent physiotherapy following surgery according to clinical protocols. All children were assessed pre and 6 months post-surgery. Kinematic data was captured using a VICON 612 system. A minimum of three gait trials were recorded, processed and averaged for each child. Motor ability was assessed using the gross motor function measure (GMFM). Maximum voluntary isometric strength of hip flexors, hip extensors, hip abductors, knee flexors, knee extensors at 90 and 30° was measured bilaterally using a digital dynamometer (MIE Medical Research Ltd.) in standardised testing positions. This method was found to be reliable in our pilot study of children with CP [2]. Each child performed three maximum isometric contractions for each muscle group. Strength measurments were normalised to body weight and the maximum values were used for analysis. Pre and post-op gait, strength and GMFM measures were compared using paired-samples *t*-tests (SPSS 11.0 software).

Results

Gait data confirmed improvements in sagittal, coronal and transverse kinematics at 6 months post-op. However, there was a marked deterioration of muscle strength ($P < 0.05$) in all muscle groups. Medial hamstrings and hip flexors showed the greatest decline with an average decrease of 60 and 48%, respectively. Hip extensors reduced the least by 18%. There was also a 10.6% decrease in the overall GMFM score, while dimension 5 of the GMFM was decreased the most by 40.8%.

Discussion

Clinical experience has shown that the rehabilitation period after multi-level orthopaedic surgery is prolonged and complete recovery should not be expected in less than 18 months. On the other hand the literature suggests that muscle or tendon surgery produces a temporary loss of strength, which is recovered in 6–12 weeks [3]. Results of this study both support and raise some issues about the role of multi-level surgery in children with spastic diplegic CP. Multi-level surgery is performed generally to improve gait in children with spastic diplegia and we confirmed this improvement in gait kinematics. However, our results quantify the magnitude of strength changes post-operatively and demonstrate that a significant weakness and loss of motor function exist 6 months after surgery. This may suggest that more emphasis should be given to muscle strengthening regimes during rehabilitation following surgery. This study is part of a randomized controlled trial, which aims to establish the effect of strength training during rehabilitation following multi-level orthopaedic surgery.

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P2.22: Gait analysis before and after Hiroshima operation

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Summary

Gait analysis was performed before and after Hiroshima operation. Increase of dorsiflexion at initial contact was observed.

Conclusions

The data suggest that the Hiroshima operation give a functional benefit. The transposition of the long toe flexors increases the dorsiflexion at initial contact.

Introduction

The Hiroshima operation was described the first time in 1980 [1]. Indication is the drop foot in most cases in combination with dynamic pes equinus caused by the weakness of the dorsiflexors. The long toe flexors are used for the anterior transfer. The technique was first described for children with cerebral palsy. To examine the functional results, gait analysis data were assessed before and after operation. No reports about dynamic effects of this procedure were found in the literature.

Patients/materials and methods

Six Patients with cerebral palsy, three with a hemiparesis, three with a spastic diplegia (three male, three female) were examined. All patients underwent a multi-level surgery. The indication for Hiroshima operation was the preoperative drop foot. One patient was treated on both sides. Gait analysis was performed before and more than 1 year postoperatively. Temporarily an orthosis was used after the surgery.

Results

The gait analysis data show a better foot function after the operation. In the mean, the position of the ankle joint at initial contact was plantarflexed (28.3 ± 14.3°). After the operation the position of the ankle joint was still not in the normal range but well improved to 7.3 ± 8.8° at initial contact.

Discussion

Reason for the weakness was a cerebral palsy. For these patients the data suggest, that the Hiroshima operation is a good soft tissue technique for functional improvement of the drop foot caused by a weakness of the dorsiflexors. Using this technique, a postoperative drop foot orthosis is necessary only temporarily. The effect is not only due to the hiroshima operation but also a result of the cuff lengthening. The kinematic data of the gait analysis after the operation are not in the normal range for the ankle dorsiflexion. Nevertheless, the indication for the hiroshima operation is easier to define with the quantitative data of a motion analysis.

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P2.23: Gait impairement in patients with knee osteoarthritis

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Summary

Thirteen patients with knee osteoarthritis participated in the study before osteotomia of tibiae. Lower extremity functional evaluation during gait was performed using the ELITE motion analyzer (Bioengineering Technology and Systems Engineering, Milan, Italy). Patients were tested during "free" walking along a 6 m walk-way. The temporal parameters (stance, swing, stride and double support time and cadence) and distance parameters (swing, velocity of each step, stride length, step length and width) were analyzed.

Conclusions

There was noted a significant lengthening of stance and swing time in patient with knee osteoarthritis as compared to normal values. Results of our study confirmed data of previous research in which has been found a gait pattern with tendency to extend the knee throughout the stance phase thus avoiding the quadriceps demand.

Introduction

The knee is the most commonly affected weight-bearing joint in as many as one-third of people 63–94 years old [1]. Common alterations in gait observed in individuals with knee osteoarthritis (OA) include knee excursion [2], altered ground reaction force [3] and muscle activity patterns of main lower extremity muscles [4,5]. Studies investigating the kinetics of gait are conflicting in regard to duration of stance and swing phases of gait and to ground reaction force changes. The aim of the present study was to evaluate the features of gait impairment in patients with knee OA.

Patients and methods

Thirteen moderately physically active patients aged 45–63 years (10 women and 3 men with body mass 75 ± 4.2 kg (mean $\pm$ S.E.), height 164.5 ± 3.6 cm; BMI 27.4 ± 1.4 kg/m^2) with knee OA before osteotomia of tibiae participated in the study. The mean duration of pain in knee was 19.8 ± 7 months, pain intensity ranged from 1 to 6 by VAS. Subjects were previously diagnosed with unilateral knee OA and they were able to safety walk a distance for testing. Lower extremity functional evaluation during gait was performed using the ELITE motion analyzer (Bioengineering Technology and Systems Engineering, Milan, Italy). Patient was tested during "free" walking along a 6-m walk-way in which a two force plate (Kistler Instruments, Winterthur, Switzerland) were embedded for measuring ground reaction forces. Six opto-electronic cameras were mounted in the motion analysis laboratory for motion capture. Twenty passive reflecting markers were attached to the selected points of the trunk and lower extremities. The temporal parameters (stance, swing, stride and double support time and cadence) and distance parameters (swing, velocity of each step, stride length, step length and width) were analyzed. Pelvic obliquity and tilt and range of movements (ROM) in all joints of lower extremity were recorded.

Results

There was noted a significant lengthening of temporal parameters (stance and swing time) in patient with knee OA as compared to normal values. Stance time for involved leg was 711.7 ± 30.2 ms and for uninvolved leg 691.7 ± 30.3 ms (69.2 and 58.2% of stride, respectively, $P < 0.001$). There were noted no significant differences of swing and stride time between involved and uninvolved extremity. Cadence, double support time and distance parameters (anterior step length, velocity, and stride length and step width) did not differ significantly from normal values.

Discussion

Results of our study indicated a significant lengthening of temporal parameters of gait for patients with knee OA and confirmed data of previous research. Andriacchi [6] found a gait pattern which tended to extend the knee throughout the stance phase thus avoiding the quadriceps demand (so called "quadriceps avoidance gait").

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P2.24: Use of inertial sensing in intelligent orthosis — a feasibility study

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Summary

The feasibility of using inertial sensing for supplying accurate and reliable data for controlling and monitoring an intelligent active KAFO orthosis was examined. Required are reliable gait phase detection and accurate knee and ankle kinematics estimation in walking and basic posture detection. Methods were tested against a forceplate and Vicon set-up.

Conclusions

Inertial sensing seems to offer a robust and accurate means for detecting (gait phase) initial contact and toe-off and estimate knee and ankle angle in KAFO walking also in less favorable floor conditions.

Introduction

In a collaborative project Gait an intelligent KAFO orthosis is developed. This paper studies the possibilities of using inertial sensing to provide the required data for gait phase detection, knee angle control and guarding safety. Inertial sensors on thigh, shank and foot deliver full 3D global and local orientation, angular velocity and acceleration data. Robustness and accuracy of several subsets of sensors and analysis algorithms are examined in a trade-off between hard-and eambedded software demands versus reliability and accuracy.

Patients/materials and methods

In several sessions on healthy subjects the data collected with inertial sensors was compared with the data gathered from more traditional alternatives like potentiometers and FSR switches for foot contact detection. For reference lower body kinematics were assessed with a six-camera Vicon system and ground reaction forces with a force plate. Frontal and sagital split video was added for visual reference.

Miniature inertial sensor modules were placed on KAFO beams for thigh, shank and foot segments capable of delivering 3D angular velocity, 3D linear and angular acceleration and 3D global orientation in an earth reference frame. Each sensor module comprised three accelerometers, three gyroscopes and three magnetometers. Kalman filtering techniques were used to derive orientation data. Data is presented from normal subjects wearing an instrumeted UTX orthosis. The subjects performed normal and slope walking in the lab at two speeds, walking on a carpet and walking outdoors on a non level asphaltus footpad.

Results

First results indicate that angular velocity and linear and angular acceleration data in the sagittal plane (one gyroscope and two accelerometer) on the foot segment already gave enough redundant information to reliably detect initial contact (heelstrike) and toe-up in normal walking, walking on slopes and on carpets at all speeds. Reliability was enhanced by using the same dat form the shank. Detecting heel up seems also possible although the reliability of this algorithm was not established yet. Using this configuration also foot, shank, thigh, knee joint and ankle joint angular velocities and accelerations are available, supplying, e.g. direct information on the direction of knee and ankle moments. This is important for a stable control algorithm by ensuring extension assistance only when initial knee extension by the subject has started. During walking angles in the orthosis knee joint could be estimated within 3° accuracy using only uni-axial inertial sensing using one gyrosope and three accelerometers per segment. Inertial sensing provides the additional advantage of easy detection of standing, sitting and inclination of the floor.

Discussion

Results indicate that inertial sensing shows reliable and accurate gait phase detection possibilities, where foot switches are known to be less reliable and robust especially on non-flat floors. The full 3D orientation estimation was not required for detection nor for kinematics estimation. Theoretically integration drift can be prevented 100% in walking. Still for this application and this type of walking this has to be established by evaluating longer recordings under natural gait.

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P2.25: Selective dorsal rhizotomy revisited—a selective approach to cerebral palsy phenotypes

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Summary

SDR treatment remains a controversial treatment for some cases of cerebral palsy. We have experience of the operation and believe patient selection is critical. This is dependant on many factors, the most important of which is the heterogeneity of the condition. We postulate that some of the poor results of SDR as reported might be caused by inappropriate *selection* of cases. Our criteria are described and our methods used.

Introduction

Selective dorsal rhizotomy (SDR) has been performed at our hospital after gait laboratory investigations. Several randomised controlled trials [1–3] have failed to agree whether the procedure leads to long term functional improvement. We believe disparate results from different centres may be related to lack of standardisation in (a) patient *selection* (b) intra-operative technique (c) post-operative physiotherapy regimes (d) outcome measures. Cerebral palsy is a heterogeneous condition and we have used standardised clinical criteria for selecting children who could benefit. Defining *selection* criteria is likely to grow in importance in all gait laboratory measurement.

Patients and methods

We report as follows.

Over the last 5 years 53 children have been referred for consideration of SDR. Each child was reviewed by a multidisciplinary team including an Orthopaedic Surgeon, Paediatric Neurologist and Physiotherapist. Gait analysis including dynamic EMG and energy cost assessment was performed where appropriate.

Selection criteria employed were as follows:

History	Examination	Investigation
1. Age range 5–10	1. Diagnosis spastic diplegia, severe hemiplegia or HSP	1. Moderate to low energy cost (no PCI > 3).
2. Absence of chronic conditions	2. Spasticity moderate to severe	2. No hip dysplasia
3. Cognitive ability — IQ 70 or above	3. Mean lower limb power >3 on MRC scale	3. No basal ganglia change on MRI
4. Well motivated, emotionally robust child	4. Movement control at least moderate	4. Weight not disproportionately
5. No previous multilevel surgery	5. Balance — at least moderately good	
6. Good family/social support	6. Absence of severe fixed joint deformity	
	7. No involuntary movements or dystonia	

Results

Nineteen children were chosen for SDR and the reasons will be expanded upon. Thirty-four children were not *selected* (including 14 considered to have insufficient spasticity). This and other investigations commonly carried out during gait assessment of these 34 children will be discussed.

Discussion

The importance of patient *selection* for the SDR operation – still a controversial procedure in the management of cerebral palsy – is obvious. In most of the papers published about SDR, the patient type is rarely mentioned – for example CP diplegia and hemiplegia and the age of the child and the use of aids is assumed. Patient function and the depth of the impairment are not mentioned much. We have attempted to alter this. The measured gait parameters in those having SDR are considered in the accompanying paper. We believe our encouraging results are related to our stringent selection criteria and that establishing clearly defined, widely accepted criteria will lead to improved outcomes for SDR. These criteria have a general interest for those managing cerebral palsy children.

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Physiotherapy

P2.26: Patterns of locomotion in patients with Parkinson's disease after PNF method of therapeutic rehabilitation

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Summary

This paper present results of 3D gait analysis in the Parkinson's disease (PD).

Conclusion

During therapy, using the PNF method, the spatiotemporal parameters of gait were rallied.

Introduction

The different techniques of walk analysis be practiced [1]. Planning and verification of progress of efficacious physiotherapeutic effect on Parkinson's disease (PD) depends notably on the right identification of areas and scope of dysfunction of motoric systems. Biomechanical evaluation of motoric organ disability made with using of the three-dimensional motion analysis by "Vicon" system can make it considerably easier.

Materials and methods

Thirty-one patients (13 women and 23 men) with the average age of 66 and a diagnosis of idiopathic parkinsonism (PD) and the control group (average 62 ± 4) have been examined for the purpose of this evaluation.

Based upon results of the three-dimensional motion analysis (Vicon 250) of these patients, dominant individual movement disorders were determined and individual therapeutic rehabilitation with use of the PNF method (special techniques using motor patterns for pelvis,upper and lower limbs) was planned in order to improve movement through an approach of assessed parameters to the biomechanical standard. After 3 weeks of therapy, specific characteristics of gait were examined again. All data were averaged.

Results and discussion

The motor control of gait in Parkinson disease presented [2], a method of rehabilitation patients [3]. On the basis of research results before therapy, it was found that these patients had none or limited scope of plantar flexion of feet, excessive dorsal flexion of feet (Fig. 1), lengthened duration of stance phase, considerable excessive external rotation of shanks and excessive anteversion of the pelvis (Fig. 2) during gait cycle.

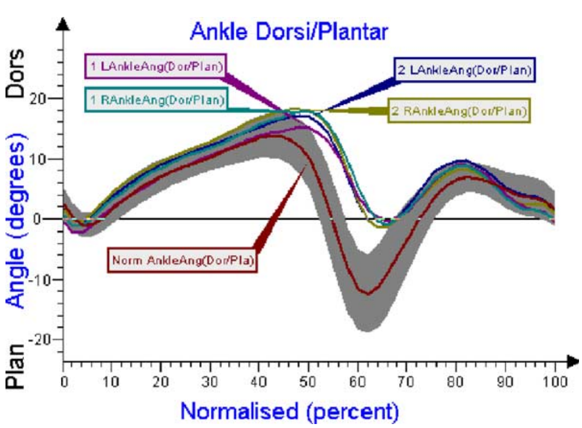

Fig. 1. Ankle dorsi plantar angles in sagittal plane of patients with PD in first examination after the therapy on the background of control group values.

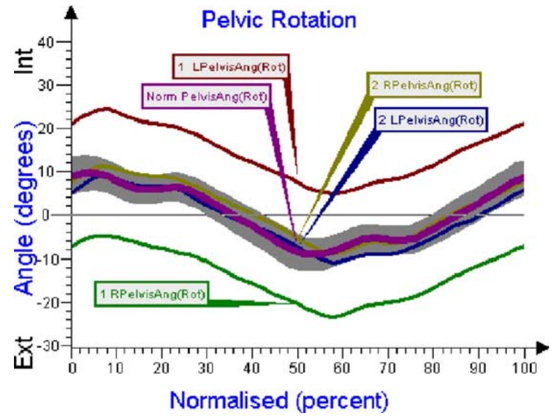

Fig. 2. Pelvic rotation angles in transverse plane of patients with PD in first examination after the therapy on the background of control group values.

Also big differences in values of the spatiotemporal parameters (such as walking speed and frequency, stride length and time of single limb support) between the patients and healthy people were observed.

Table 1. Value of spatiotemporal parameters of the footstep pattern in first and second researches

	Cadence (steps/min)	Step length (m)	Single suport (s)	Walking speed (m/s)
First examination	102 ± 16.6	0.55 ± 0.10	0.41 ± 0.064	0.93 ± 0.26
Second examination	107 ± 14.0	0.59 ± 0.10	0.39 ± 0.020	1.09 ± 0.20
Control group	114 ± 7.20	0.68 ± 0.061	0.39 ± 0.022	1.29 ± 0.16

Discussion

After therapy a marked variability in the scope of angular changes to the above-mentioned dysfunction has not been observed. Only proportions between the duration of stance phase and swing phase have improved noticeably, so that they have directly resulted in better rhythm of gait. They have considerably approached the standards of frequency and speed ($P = 0.05$). However, step length and duration of single limb support has not changed significantly.

Acknowledgement

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P2.27: Feasibility of using instrumented gait analysis in clinical practice of physiotherapy

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Summary

A new gait analysis method, based on a one-unit accelerometer device fixed to the lower back of the patient, is being in a pilot study for testing in physiotherapy practice. A repeated measurement under different walking conditions is a simple protocol to test the feasibility of such a new device. The DynaPort GaitTest is easy to implement in the daily practice.

Conclusions

An easy to use instrumented gait analysis system with automated analysis seems promising for clinical decision making in the physiotherapy practice. The method can be implemented in clinical practice. Walking parameters in the spatio-temporal domain based on position and displacement are easier for interpretation compared to the acceleration parameters. Further clinical validation studies have to be organised to explore the transformation of gait parameters into terms of improving or worsening of gait.

Introduction

More than 20% of the physiotherapy volume in The Netherlands focuses on the improvement of gait. Diagnosis and evaluation of effects of treatment are done with visual inspection, sometimes supported with systematic observation. In an English study amongst 1826 physiotherapists, 91.8% need a new measurement system for gait analysis [1]. Recently, the DynaPort GaitTest based on the DynaPort®Minimod (McRoberts BV, The Netherlands) was developed. This device includes three orthogonal mounted accelerometers. With the unit mounted on the lower back, basic gait parameters can be assessed. In Dutch physiotherapy there is growing interest to treat based on evidence. The aim of this pilot study is to find out whether a simple objective gait analysis system would be practical and relevant in clinical practice.

Patients/materials and methods

On the basis of a questionnaire amongst physiotherapist a pilot study has taken place. The pilot consists of case studies with repeated measurements under different walking conditions. In total 22 patients were assessed in seven sites, of which three cases are included in this paper; two patients with leg length discrepancy, and one with pelvic instability. All assessments were done within the time frame of normal treatment. The patients are instrumented with the DynaPort®Minimod positioned with a belt or adhesive tape at the lower back (picture). The weight is of the unit is 75 g, sample frequency is 100 Hz, data are stored on an SD Card. A walking trajectory of 10 ms was walked several times. The acceleration signals were analyzed from start of walking to standstill. The GaitTest software is fully automated. The following parameters were calculated: step parameters (foot strikes, left and right steps [2], step times, step frequency, walking speed, walking distance [3]), acceleration parameters (mean normalized left and right step patterns and standard deviation for the three signals, total acceleration per walked meter, kinetic energy), inclination of the pelvis (mean inclination during standing and walking and during walking for left and right steps), displacement of the COM (vertical and left right displacement of the MiniMod).

Results

The pelvic orientation can be easily assessed in standing and walking. Different walking conditions (crutches, pelvic band and shoe correction) influence the left right inclination of the pelvis during left and right steps during walking. The standard deviations of the normalized acceleration signals are systematically lower during treadmill walking than during over ground walking. The total acceleration vector per walked trajectory changes with different walking conditions.

Discussion

The ease of assessment of gait and automated analysis and the time involved makes the DynaPort®Minimod and GaitTest very promising for support of clinical decision making. Step parameters and inclination of the pelvis and the thorax, the measured body segment and displacement of the COM are directly interpretable and therefore almost ready for clinical use. The acceleration patterns and the stand deviation need further interpretation. Clinical validation studies are needed to further explore these parameters.

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P2.28: Aspects of neck movement patterns in patients with whiplash associated disorders

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Summary

Objective neck movement analysis can be used as an assessment tool in the examination and rehabilitation of patients suffering from chronic whiplash associated disorders (WAD). In two earlier studies we have shown significant differences in head movement pattern between a group of WAD patients and a control group, e.g. head movement range and rotation angle velocity [1,2]. In this study, the variability of the head movement pattern within repeated head rotations were investigated. Statistically significant differences were found between controls and subjects with chronic WAD.

Conclusions

The study indicates that WAD patients tend to have a larger variability in their movement pattern than controls during repetitive head rotations. Studying variability during repeated head rotations might therefore enhance the clinical examination of WAD patients.

Introduction

WAD are a common diagnosis after neck trauma, caused by sudden acceleration and deceleration forces acting on the head and neck, often related to rear-end car accidents [3]. In clinical practice, WAD patients report two main areas of complaints: increased muscle tension and pain during repetitive arm and shoulder movements and increased pain and stiffness during repetitive neck movements. The clinical examination generally includes palpation of muscles for pain and visual inspection of range-of-movement in neck and shoulder joints. It is difficult to identify subgroups and thus establish a more precise diagnosis, and imaging techniques such as X-ray and magnetic resonance therapy seldom reveal any pathological changes. An objective decision support system, based on repeated head rotations, might increase the ability to identify different clinical subgroups of WAD and thereby enhance the development of more precise diagnostic procedures for WAD patients.

The aim of this study was to investigate the variability in the head movement pattern for repeated head rotations within a group of controls and patients suffering from WAD.

Patients/materials and methods

A group of 56 controls and 59 subjects suffering from WAD were selected. All WAD patients had chronic symptoms lasting longer than 3 months and received their diagnoses by a physician with daily experience in the diagnosis and management of WAD. The subjects performed 16 rapid head movements in random order, i.e., flexion–extension and right–left axial rotation. The motion data was collected by a commercially available motion analysis system and the head rotation angle, Θ, was calculated [1,2]. Variables describing the variability within repeated head rotations was studied, e.g. the variance in time (s_t) to reach choosen levels of Θ (10, 20, ..., 80% of Θ_{max}). Group differences were investigated using independent-samples *t*-test.

Results

The variability was in general higher in the WAD group compared to the control group. Significant differences in s_t was found for extension (10–50% of Θ_{max}) and axial rotation (40–80% of Θ_{max}).

Discussion

There are indications, that clinical test used in the assessment of patients with neck/shoulder problems may be unreliable [4]. In this study, movement analysis of simple rapid neck movements was used. This approach is near the physician's way of examining patients suffering from WAD, but gives more detailed information about the effects on the movement pattern from repeated head rotations. In earlier studies we have shown significant differences in neck movement aspects such as movement range and rotation angle velocity [1,2]. Here, significant differences in variability in the movement pattern were found. The method may be generalised into an assessment tool for examination and rehabilitation of patients with different neck and shoulder problems.

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Posture

P2.29: The effect of vision on stance control mechanisms

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Introduction

The regulation of posture involves several different sensory modalities, namely, visual, vestibular, and somato-sensory systems. In the case of visual system the most commonly used test involves the comparison of postural sway with eyes open and eyes closed. Researchers have evaluated postural sway by using a force platform to measure displacements of the Centre of Pressure (COP). Attempts to interpret stabilogram, a plot of time varying coordinates of the COP, from a motor control perspective have not been successful.

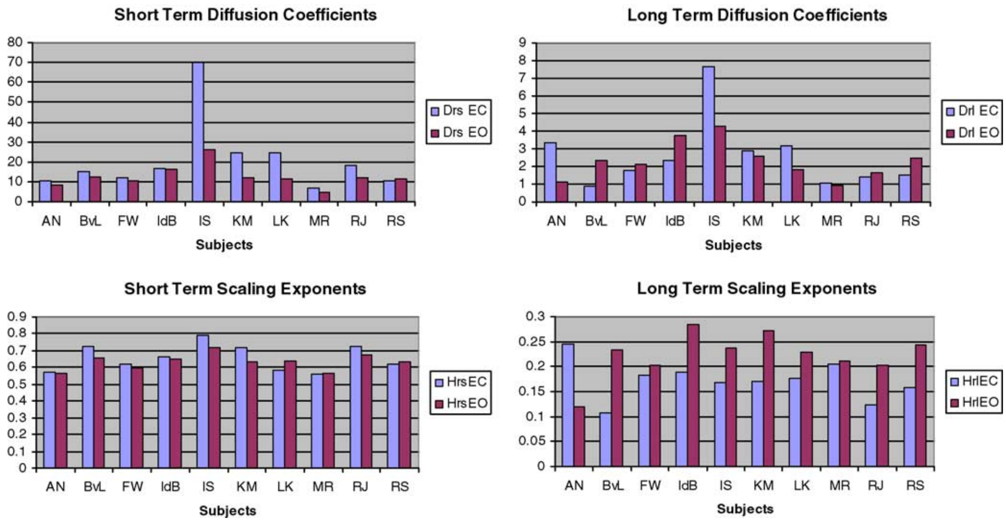
Collins and DeLuca (1993) introduced a new method for analyzing COP trajectories known as stabilogram diffusion analysis. The displacement analysis of COP trajectories is carried out by computing the square of the displacements between all pairs of points separated in time by a specified interval (Δt). The square displacements are then averaged over the number of Δt making up the COP time series. This process is repeated for increasing Δt. A plot of mean square COP displacement versus Δt is known as stabilogram diffusion plot. The analysis generates three sets of six parameters. The parameters are long and short term diffusion coefficients (*D*), long and short term scaling exponents (*H*) and critical point coordinates. Diffusion coefficients are calculated from the slopes of the resultant linear–linear plots, scaling exponents are calculated from the slopes of the resultant log–log plots, and the critical point coordinates approximate the transition region that separates the short term and long term regions. The sets are for medio-lateral, antero-posterior planar displacements. The two parts of plots suggest two different control regimes namely, a short term open loop control and a longer term closed loop control.

Method

Ten able bodied, healthy subjects participated in the study. Their age ranged from 21 to 49 years. During trials the subjects were asked to stand, barefoot, in an upright position in a standardized stance, as quiet as possible, on a force platform. The platform measured the time varying displacements of the COP. Each trial lasted for 30 s. Two test conditions were randomly tested, namely eyes open and eyes closed. For each condition two series of 10 trials were conducted. The data was analysed according to the method described by Collins and DeLuca. Statistical analysis, ICC calculations were carried out using SPSS v11.5 to study the reliability of findings obtained for the test conditions.

Results

ICC for majority of parameters for both test conditions represented fair to excellent reliability. The parameters for planar displacements were studied in detail for trends. Figure shows short and long term *D* and *H* in both conditions. The critical point coordinates were similar for both test conditions.



Discussion

Open loop control mechanisms, when interpreted physiologically, indicate inherent stability of the body and closed loop control mechanisms indicate the efficacy of the feedback mechanisms and the corrective actions. With eyes closed almost all subjects became unstable, as indicated by higher *D*. These results are different than what [2] found. On a longer term basis the effect is variable. This probably is due to different efficiencies of feedback and corrective measures. Short term *H* indicated persistent behaviour and similar for both conditions. However, as shown by long term *H*, even though being anti-persistent, with eyes open almost all subjects allowed more latitude before taking corrective measures.

Conclusions

With eyes closed body becomes more unstable. Effect of corrective measures depends on the efficacy of the feedback systems. With eyes open body allows more latitude before taking corrective actions.

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P2.30: Effects of the complex traumas of the foot on balance

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Summary

A Movement Analysis study of patients submitted to reconstructive surgical treatment after complex foot traumas is presented. The analysis of GRF and pressure distribution on one foot during shod upright posture is used to evaluate the disease effects.

Conclusions

Preliminary results allow to quantify the reduction of the ability to balance produced by proprioception deficit and musculo-tendineous damages; therefore an increase of risk of falling and modifications of foot function can be recognised.

Introduction

The surgical reconstructive treatment adopted in cases of complex traumas of the foot is usually aimed to reconstruct morphology and to induce a functional recovery of the injured foot. The foot damages here considered (usually due to traumatic accident) involve large loss of skin and soft tissues; they quite often require coverage with free flaps. Substitution of specific skin and muscles with distant donor areas tissues (tegumental, muscular) cannot restore proprioception. Rather frequently damages of somatosensory system hold; consequently ability to maintain a stable upright position can be reduced. In fact it is well known that vestibular, visual and somatosensory information are utilized to control the position of the body's center of gravity over the base of support. Disruption and/or degradation of one or more of these information channels results in postural deficits. Into the literature the effects of the somato-sensory system impairment on the posture maintenance is described for diabetic [1] or parkinsonian [2] subjects. The aim of this study is to evaluate the effects on the postural balance of foot traumas involving proprioception deficit and damages to the musculo-tendineous structures.

Patients/materials and methods

Twenty subjects (mean age 31.74 ±17.15 S.D.) affected by traumas at the dorsum, the calcaneal area and the forefoot have been tested up to now. Four of them are examined for a second time, 6 months after the first upright posture test. The inclusion criteria are: (1) no specific footwear and/or presence of special arch support; (2) no pretraumatic vascular or metabolic pathologies nor degenerative invalidating pretraumatic pathologies, nor pre and/or post operative trophic ulcers of the sole or injuries of the main nervous trunks; (3) injuries limited to the tegument or complex trauma of the foot. Control population is composed by 16 subjects matched for age and gender with the sample population. Each subject is asked to stay, wearing his/her shoes, in upright posture for 40 s with open eyes, keeping only one foot on the force platform and the other on the walkway. The indications reported in [4] are followed during the upright posture test. Shod condition is adopted to avoid discomfort. One trial for each leg is performed. GRF (Bertec© platform, $f_{acq} = 500$ Hz) and pressure distribution (*F*-Scan System, $f_{acq} = 150$ Hz) are recorded. Raw CoP signal is filtered with a fourth order, zero-phase shift, Butterworth-type low pass filter ($f_{cut\ off} = 5$ Hz) before signal analysis [4]. Total excursion of the CoP path over the fixed time period (central 30 s of the 40 s test period) is recorded. The range of the path of the CoP in the anter-posterior (CoP_{AP}) and medio-lateral (CoP_{ML}) directions, the total length of the CoP path (CoP_L) and the its average velocity (CoP_{VEL}) and the plantar pressure distribution are used to appraise the stability of the subjects.

Results

With respect to the control population patients behavior is different according to the foot area involved in the traumas. For "rearfoot" and "dorsum" group all the parameters considered are inside the normal range. For the "forefoot" group the CoP_{AP}, CoP_L and CoP_{VEL} ranges are larger than for the same parameters related to the control population. It is relevant to observe different between affected and unaffected foot. All the patients groups present asymmetries. CoP_{AP} excursion show differences between affected and controlateral foot. For the "dorsum" group the CoP_{AP} range is larger for the affected foot (Fig. 1) while the opposite happens for subjects belonging to "forefoot" and "rearfoot" groups. For all patients groups, CoP_L and CoP_{VEL} are larger for the affected foot than for the controlateral one.

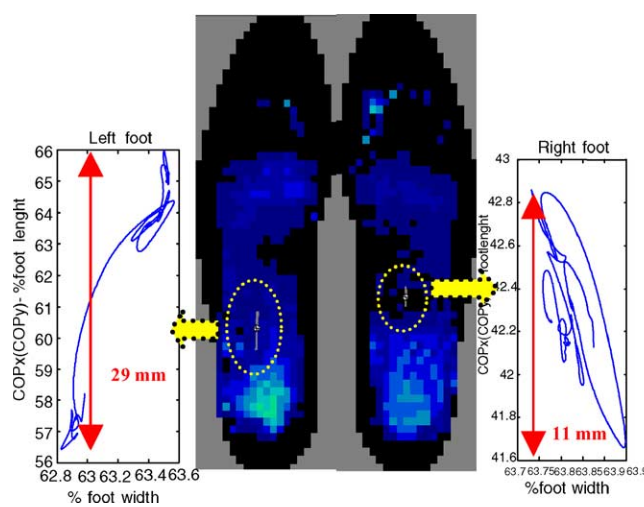

Fig. 1. CoP normalised trajectories of operated (left) and controlateral (right) foot during the upright standing ("dorsum" subject).

Discussion

Alterations of CoP trajectory during the upright standing confirms some postural stability disorders due to the proprioception deficit [1]. Asymmetries let think about modification of balance mechanisms but it is not yet clear why patients, with poor or in some cases absent plantar sensibility, such as those belonging to "forefoot" and "rearfoot" groups, show smaller CoP_{AP} excursions for the affected foot than for the controlateral one.

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P2.31: Influence of backpack load on posture and gait in children

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Summary and Conclusions

The objective of this study was to evaluate how a loaded backpack in young healthy children influenced gait and posture. A group of children underwent 3D gait analysis including EMG and recordings of the centre of pressure (COP) during quiet stance with and without a loaded backpack. By carrying a load on the back, children became less stable while standing still, walked slower in a more leaned forward position, and showed altered muscle activity. Paraspinal muscle activity was decreased due to the increased spinal extension moment which

works against the normal spinal flexion moment in unloaded gait. Reducing the exposure to load carrying, i.e. heavy school backpacks, at young age might help preventing back pain at adolescent age.

Introduction

The use of backpacks is common in school age children. Epidemiologic studies have identified that risk factors associated with back pain in adolescents and daily use of a heavy backpack may be important. The current recommendations are that a child's book bag weight be limited to 10% of his or her body weight. A book bag weighting more than 15–20% of a child's weight is associated with back pain [1]. The objective of this study was to evaluate how a loaded backpack in young healthy children influenced gait and posture.

Patients/materials and methods

3D gait analysis (VICON 460 motion capture system, EMG, COP in quiet stance) was performed on 12 healthy children (age: 8.4 ± 0.9 years). For data collection all children walked barefoot at a self-selected speed in an unloaded condition and with a 4 kg backpack ($15.0 \pm 2.7\%$ body weight). The lower body model reported by Kadaba et al. [2] was used and data were normalised to percentage of gait cycle (GC). Subsequent markers were placed on shoulders, chest, and head. Surface EMG was recorded according to the SENIAM guidelines of the m. gastrocnemius medialis (GM), m. tibialis anterior (TA), m. gluteus medius (GLM), m. semitendinosus (ST), m. rectus femoris (RF) of the dominant leg preferred in hopping. EMG was also recorded of the ipsi- and contralateral paraspinal (PARAS) muscles at L2 region. Of each child data of six trials were averaged and paired *t*-tests were used ($P < 0.05$) for statistics. COP data were collected during quiet stance on a Kistler forceplate. The children were asked to stand as still as possible looking at a point 3 m away. Four 10 s trials were recorded.

Results

The temporal-spatial parameters showed that with a 4 kg backpack the children walked slower as a result of taking smaller steps with unchanged cadence. With the slower walking speed, double support phase and stance phase increased. The sagittal plane kinematic data showed an increased mean anterior pelvic position over the whole GC. Hip flexion was also increased over the whole GC with unchanged range of motion. Movement at the knee joint was unchanged and at the ankle joint a reduced peak dorsiflexion in stance phase was recorded. Compared to unloaded walking, increased muscle activity was recorded with a loaded backpack during mid-stance in the GM (10–30% GC) and ST (20–30% GC). GLM activity was also increased in the second half of terminal-stance phase (40–50% GC) and the TA activity in pre-swing phase (50–60% GC). The PARAS muscles on the ipsi- and contralateral sides of the spine were less active at the second half of terminal-stance and in pre-swing (40–60% GC). No changes in RF activity were recorded. Postural steadiness of stance, represented by the COP, was decreased in quiet stance in both anterior–posterior and medial–lateral direction.

Discussion

Decreased walking speed and increased double support time during load carrying can be attributed to the need for stability [3]. This is supported by the decreased postural steadiness of quiet stance. Findings regarding decreased lumbar PARAS muscle activity in the loaded condition are in agreement with the literature [4,5]. This is due to the increased spinal extension moment provided by the external load which acts in opposition to the normal spinal flexion moment in unloaded gait [5]. Literature suggests that adolescents with back pain are at increased risk for experiencing back pain as adults [6]. Reducing the exposure to load carrying, i.e. heavy school backpacks, at young age might help preventing back pain at adolescent age.

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Prosthetics

P2.32: Effect of walking aids on muscle activation patterns in stroke patients

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Introduction

Regaining the ability to walk is a major goal during the rehabilitation of stroke patients. Factors important to reach this goal are early, functional, goal oriented intensive training. In clinical practice direct assistance during exercise is intentionally restricted and strong personal involvement of the patient is encouraged. Walking aids are often used in order to maintain safety and increase independence during gait training [1]. However, based mainly on theoretical assumptions, different opinions exist among therapists, on the effect of walking aids on the gait pattern of stroke patients. In the scientific literature [1–3] no clear consensus exists on the effects of walking aids on symmetry of gait, walking speed and weight bearing. Furthermore, there is a distinct paucity of detailed studies on muscle activation patterns. The purpose of this study was to investigate changes in muscle activation patterns with respect to timing and amplitude that occur when subjects with stroke walk with and without a walking aid. This knowledge could help therapists in their decision whether or not patients should use a cane or quad stick while walking.

Patients/materials and methods

Thirteen patients suffering from a first unilateral ischemic stroke were included. Surface EMG of the erector spinae, gluteus maximus, gluteus medius, vastus lateralis, semitendinosus, gastrocnemius and tibialis anterior of the affected side were measured during three different conditions: (1) Walking without a walking aid, (2) walking with a cane, (3) walking with a quad stick. Timing and amplitude parameters of the activation patterns were quantified, using an objective burst detection algorithm [4] and statistically evaluated.

Results

Results show a statistically significant and clinically relevant decrease in burst duration of both erector spinae ($P = 0.39$) and tibialis anterior ($P = 0.16$) when walking with a cane. The amplitude of especially the vastus lateralis ($P = 0.003$) and tibialis anterior ($P = 0.006$) drops when walking with a cane and quad stick, respectively.

Discussion

The decrease in amplitude and burst duration of the erector spinae is likely to be related to the support that is given by the use of a walking aid. The decrease in timing and amplitude of the tibialis anterior appeared during swing phase and therefore cannot be related to the support given by the walking aid directly. Indirect effects however might give hold to NDT therapists believing that trunk stability is an important prerequisite for normal arm and leg movement. Overexertion will produce an overflow

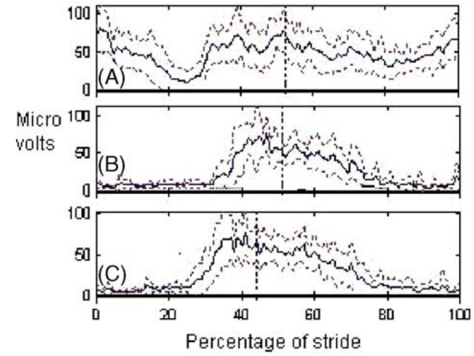

Fig. 1. Typical example: changes in muscle activation pattern of the stride normalized Smooth Rectified EMG (SRE) of the erector spinae is presented for the three different walking conditions. 'A' presents the sEMG of the erector spinae when walking without an aid, 'B' when walking with a cane and 'C' when walking with a quad stick. The dashed vertical line represents toe off.

and irradiation through the body, thereby reinforcing abnormal tone and stereotypical mass patterns of the affected side.

Conclusions

Results show that, when therapy given to stroke patients aims at normalisation of muscle activation patterns, the use of a cane should be considered.

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P2.33: Can instrumented gait analysis guide lower limb prosthetic alignment? A clinical study

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Summary

The purpose of this study was to investigate the effects of prosthetic misalignment of transtibial prostheses on selected parameters of the gait pattern with instrumented gait analysis in a clinical setting. To our surprise, relatively few systematic effects were observed in step and stride characteristics, ground reaction forces and net joint moments in 5 transtibial amputees who walked with systematically misaligned prostheses.

Conclusions

In the current study the gait analysis method applied and variables selected showed little responsiveness to prosthetic misalignment. More research is necessary to investigate the effect of prosthetic misalignment on gait characteristics and to explore the usability of instrumented gait analysis in the process of prosthetic alignment.

Introduction

The alignment of lower limb prostheses is expected to be an important determinant for regaining a satisfying walking function and functionality. The process of prosthetic alignment is, however, still a very subjective process. With the introduction of gait laboratories in clinical institutions, it is of interest to see whether instrumented gait analysis can contribute in an objective way to prosthetics alignment and the optimisation of gait. However, only little is known on how prosthetic alignment affects the different gait characteristics that can be studied using instrumented gait analysis [1]. Therefore the purpose of this study was to investigate the effect of systematic prosthetic misalignment on selected parameters of the gait pattern that can be observed with instrumented gait analysis in a clinical setting.

Patients/materials and methods

Five males with a transtibial amputation participated in this study. Subjects walked at a self-selected speed on a walk-way of 10 m with the prosthetic alignment they currently used, and with their prosthetic pylon misaligned under eight discrete conditions: 15° into flexion/extension, valgus/varus, exo/endorotation or foot plantar/dorsal flexion. Video recordings were made in the frontal and sagittal plane (25 Hz) and ground reaction forces of the prosthetic step were recorded (100 Hz) using the Sybar System (Noldus, The Netherlands) [2]. From these data walking velocity, stride and step characteristics were derived. In addition, the amplitude and timing of the different peaks in the ground reaction force patterns were quantified and the net joint moments in the frontal and sagittal plane were assessed by scoring the magnitude of the lever arm of the ground reaction force on an ordinal scale using the two-dimensional overlay of the ground reaction force vector on the video images. Differences between conditions were tested for significance using a non-parametric Friedman test ($\alpha = 0.05$).

Results

Prosthetic misalignment had no effect on walking velocity or step and stride characteristics. Ground reaction force patterns in vertical and fore-aft direction were unaffected, but in medio-lateral direction a significantly larger medial force was found when the prosthesis was aligned to either exorotation or valgus compared to endorotation or varus. In conjunction, the lever arm of the ground reaction force with respect to the ankle in the frontal plane was larger and more to the lateral side of the ankle joint at the end of the step when the prosthesis was misaligned in exorotation compared to endorotation and varus.

Discussion

Despite the large changes in alignment, relatively few systematic effects were observed in the selected parameters. This seemingly low responsiveness of the applied method could be attributed to a lack of resolution of the measurement instruments. On the other hand it can be argued that the lack of results can be due to variability in the response of the different subjects and/or to the fact that the well-trained subjects used in this study possessed well-developed compensation strategies that minimized the effect. Further studies are currently being performed to explore these issues.

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Technology

P2.34: Using a physical pendulum to test accuracy and precision of the proreflex 500 system

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Summary

A physical pendulum was used to test accuracy and precision of the Proreflex 500 camera system in timing events during a movement cycle. Despite changes in the pendulum orientation with respect to the cameras, there would appear to be a high level of accuracy (absolute error, 0.02 s) and precision 0.55%–1.65% coefficient of variation.

Conclusions

The Proreflex 500 is highly accurate and precise in measuring the period of a physical pendulum.

Introduction

Motion data should be interpreted in context of the accuracy and precision of the capture system. Proreflex 500 (Qualisys) is a commonly used system for movement analysis, however little independent accuracy and precision data is available. The system at Glasgow Caledonian University is currently being used to time events during functional movement. To reflect this type of measurement it was felt appropriate to test the system in timing moving bodies. Given the predictable nature of a pendulum swing and its comparability to the motion of body parts during functional activities such as sit to stand and gait it was felt to be a suitable motion to test the system.

Methods

The cameras were calibrated according to manufacturer's instructions and the setup remained constant. A rigid pendulum, length (0.97 m), mass (0.21 kg), was hung from a frame (1.6 m in height). The centre of mass of the pendulum was located 0.81 m away from the axis. The pendulum was rotated to its release position 0.76 m above the ground, creating an angle of 30° to the vertical. A reflective marker (0.02 m diameter) was fixed at the end of the pendulum, the pendulum was released and allowed to oscillate freely. The cameras captured the motion data five frames before release and for 20 s after at a rate of 60 Hz. This process was repeated five times, then the whole apparatus was rotated first 45° clockwise and then 45° anti-clockwise with five data captures being taken in each position. The data were analysed in Qtools (Qualisys), the period of oscillation being the time between successive peaks in the horizontal displacement of the marker.

This was compared to the predicted period of oscillation (calculated at 1.79 s using the equation $2\pi\sqrt{I/mgL}$, where $\pi = 3.14$, m = mass (0.21 kg), I = moment of inertia of pendulum, g = 9.81 m/s and L = length of pendulum) to estimate error. Variation in each position was used to estimate precision.

Results

Table 1. Mean, error and variation of the pendulum period according to orientation

	Mean (s)	Absolute error (s)	Standard deviation (s)	Coefficient of variation (%)
Zero rotation	1.81	0.02	0.03	1.65
45° clockwise	1.81	0.02	0.01	0.72
45° anti-clockwise	1.81	0.02	0.01	0.55

Discussion

The Qualisys Proreflex 500 demonstrates excellent accuracy and precision when measuring the timing of a moving body under predictable conditions. The absolute error may be explained by the approximations for acceleration due to gravity and Pi as well as error in measuring the physical properties of the pendulum. This method of testing has not been reported in the literature but would appear appropriate for movement analysis based on timing events of moving bodies.

P2.35: Instrumented crutch with an indirect feedback system

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Summary

By means of a case study we present a newly developped crutch which is able to measure the supporting force on the crutch and passes this information on to the patient by help of an indirect feedback system so that he can reach the optimum concerning the load being put on the lower extremities.

Conclusions

By the help of this individual adaptability the newly developped crutch which is now presented offers an auxiliary device to the patient which can always be adapted and varied perfectly in order to optimize the situation of putting load on the lower extremities.

Introduction

Different types of auxiliary walking devices are used in order to give a patient back his mobility — especially after operations on the lower extremities; firstly to stick to the prescribed limit of permissible load and secondly to develop a symmetric gait. Not always is the patient able to use these auxiliary walking devices in an optimal way, quite often an unnecessarily strong utilization of the crutches can be observed.

Patients/materials and methods

The newly developped supporting crutches being introduced here offer the opportunity to the patient to achieve an optimum use of the auxiliary walking device by means of an indirect feed back which measures force that is used to support the patient from the crutch.

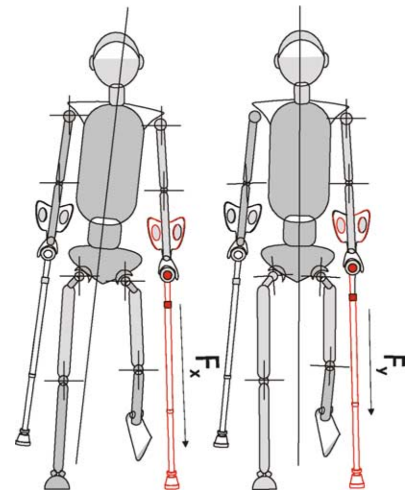

Fig. 1. The use of the new developed crutch optimizing the situation of putting load on the lower extremities.

Standphase right without information about the supporting force on the left crutch (left) and optimized situation using the newly developped crutch.

Results

The study describes the use of the crutch and the resulting optimiziation which could be reached in the situation of load during walking on the one hand. A reduction of the supporting force on the crutch of 50% was to be observed.

On the other hand asymmetric motion patterns can be reduced or avoided also.

P2.36: Ambulatory gait analysis in parkinson's disease: application of a novel method based on kinematics sensors

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Summary

Using our ambulatory monitoring system, ASUR, 13 Parkinsonian patients were monitored for periods of up to 5 h while they were free to perform activities at will. Every 1 h patients did a UPDRS test as the clinical assessment. During the period of the monitoring, subjects had their Stimulation ON and OFF. Analyzing the data, periods of gait have been detected and gait parameters were calculated. We've found significant correlation between the results of this objective method and those of the clinical score.

Conclusions

With minimal number of sensor sites, we could detect and analyze the gait parameters of PD patients as they were performing normal, unrestricted activities; while the results show a correlation to clinical scores. Using this method an objective evaluation method to assess gait in PD patients for extended periods of time is possible.

Introduction

Parkinson's disease (PD) influences gait with aggravation of quantitative parameters like gait cycle time (GCT), period of swing (SW), double support (DS), stride length (SL), speed (SP), range of rotation of shank (RS) and peak angular velocity of shank (PV) that have been shown to be improved by bilateral STN [1]. We have designed a new ambulatory system (ASUR) to monitor PD patients while they are performing they daily activity. We have used our analysis algorithm to quantify gait parameters in PD subjects while they were performing normal, unrestricted activities.

Patients/materials and methods

Thirteen PD patients with the age of 64 ± 8 participated in this study. Subjects were treated by Sub-Thalamic Nucleolus Deep Brain Stimulation (STN-DBS). Each measurement took up to 5 h during which subjects were free to move around in the hospital area. Two observers took note of the subject's activities using portable computers. To measure gait parameters, ASUR devices, with an integrated uni-axial gyroscope in sagittal plane, where attached to each shank of the subjects. System had a sampling rate of 200 Hz and angular velocities of shanks were recorded in a range of ±600°/s. At the beginning of the measurement and then after each 1 h, a UPDRS test was performed. Subjects started with STN ON, subsequently it was turned OFF for 3 h and ON again for the last hour. By running our analysis program after the measurements, gait periods were automatically detected and respective gait parameters for each gait cycle were calculated. To compare to the clinical score, for each hour the average of the values of the gait parameters during that period was calculated. The first period was used as the baseline and the correlation between changes in UPDRS sub-scores (27; 28; 29; 30) and changes in gait parameters from the baseline were calculated using Pearson method.

Results

Walking periods could be detected with a specificity and sensitivity of more than 97%. For each walking trial, gait parameters for each gait cycle were calculated. We could find a significant ($P <$ 0.0001) correlation between the UPDRS sub-score and RS ($r = -0.68$), SL ($r = -0.68$), SP ($r = -0.65$), PS ($r = -0.65$), SW ($r = -0.65$) and DS ($r = +0.65$). GCT however, had no significant correlation to the clinical score.

Discussion

Gait in PD has already been assessed in gait labs with standard methods (like using force-plate or camera). Also in our own previous studies, good correlation between clinical scores and gait parameters has been reported but in our knowledge so far there has been no available method to analyze gait in PD, follow the fluctuations and have a correlation to the clinical scores while subjects were performing activities on will for several hours.

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Botulinum Toxine

P2.37: Botulinum toxin with and without casting in the treatment of equinus in cp: a comparative study

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Summary

Although limited data are available on the effect of a combination of botulinum toxin type A (BTX-A) injections and casting in ambulant children with CP, this combined treatment is often applied in clinical practice. This present study compares the effect of intramuscular BTX-A on objective gait parameters in two groups of CP patients with spastic equinus. The first group (12 patients) was treated with BTX-A alone and the second group (nine patients) received casting for 2 weeks immediately after injection. We observed that, for both groups, all sagital plane ankle parameters improved significantly 6 weeks and 3 months after treatment. The group BTX-A and casting demonstrated a more pronounced gain in dorsiflexion in both mid stance and mid swing. This better result had also a more beneficial effect on walking mechanics with a reduction of the external work performed to move the body centre of mass.

Conclusions

The present study supports that the combined treatment of BTX-A and casting are more beneficial than the BTX-A alone in the improvement of the ankle position during the gait cycle and are more effective on the gait mechanism in CP patients with dynamic foot equinus deformity.

Introduction

The effectiveness of BTX-A in the management of the dynamic spastic equinus in cerebral palsy has been verified by previous studies. Serial inhibitive casting has a beneficial effect for non surgical treatment of calf tightness. In many cases of spastic equinus in cerebral palsy, both dynamic muscle shortening and early contractures contribute to foot deformity, especially when the child is older. That's why the combination of BTX-A and serial casting is very often used in clinical practice, but only a few studies have demonstrated convincingly that this combined treatment is more effective that the BTX-A alone. The aim of our present study was to compare the clinical and the functional effect of the treatment with BTX-A with and without casting on objective gait parameters in ambulant CP with a spastic dynamic equinus.

Patients/materials and methods

Twenty-one patients were recruited for this study. All of them were ambulant children diagnosed with CP and muscle spasticity associated with dynamic equinus. The patients were divided into two groups: group 1, 12 patients mean age of 5 years treated with BTX-A only and group 2, 9 patients mean age of 7 years 2 months treated with BTX-A and casting. The identification of the injected muscles was based on objective measurements of the pathological gait and clinical evaluation. The dose per muscle varied between 2 and 5 U Botox®/kg muscles. Immediately, after injection a cast was applied over a period of 2 weeks for the group 2. A clinical examination and a three-dimensional gait analysis were performed before treatment and subsequently 6 weeks and 3 months after injection. A two way repeated measures ANOVA was performed on nominally recorded data to compare the change across the two groups and the period.

Results

This study focused on the objective gait analysis. For both groups all ankle kinematics parameters improved significantly 6 weeks after injection, the beneficial effect was less pronounced at 3 months. The gain in dorsiflexion was significantly greater in group 2 at mid stance and mid swing. Additionally, the reduction of foot equinus improved the walking mechanism with a significant reduction of the external work. This reduction was greater in the group 2 up to 40% compared to the group 1.

Discussion

In many cases of spastic equinus, there is a coexistence of spasticity and muscle stiffness. BTX-A acts on the dynamic component whereas casting acts mainly on muscle contracture. There are a few studies [1,2] which have demonstrated the usefulness of a combined treatment BTX-A and casting. Our data are comparable to these studies which have confirmed the additional benefits of this combined treatment on the sagital plane ankle kinematics. However, we also found that the more appropriate lengthening of the calf muscle led to a significant reduction of the external work and consecutively a greater improvement in the locomotor mechanism.

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P2.38: The use of botulinum toxin on rectus femoris and semitendinosus in CP child: a preliminary report

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Summary

We report the results of using botulinum toxin on agonist and antagonist muscles as rectus femoris and semitendinosus. Improvement of both kinematics and kinetics data is better than the only slight lengthening obtained with toxin and previously reported [6]. We report three cases to sustain the subject.

Conclusion

As previously suggested [6,8], we advocate a functional approach of the treatment of spasticity. We think that a better outcome will be obtained by a treatment of spasticity simultaneously on agonist and antagonist muscles. In our opinion, both rectus femoris and hamstrings are involved in gait worsening in CP.

Further investigations are needed to support this hypothesis. A study involving a larger population is conducted at the present time.

Introduction

The biarticular muscles of the lower limbs work as activable slings and reduce the overall energy consumption during gait. The co-ordinated linked movement of the rectus femoris and hamstrings requires a high level of motor control. Filipetti et al. [1] had shown gait improvement after selective partial neurotomy to decrease spasticity of rectus femoris and semitendinosus muscles. The aims of this study were, (1) to assess the interest of treating spasticity simultaneously on both muscles and (2) better understanding of the involvement of these two muscles in gait worsening in cerebral palsy (CP).

Materials and methods

Three CP children (9–16 years old) with spastic diplegia and free from any other treatment during the last 6 months, were studied. A total dose of 10 U/kg (BOTOX® Allergan™) [2] of botulinum toxin was used for each patient in a multi-site injection on the two muscle, on both sides. Usual treatment and rehabilitation of the patients were not changed during the study.

Passive range of motion, muscle spasticity (Aschworth modified scale, Duncan-Ely-test), popliteal angle and functional evaluation were assessed before the toxin injection and 1 month later. Gait analysis was performed before treatment and 1 month later; five trials were collected on both sides, and then a mean pattern was computed for each situation.

A biomechanical model previously developed [3], based on the homogeneous matrix concept developed by Legnani [5], was used. This model calculates the three-dimensional kinematics and 3D net moments of each joint from simultaneous measurements of cutaneous marker displacements (Motion Analysis system) and external mechanical actions (AMTI force platform). Additional data as electrical activity of surface muscles collected by an EMG device were recorded on.

Anthropometric parameters are used in Zatsiorsky's regression equations to define mass and inertial characteristics of each body segment [4].

Results

After treatment, all patients had a functional improvement during the day life. None passive range of motion improved except hip extension and popliteal angle from 10° to 15°. Spasticity was improved in all patients according to 1 or more point in the used scales.

Time-distance parameters, as well as repeatability of the data were improved in all cases after treatment. Power generation was improved. Ground contact actions go toward normalization in both anteroposterior and vertical components. Kinematics and kinetics data in sagittal plane showed improvement (Fig. 1) in hip extension, hip extension moment, knee extension, absorption moment of the rectus femoris and knee extension at heel strike. No worsening was noted in hip flexion and knee flexion.

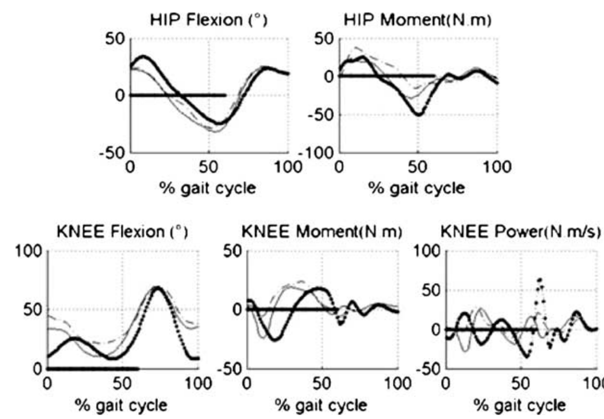

Fig. 1. Kinematics and kinetics in the sagittal plane. (Dashed line: before injection; thick light grey line: after injection.)

Discussion

Effectiveness of botulinum toxin in CP children is now well recognized. Its use on rectus femoris and simultaneously on semitendinosus has not been so far reported. Efficiency of botulinum toxin on rectus femoris and semitendinosus is confirmed by functional improvement. As previously observed, botulinum toxin improves popliteal angle from 10° to 15° and knee extension without any rehabilitation [6,7]. Objective improvement on hip and knee function is shown in gait analysis. Pelvic anterior tilt increases when pelvis was previously on retroversion. Hip extension during stance phase increase without decreasing hip flexion during oscillation. Knee extension increases both in stance phase and at heel strike. Kinematics and kinetics data show better improvement in using botulinum toxin on both muscles than only hamstrings [6,7].

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P2.39: Assessment of outcome of botox® intervention in upper limb neurology: a pilot study of upper limb EMG and kinematics alongside lower limb analysis

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Summary

Classic functional problems of the upper limb in the neurologically impaired patient are well documented and the effect of upper limb spasticity on the gait pattern has been hypothesised historically by Bobath physiotherapists. However, it is only recently that attempts have been made to formally describe the 3D behaviour of the upper limb during gait. This paper demonstrates the potential of movement analysis in assessing the impact of upper limb intervention (Botox®) on the upper limb kinematics, upper limb EMG and in addition on lower limb 3D gait kinematics and kinetics.

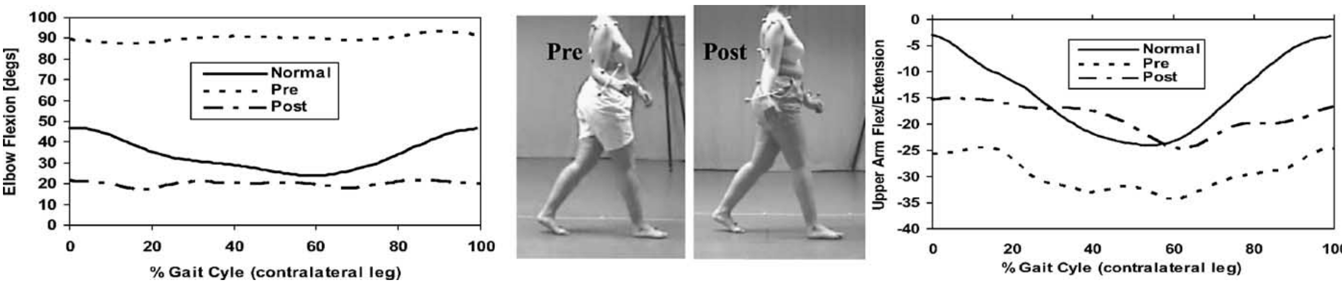

Fig. 1.

Conclusions

Movement analysis can provide quantitative evidence with respect to the upper limb as well as the lower limb. The successful influence of botulinum toxin intervention on the pathological upper limb gait pattern has an impact on lower limb gait kinematics. This work demonstrates the potential for the application of movement analysis techniques to provide whole body quantitative outcome measures and guidance in the holistic treatment of adult and paediatric (neurology) patients.

Introduction

Botulinum toxin is increasingly used to mediate the effects of spasticity in the treatment of neurological impairment such as head injury, stroke and cerebral palsy. Precise quantitative evidence of its effects on an integrated upper and lower limb are sparse and often reported in the form of subjective scales of measurement and patient perception.

Patients/materials and methods

A 25-year-old female who sustained a head injury at the age of 4 years is used to illustrate the application of upper and lower limb gait assessment as an outcome measure and the potential link between upper and lower limb kinematics. The patient walked unaided but had severe right upper limb spasticity and associated reactions observed during gait and activities of daily living. A lower limb 3D gait assessment (VICON Plug in Gait Lower Limb Model) together with right upper limb kinematics [1] and electromyography of seven upper limb muscles bilaterally was performed pre-injection and 6 weeks post targeted injection of Botox®.

Results

Marked changes were seen in elbow flexion and shoulder extension (Fig. 1). Reduced (left) side-flexion, external rotation of the trunk, abduction, external rotation of the upper arm and reduced supination of the forearm were also observed. Modified hip and knee flexion in loading and mid stance were seen on the (upper limb) affected side together with reduced pelvic obliquity and hip abduction. The slightly increased pelvic rotation was maintained. The activity of (treated side) infraspinatus and posterior deltoid increased, whilst that of the anterior and middle deltoid decreased. On the unaffected side, increased activity in anterior deltoid and infraspinatus was observed.

Discussion

Successful intervention in the right upper limb has resulted in changes in upper and lower limb kinematics and in changes in muscle activity on the contra-lateral arm. These results add support to the use of movement analysis techniques to assess outcome in both upper and lower limb kinematics and indicate the potentially complex interaction between upper and lower limb kinematics of gait.

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P2.40: Can BTX-A treatment improve the walking pattern of elder children in CP?

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Summary

The aim of the present study was to evaluate the effect of a multi-level botulinum toxin A (BTX-A) treatment on objective gait parameters for elder children with CP (9–16 years of age), and to estimate the impact of previous BTX-A treatments at younger ages.

Conclusions

Integrated multilevel treatment with BTX-A for the elder child with CP results in improved walking performance 2 months after treatment. Similar as for younger children, children from 9 to 16 years of age, improve significantly at the level of the ankle joint. Typically for elder children are significantly improved knee kinematics and pelvic stability in sagittal plane. Previous BTX-A treatments (before age 9) assure a better outcome of BTX-A treatments at a later age.

Introduction

BTX-A has gained widespread acceptance for the management of some neuropediatric disorders for young children with CP. The effect BTX-A on the gait pattern for elder children with CP is still unknown.

Patients/material and methods

Thirty three children with cerebral palsy (18 with diplegia, 15 with hemiplegia) were selected from a group of 309 children (who were older than 8 years when they were treated with BTX-A between 1997 and 2003). The inclusion criteria were: (1) ambulant, without walking aids, (2) predominantly spastic-type of CP and (3) a full barefoot walking gait analysis before and after BTX-A treatment. The children were studied at baseline and at 2 months after treatment, using objective gait analysis, including 3D kinematics and kinetics (6 camera VICON system® and two AMTI force plates), combined with bilateral surface EMG of seven lower extremity muscles and an extended standardised clinical examination. As part of the integrated approach [3] the treatment was always combined with lower leg casting, appropriate physiotherapy and orthotic management. Data analysis included comparison of 88 gait parameters by using a paired *t*-test or a wilcoxon signed rank test. The proportional gain [1], defined as the observed change in outcome divided by the maximum (or targeted) possible change in outcome, was calculated with standardized *z*-scores (using mean and S.D. of normal children).The results of the elder children were compared with the results of young children, evaluated in a similar way [2]. To evaluate the influence of previous BTX-A treatments, two matched subgroups of eight children were selected from the total group. The first group of children received their first BTX-A treatment after 8 years of age. The second group had a history of previous BTX-A treatments before age 9.

Results and discussion

Similar as for the young children, most significant changes were seen at the ankle joint, with an improved ankle position at initial contact, during second rocker and during swing ($P < 0.0001$), with a proportional gain ranging from 40% to 53%. Knee flexion at initial contact decreased ($P < 0.001$), knee extension in stance increased ($P < 0.05$, proportional gain of 25%) and knee flexion velocity in swing increased ($P < 0.001$), after BTX-A treatment, compared to baseline conditions. Hip extension at terminal stance increased slightly (NS), and pelvic stability improved, mainly in the sagital plane ($P < 0.05$). Furthermore, we found an improved phasic activity for gastrocnemius and tibialis anterior ($P < 0.001$). Lateral hamstrings and rectus femoris showed reduced cocontraction patterns post BTX-A, compared to baseline condition.

Elder children more easily improve knee extension at initial contact, compared to young children. Similar as four young children, elder children have difficulties to correct for increased pelvic anterior tilt post BTX-A. Children who received their first BTX-A treatment after age 8 have more difficulties to correct rotational gait deviations and increased pelvic anterior tilt and instability, after BTX-A, compared to children who already received one or more BTX-A treatments prior to age 9. These results may indicate that BTX-A treatment is more effective in elder children with CP, when severe secondary problems are absent due to previous BTX-A treatments.

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Upper Limb

P2.41: Evaluation of an extramural training device for rehabilitation of the upper extremities using 3D movement analysis

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Summary

The number of people requiring rehabilitation and postoperative care is increasing. To maintain the best possible therapy-outcome without extending the demand on physiotherapists and doctors, it is necessary to let the patients perform extramural rehabilitation exercises at home or in the working environment. An assistant feedback system can ensure the accuracy of the movement performed and can be adapted to the individual needs of the patient to increase the success of therapy. In this study, the efficiency of the training device was evaluated by comparing the movements of the upper extremities with and without its guidance.

Conclusion

Using 3D movement analysis the training device was evaluated and it could be shown, that the reproducibility of the exercises is increased when the extramural rehabilitation is performed with feedback provided by the training device.

Introduction

After orthopaedic intervention, rehabilitation and postoperative care improve the chance of the patient continuing to live independently and quickly returning to work. The performance of the exercises in physiotherapy is strongly correlated with the recovery process of the patient. Furthermore the success of rehabilitation can be increased by adapting the training to individual deficits or needs. Optimally, exercises should be done several times a day over a longer period of time. That implies, that these exercises have to be done at home. Extramural training implies fewer ambulant patient consultations and thus less guidance by physiotherapists. This was the motivation to develop an intelligent user-tailored training facility for patients in their home and work environment. In this study the function of the training facility has been evaluated by 3D upper extremity movement analysis [1,2].

Patients and methods

The evaluation procedure is based on video-based 3-dimensional movement analysis of the upper extremities. Infra-red light reflecting markers are attached directly to the skin on specific body segments. The calculation of joint-angles is based on the rigid body model introduced by Schmidt in 1999. This model utilises rigid segments for the head, trunk, upper arm, forearm, and hand connected by ideal ball socket joints. From this model, movement in all anatomical joint axes of the upper extremities can be determined. Based on this approach a collective of healthy patients has been investigated while performing exercises common in upper extremity rehabilitation with and without the training device. The reproducibility of the movement performed with respect to the manner of performance, range of motion, velocity and amount of force has been compared.

Results and discussion

Preliminary results show that there is a clear increase in the reproducibility of the movement performed when using the training device. Securing a high degree of reproducibility is an indispensable prerequisite for implementation of advanced extramural training. Additionally, a more personalised training becomes possible when the training device gives the patient detailed guidance or feedback.

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P2.42: Impaired coupling of the reach and grasp components of a two handed catch in children with developmental coordination disorder

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Summary

The transport and grasp phase of a two-handed catch and the coordination of such was examined in children aged 7–10 years both with and without a Developmental Coordination Disorder (DCD). Fifteen two-handed catches of a ball released on a pendulum were performed by all participants. Kinematic analysis was undertaken of various temporal landmarks of the reach and grasp phase of both hands for the catch and the coupling between the two components investigated.

Conclusions

DCD children show impaired and highly variable coupling of the reaching and grasping components of a catch, this in turn affect the success in such a motor skill.

Introduction

It has been previously recognised that DCD children exhibit considerable difficulty during isolated reaching and grasping movements using an interception task [1]. For a successful catch the reaching and grasping subactions have to be finely integrated into a successful, efficient overall action. The coupling of the two-subactions has not been investigated before in this group of motor impaired individuals and it is hoped that an investigation of such could shed light upon some of the difficulties these children have and what the underlying causes may be.

Patients/materials and methods

The sample consisted of 20 children aged 7–10 years of age ($M = 9.23$, S.D. = 9.3), 10 whom met the clinical criteria for DCD taken from the DSM-IV (1994) and 10 who did not (AMC). To confirm group membership the Movement ABC was used [2]. All participants attempted 15 two-handed catches of a ball presented to them as a pendulum. A 3D Kinematrix system was used for collection and subsequent analysis of all kinematic data.

Results

In the DCD children the transport phase of the catch was initiated later ($P \leq 0.00$) and the peak deceleration of such was reached later then the AMCs ($P \leq 0.00$). The grasp phase was initiated earlier ($P \leq 0.00$) and maximal grasp aperture was larger ($P \leq 0.00$). The time MGA occurred was more variable in children with DCD ($P \leq 0.00$) and was reached approximately 150ms prior to peak deceleration. The AMC's produced highly invariant MGA relative to peak deceleration and MGA was reached within 20 ms of peak deceleration.

Discussion

DCD children showed abnormalities in reach and grasp movements and in the coupling of these two sub-actions. Indeed the DCD children show impaired and variable timing when the MGA is analysed is examined in relation with peak deceleration. The data suggests that the DCD children may use a 'decomposition' strategy [3] in an attempt to simplify the movement control of the transport and grasp phases of a catch. In contrast the AMC children show a uniform opening and closing sequence with a single peak that is well synchronised with the deceleration in hand transport suggesting a reproducibly coupled synergy defined by a central coordinative organisation.

References

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P2.43: Three-dimensional dynamic kinematic analysis of the shoulder with ultrasound based motion analyzer

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Summary

Many disorders of the shoulder complex are accompanied by changes in the pattern of scapular movement, which is difficult to measure radiologically. In order to study the three-dimensional motion of the scapula secondary to arm movements, a measuring method has been developed using an ultrasound-based motion analyzer. The accuracy of the method is comparable to that of shoulder mapping. Measurements of scapular plane rotations during elevation showed particularly good agreement with each other and with the data published.

Conclusion

The authors have demonstrated a feasible method for the measurement of scapular movement, which is believed to be suitable for use in a clinical setting. Accuracy studies suggest that the method is reliable; comparison of the results of the two methods with each other and with published data [1,2] indicates a good agreement.

Introduction

Shoulder disorders change the pattern of scapular motion. Several methods have been developed earlier to study the 3D motion of the scapula secondary to arm movements [1,2]. As different shoulder disorders may lead to different shoulder rhythm, exact dynamic kinematic analysis could be a useful tool in the diagnosis of shoulder disorders or in the follow-up of the rehabilitation process. The aim of our study was to develop a feasible technique for detecting the scapular motion dynamically during different arm movements.

Materials and methods

Orientation and dynamic movements of shoulder bones were determined in 15 healthy subjects. (27.6 ± 2.12 years, 164.1 ± 33.3 cm, 61.1 ± 4.5 kg). Our approach is based on a mechanical axiom, which states that the position and orientation of a segment of the human body is determined by an array of three points per segment. The triplets, which represent three points of a body segment were over the sternum (representing the trunk), the clavicle, the acromion (representing the scapula), the upper arm and the forearm. Sixteen anatomical points were investigated in kinematical analysis. Before measurement, the position of investigated anatomical points in relation to the fundamental points has to be given by an ultrasound-based pointer. The position of fundamental points of each segment of the human body has to be measured during motion by the Zebris ultrasound-based device. A computer code calculates the position of anatomical points from the above data on-line. From the spatial coordinates of anatomical points the spatial angle between the different segments and the rotation of the scapula are calculated. Elementary and complex motions were performed to test the scapular rhythm. The accuracy of the method was tested by the mapping program of the Zebris system, whereas during different humerus positions the exact coordinates of bony landmarks were repeatedly defined.

Results

Based on the spatial coordinates of the anatomical points investigated, complete dynamic kinematic descriptions with anatomical joint angles are estimated. No significant statistical difference was observed between the values presented and those found in literature [1,2]. On the basis of the results we could support that the elevation proved to be the most reliable movement type to compare scapulo-thoracal motions to arm movements. The accuracy of the method were found to be in concordance with the literature.

Discussion

On the basis of the results of both measurements, we can establish that the 2:1 ratio of the arm motion and the scapulo-thoracal movements can be detected by either methods. The intra and inter observer studies show a good agreement. The advantages of our method are that the 16-point model is able to determine the scapula rotation and the spatial angle between the segments and that the movement analysis can be achieved during several cycles, providing additional information. A limitation of the method is that the arm elevation may reach only approximately 120°. Over approximately 120° of elevation or abduction, skin movement displaces the sensor thus the measurement cannot be continued.

References

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P2.44: The effect of arm swing on spatio-temporal parameters in normal walking

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Introduction

Arm swing in human walking is an active natural motion, which involves the entire upper extremities and the shoulder girdle. Several researches described the inter-relationship between arms and legs during walking, in terms of kinematics and kinetics; however the effect of arm swing on the dynamic parameters in normal gait, is unclear.

The objective of this research was to investigate the effect of arm swing on spatio-temporal parameters in healthy walkers.

Materials and methods

Fifteen healthy male volunteers (age 20–30 years, height 158–192 cm, weight 50–80 kg) walked for 10 min on a treadmill at four velocities: customary walking speed (cws = 100%), slow walking speed (sws = 80% of cws), fast walking speed (fws = 120%) and very fast walking speed (vfws = 140%). At each velocity, they walked once with normal arm swing and once with restricted arms. The order of trials was randomly chosen. Cadence and stride length measurements were taken at the last 3 min of each walking mode.

Results

At all four velocities, walking with restricted arms caused a significant reduction in stride length (*pair t-test*, $P < 0.000$–0.003) and an increase of the cadence ($P < 0.000$–0.002) compared to walking with the arms swinging. The consistency of the results within subjects and between velocities was highly correlated ($r = 0.759$–0.983) and statistically highly significant ($P < 0.000$). Repeated measurements revealed significant interaction between arms mode and walking velocity ($P < 0.000$)

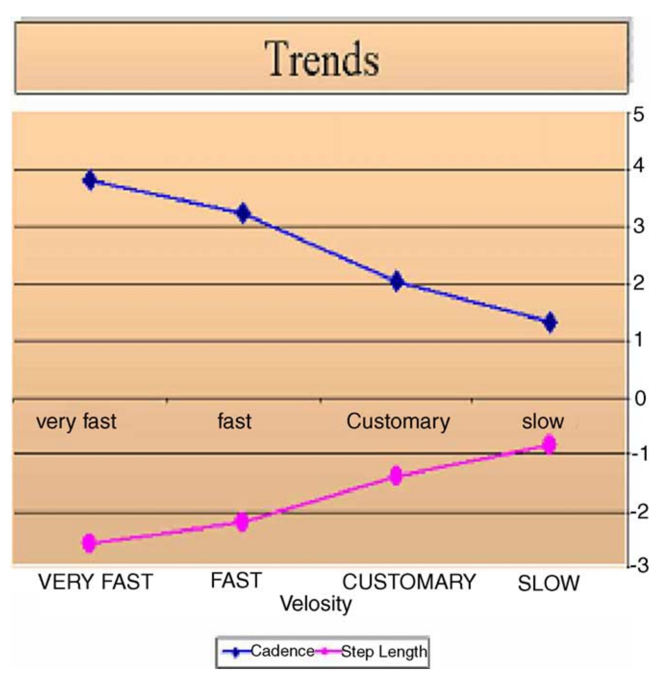

Fig. 1. Mean of the differences in step length and cadence between walking with restricted and free arms, at four velocities.

Discussion

Arm swing in normal walking reduces cadence and increases stride length, hence, contributes to gait efficiency. The results of this study are extremely relevant to gait efficiency of patients suffering from upper extremities dysfunction such as hemiplegics, amputees and Parkinson disease.

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P2.45: Upper extremity — optical marker based joint center calculation and elbow flexion angle determination

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Summary

Synchronous marker based optical and clinical goniometric measurements on five normal subjects were performed in a variety of different upper limp postures and movements. Next to joint center determination of wrist, elbow and shoulder the study focussed on accurate elbow flexion angle determination near the full extension.

Conclusions

With a new modeling approach a better agreement between marker based optical and clinical goniometric measurements could be obtained. In the problematic region around full elbow extension the model leads to valid elbow flexion angles and is feasible for clinical application.

Introduction

Several models describing elbow motion based on optical 3D reconstruction of skin mounted markers have been reported. Typically markers are placed on the olecranon [3,4] and/or the lateral and/or medial epicondyles of the elbow [1,2,4] with little consideration of the skin movement. However, accurate and precise determination of the elbow joint center and flexion angles especially at or close to full extension is still a challenge. Clinically this angular region is important since it appears in daily life movements as reaching-out for an object. Also in gait the upper extremities are often close to full elbow extension. Furthermore precise elbow joint center calculation is needed for the calculation of dynamics.

Patients/materials and methods

Synchronous optical and clinical goniometric measurements of static positions at six different elbow flexion angles within the full ROM of the elbow have been performed. For the optical measurement a 9-camera-Vicon 612-system was used. Fourteen millimeter diameter marker were applied following [3] with addition of a twin marker at the olecranon where one marker is located directly at the skin surface and the other mounted on top by a wand 2.5 cm apart. The wrist joint center and the glenohumeral joint center were defined as described in [3]. The elbow joint center and axis are defined by the following steps: (1) skin movement of the olecranon twin marker is compensated by calculating the position of a virtual marker with a fixed distance to the wrist joint center based on the distance of a static trial at 45° flexion. (2) The position of the elbow joint center then is optimized with the constraint of a constant distance between elbow and glenohumeral joint center. (3) Finally, the elbow joint axis is defined as cross product of the two vectors from the corrected olecranon wand marker to the wrist joint center and to the glenohumeral joint center. Synchronous clinical and optical data were assessed for five different subjects (age 27.6 ± 16.1, three male, two female) by the same tester. Intra-tester and inter-tester reproducibility of the model was tested by five repeated sets of measurements each.

Results

The model data show a good agreement with the clinical goniometric measurements in static as well as in dynamic situations. Inter-subject reliability was tested by adjusting the subject's posture to predefined postures at five different flexion angles as shown in Table 1. Reproducibility (intra-tester) and objectivity (inter-tester) both show also a good agreement with the clinical measurement with a maximum deviation of 4° in the whole ROM relative to the clinical measurement.

Table 1. Inter-subject reliability tested for 5 different subjects. Mean and STD values are given

Clinical	0	30	60	90	120
Optical	0.4 ± 1.6	32.2 ± 7.3	57 ± 3.9	88.4 ± 4.0	121 ± 11.2

Discussion

The use of a twin marker at the olecranon allows a robust definition of the elbow flexion axis close to full extension or even at full extension where solely skin mounted marker sets fail since the positions of the wrist joint center, the glenohumeral joint center and the elbow skin marker are collinear. The inter-subject reliability is reasonable in the ROM which was assessed. However an exceeding precision is noticeable at 0° and 90°. Since there is no particular sensitivity of the model at these angular positions it leads to the conclusion that rather the clinical goniometric measurement is facilitated at intuitive angles such as 0° or 90°. Furthermore it can be argued that the differences between the two methods for angular determination are mainly due to insufficiencies in the clinical determination but it is still the most commonly accepted method.

References

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Saturday 25th September Keynote lecture 2: 8:30 to 9:10

History of cerebral palsy

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Carolus Linnaeus (1707–1778) first described a cerebral palsy child in a beautiful poem after his visit in Greenland. It was presented as an unknown disorder of a handicapped boy with a sever functional impairment but with normal intelligence.

The first scientific description of cerebral palsy was made by William John Little (1810–1894), an English orthopedic surgeon, who suffered on hemiplegic form of spastic paresis himself. After successful surgical treatment of his left foot deformity he decided to devoted his professional work for the children with any kind of brain injury associated with difficult birth. His hypothesis that dynamic or static orthopedic deformities were the consequence of prenatal or neonatal brain injury appeared as a revolution among the older opinions about the primary causes of this "paralytic syndrome". W.J. Little thought the pathologic condition was the result of a lack of oxygen during labor because many of the children were born after premature or complicated deliveries. Thanks to his work for many years the syndrome was known as a Little, a disease.

In 1897 the psychiatrist Sigmund Freud (1856–1939) established the classification system of cerebral palsy and recognized the spastic diplegia and its close association between all types of cerebral palsy.

The term "Cerebral Palsy" was introduced in 1888 by Sir William Osler and popularized consequently. He divided the etiologies of the disorder on seven categories: congenital syphilis, alcohol-related, difficult labor, forceps delivery, postnatal head trauma, infant's infection desease, convulsions and embolism.

The most important epidemiological trends observations were done by B. Hagberg from Sweden. His observations were performed over the period of 30 years.

The fundamental basis for the treatment of children with cerebral palsy is the neuro-developmental approach. The level of child's function plays the main role in the programming process of the establishing the optimal rehabilitation — treatment program. The founders of such kind of therapy were: K.B. Bobath, V. Vojta and Th. Hellbrugge.

The operative approach to muscle dysfunction has been in two large fields: surgery of nervous system, and surgery of the extremities. To the first one belonged all the techniques witch included the pharmacological treatment options or neurosurgical treatment. The surgical, orthopaedic treatment on the non-central nervous system devised to improve the functional status or general comfort of child's life. Regarding to Eggers and Evans the development of the surgical procedures may be classified into four periods: (1) the period of elimination–elimination or alterationof muscle function by means of neurectomy; (2) the period of alteration–balance the motor function by shifting extensors to flexor position or vice versa; (3) the period of negation–conversion of two joints muscle to one joint muscle; and (4) the negative–positive period which combined the orthopedic efforts of all mentioned above programs.

Currently the treatment philosophy is based on the results of functional evaluation of the child locomotion. In my opinion it is the fifth functional/biomechanical period of the therapeutic approach. The elementary rules of this biomechanical treatment philosophy of cerebral palsy child are based on lever arm deformities caused by powers and movements generated by muscles and joints' positions.

Session 7 (oral): 9:10 to 10:22

Gait

S7.1: Functional status of children after CNS malignant tumors treatment

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Summary

Gait and balance study was done in patients after malignant CNS tumors treatment. The functional deficits exhibit by patients were not dependent on the tumor localization or age of illness onset. The time between end of the treatment and time of the study was much longer in children with mild or no functional deficits. Gait deficits were more severe in children with balance problems.

Conclusions

In patients with CNS tumors the functional deficits are similar regardless of the cancer localization. The repairing mechanisms could overcome the problems caused by oncology treatment: indication for early rehabilitation.

Introduction

Treatment of central nervous malignant tumors comprises of neurosurgery, chemotherapy and radiotherapy. All three procedures could cause the functional impairments of the patients, but little is known about their nature. In one study the balance problems were found in leukemia patients [1]. Rapid progress in oncology increases the survivor rate, thus the long-term consequences of the oncological treatment becomes more and more important. The aim of the present study was the assessment of the gait and balance of children after treatment of central nervous system (CNS) tumors.

Patients/materials and methods

In the study participated 41 patients, 17 girls and 24 boys, aged 6–17 years old, treated in Department of Oncology due to CNS neoplasms. There were six subgroups of patients: 18 medulloblastoma patients with tumors of posterior fossa; 9 treated for midline tumors; 6 treated for left and 2 for right side brain tumors; 3 patients treated for brain stem tumors and 3 for spinal cord tumors. All children completed their treatment: neurosurgery, chemotherapy and radiotherapy.

Gait analysis was performed using six camera VICON 460 system. Ground reaction forces (Kistler) and EMG (Motion Lab System) were recorded simultaneously. Children walked several times on 6 m walkway. Data were processed using Polygon software. The spatio-temporal (speed, cadence, etc.) and sixteen kinematic parameters [2] were further analysed. For speed, and step length the normalization proposed by Hof [3] was used. Step width was normalized by asis-asis distance.

Balance tests were performed on Kistler force plates. From stabilograms (center of pressure (COP) trajectory) following parameters were calculated (by own Matlab procedure): medio-lateral and antero-posterior displacements, mean radius of gyration and total path [4] during 30 s quiet standing, in two conditions: eyes open, and eyes-closed.

Results

In 20 patients the results of the balance tests did not differ from the healthy subjects. In 21 other patients the results showed balance impairments. In all cases the total path was significantly increased. Apart from four cases the results from eyes-opened and eyes-closed test were the similar. In one case the patient was unable to complete the eyes-closed test. In few cases the increased medio-lateral and/or antero-posterior displacements were found. In three cases the mean radius was also increased. In all subgroups there were patients with good and bad balance test results, approximately in equal proportions.

The was no difference of the age of illness onset between the groups. The mean time between the ending of the treatment and the time of the study was 5.8 years in good balance group, and 3.7 years in bad balance group ($P = 0.023$).

Patients were divided into two groups: with good balance and with balance deficits. The gait parameters were assessed in these two groups. Although no statistical significant difference was confirmed using statistical test some tendencies could be noticed. Children with poor balance walked with slightly higher speed, due to increased cadence. Their step width was increased, as well as the stance phase. They walked with increased external rotation in hip joints and the knee flexion at initial contact was slightly increased (here the statistical significance was found: $P = 0.043$).

Discussion

Balance problems were found in half of the evaluated patients' group. In most patients with balance deficits they were present in both eyes-opened and eyes-closed conditions. Thus the visual feedback did not in most cases compensate the balance deficits. In three quarters of children with balance children the only increased parameter was the total sway path, with other parameters within normal range. This finding suggests that the sense of the body orientation and position is intact (the excursions of the COP were normal) but keeping normal range of radius of gyration requires constant corrections from CNS.

Patients with balance deficits exhibit also gait pattern changes. The increased external rotation in the hip joints together with increased step width increases base of support, making dynamic balance during gait easier. The increased knee flexion at initial contact could help patients with deficits to maintain balance in case of uneven ground. Balance and gait deficits could be found in patients with CNS tumors, regardless of their localization.

It is supposed that the younger children are more vulnerable to the cancer treatment, due to treatment acting on still developing brain. Our results suggest that after finishing the treatment the repairing mechanisms could overcome the deficits.

Acknowledgement

Study was supported by research grant C028/P05/2002 by Ministry of Health and Polish Committee for Scientific Research.

References

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S7.2: Basic gait parameters of healthy and CP children assessed by accelerometry

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Summary

Spatio-temporal walking parameters (number of steps, walking distance, displacement of the COM) were accurately detected by a miniature accelerometry device (DynaPort MiniMod) for healthy and CP children in non-laboratory settings.

Conclusions

The device allows an exact assessment of basic gait parameters under free living conditions. Further research will be performed to enhance the outcome of the device. The final goal is to provide a tool for the assessment of daily activities, which will include gait parameters and the detection of posture.

Introduction

The objective analysis of normal human gait, gait pathologies and their treatment is the focus of interest of movement scientists and clinicians. With modern technology, it is possible to assess and analyze human activities precisely in laboratory settings. However, there is an increasing demand to acquire information about physical activities of subjects under free-living conditions. Spatio-temporal gait parameters can be assessed based on a three-dimensional accelerometer attached to the lower trunk [1]. Until quite recently the measurement systems that are needed for obtaining these acceleration signals were rather bulky and heavy. Recently, the DynaPort MiniMod (McRoberts B.V., The Netherlands) was developed. This miniature device includes three orthogonally mounted accelerometers and it can be used for monitoring human posture and gait parameters. In order to become a useful tool for the assessment of daily activities and gait parameters of children, the system ought to be able to discriminate single steps and to determine the walking distance from the acceleration signals.

Patients/materials and methods

Group 1: Twenty healthy children (aged 3–16 years) walked four times 40 m for the detection of steps in an indoor environment, with no obstacles nearby, at the University Hospital of Muenster. An additional distance, blinded for the analyzer of the data, was walked for detection of walking distance.

Group 2: Twenty CP children (aged 5–17 years) from the out-patient clinic of the Orthopedic Department walked twice a distance of 20 m for the detection of steps on a floor in the hospital. Like in group 1, an additional distance was walked for detection of walking distance. The degree of limitations caused by CP was assessed using a self-made classification scale.

Both groups were videotaped for counting steps and distance. Accelerometer signals of the lower back were measured by the MiniMod, a small and lightweight device (5.6 cm × 6.1 cm × 1.5 cm, 54 g, 100 Hz) and stored on a SD card. The device was firmly fixed to the lower lumbar spine at the level of the second sacral vertebrae with double-sided adhesive tape to avoid movement artifacts. The data sets were send to McRoberts for analysis [2] and compared to the results taken from the video.

Results

Group 1: On average, the healthy children needed 273.7 steps (Min: 207, Max: 377) on the 160 m tracks for step detection, as counted from the video. The software detected 273.5 steps on average (99.97%, range: 98.5–101.5%) regarding the total number of steps. If each misclassified step is counted as an error, regardless if under- or overestimated, the accuracy is 99.6%. The automatically computed walking distance revealed 100.6% of the actually walked distance. The correlation between the medio-lateral displacement of the COM and the age of the subjects was significant ($r = -0.63$, $P < 0.01$).

Group 2: One track of one child had to be excluded because of a handling error. On average, the CP children needed 79.8 steps (Min: 57, Max: 126) on the 40 m tracks for step detection, as counted from the video. The software detected 78.9 steps on average (98.9%, range: 94.1–101.8%) regarding the total number of steps. If each misclassified step is counted as an error, the accuracy is 98.7%. The computed distance revealed 101% of the actually walked distance. Neither the correlation between the standard deviation of the medio-lateral displacement of the COM (SDCOM) and the age of the CP children ($r = -0.11$, n.s.) nor the correlation between the degree of limitation and the SDCOM ($r = -0.32$, n.s.) reached significance.

Discussion

The DynaPort MiniMod allows for an accurate assessment of important spatio-temporal walking parameters. Due to its small size and the placement on the back, it does not interfere with most activities and it is comfortable to wear. The opportunity to estimate the medio-lateral displacement of the COM with the MiniMod offers a new tool to analyze the variation of gait within non-laboratory environments.

In healthy children, the displacement decreases with age, whereas this trend does not exist in CP children. Provided that our scale truly reflects the degree of CP, there is no association between the degree of CP and the variation of gait represented by the SDCOM. In both groups, the error of the calculated walking distance was negligible.

Further research will be performed to validate the DynaPort MiniMod for other groups (e.g. children with walking impairments, various adult patient populations) and to enhance the outcome of the device in order to monitor daily activities (e.g. the percentage of standing, sitting, walking).

References

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S7.3: Kinematic analysis of normal and low arched feet in 9–10-year-old children using a 3D multi-segment model

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Summary

Three dimensional foot analysis was undertaken on 30 children; 15 normal arched and 15 with low arches. Data was normalised to the gait cycle and processed using a seven segment foot model. Kinematic differences between the two groups were examined throughout the gait cycle.

Conclusions

The intersegmental model facilitated a detailed analysis of the foot throughout the entire gait cycle. Examining values at initial heel strike and maximums and minimums throughout the gait cycle, this study found that the low arched group had a lower mean medial arch angle and reduced forefoot pronation in each case.

Introduction

Standard gait analysis has modeled the foot as a single rigid segment and therefore the dynamic behaviour of its numerous segments are not considered. In the past decade multi-segment models of the foot have emerged presenting data on the special properties and function within the foot [1–4]. The aim of this paper is to examine the kinematic differences of normal arched, and low arched feet of 9- and 10-year-old children using 3D multi-segment motion analysis.

Patients/materials and methods

Thirty subjects were analysed, 15 children with normal arched feet and fifteen with low arches. Data was collected using a Vicon 370 Motion Analysis System with seven digital cameras capturing video data at 50 Hz. Seventeen reflective marker of 10 mm diameter were attached to the lower limb as recommended by [1]. A single static trial was recorded in a normal stance position. Subjects were asked to walk at a self selected pace along a 5 m track in the centre of the capture area. A seven-segment mathematical model was used for the output of data [5]. The graphical output for the kinematic data was averaged over the five trials and normalised to the gait cycle.

Results

Using a repeated measure ANOVA with replication data was analysed for significant differences between trials and between the two groups. Significant differences between trials were only found in the lateral arch ($P = 0.01$) and subtalar rotation ($P = 0.006$) max values. The table below presents a summary of the variables that showed significant differences between groups.

Table 1. Summary of significant differences found between low and normal arched feet

Variable name	% of gait cycle	Normal arch mean (S.D.)	Low arch mean (S.D.)	Significant difference (P-value)
Med arch angle	0% gait cycle	121.3 (±7.14)	132.3 (±6.9)	0.0001
Med arch max	0–100%	128.9 (±7.6)	139.44 (±7.8)	0.001
Med arch min	0–100%	111.7 (±7.8)	122.9 (±7.3)	0.001
Forefoot supination	0% gait cycle	−16.4 (±4.0)	−7.5 (±5.8)	0.0001
Forefoot supination max	0–100%	−14.4 (±3.7)	−5.97 (±6.1)	0.0002
Forefoot supination min	0–100%	−20.17 (±4.0)	−12.9 (±6.2)	0.001

Discussion

Although many models are being developed for foot analysis the means of marking and describing the segment fixed anatomical axes have varied between authors so that comparability of the results is still limited. The patterns in many of the variables in this study were similar to those previously reported but varied in magnitude. A low medial arch angle and decreased forefoot pronation was found in the low arched group. Increased rearfoot valgus frequently associated with low arched feet was not evident in this study.

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S7.4: Lateral body sway during walking in young and older human subjects

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Summary

Lateral sway movements of the thorax during walking were measured in a group of young and older healthy adults. The older adults had significantly greater average sway than the young adults and significantly more variability in lateral sway, step length and step width. Variability in lateral sway during walking appeared to be a more sensitive discriminator of age than lateral sway while standing.

Conclusions

Stride to stride variability in lateral sway of the thorax during walking provides good discrimination between young and older adults, as does variability in step width.

Introduction

Walking is an inherently unstable activity and many falls by older adults occur during walking [1]. Large sway movements of the body during standing are well known to be associated with both ageing [2] and falling [1,3] but there have been relatively few studies of body sway during walking in older adults. The purposes of this study was to measure in both young and older adults the average lateral movement (sway) of the thorax during walking and the stride to stride variability in the sway and compare these with sway during standing.

Materials and methods

The participants included 17 young subjects (six males, mean age (±S.E.M.) 27.3 ± 1.5 years) and 21 healthy older subjects (13 male, 72.7 ± 1.2 years) with no history of recurrent falls or medical conditions affecting their balance. Movements of the lower limbs and trunk during walking were recorded using a CODA MPX30 system (Charnwood Dynamics, UK). The path followed by the thorax in the horizontal plane was compared to the line connecting successive positions of the ankles during stance. Lateral deviations between these two paths were divided into a regular component (average of 30 strides) and a variable component (the difference between the deviation during each stride and the average). Lateral sway was also observed while standing with the eyes open for 1 min. Statistical analysis was performed using ANOVA ($P < 0.05$) and the Pearson correlation (r).

Results

The older adults had significantly more lateral movement during walking in both the regular ($P < 0.05$) and variable ($P < 0.01$) components. Eight of the older adults had values for the variable component that exceeded the 95% confidence limits for the young adults. Only two of the older adults had standing sway values outside the confidence limits for the young adults. The step lengths, width and times were similar for the two groups but there was a significant difference in variability of both step length ($P < 0.05$) and step width ($P < 0.01$). The variable component of lateral sway was associated with variability in step width ($r = 0.81$, $P < 0.01$).

Discussion

The results indicate that the age related increase in lateral sway during walking is due to an increase in both the regular and variable components of sway. However, the variable component is more affected by age in terms of amplitude and consistency. There was a strong correlation between variable lateral sway and variability in step width in the older group. Bauby and colleagues [4] demonstrated that a reduction in visual input had a large impact on variability in step width and suggested that lateral balance is actively controlled via visual-vestibular feedback and is therefore vulnerable to sensor noise. Age-related changes in the visual and vestibular systems have been widely reported and may be partly responsible for the increased variable sway observed in the older adults. In this study measures of variable sway during walking appeared to be more age sensitive than measures of lateral sway during standing. It remains to be seen whether differing patterns of lateral sway during walking are observed in older adults who fall and whether these measures can be used to predict falls.

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S7.5: Quantification of spatio-temporal characteristics of walking trajectories of cerebellar patients

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Summary

We present a new computational method for the identification and quantification of kinetic impairments of cerebellar patients. Our method (Hierarchical Spatio-Temporal Morphable Models, HSTMM) is based on space-time correspondence, and permits an accurate characterization of spatial and temporal deformations of movement trajectories in comparison to normal controls.

Conclusions

Using HSTMMs we are able to quantify coordination and kinetic deficits in cerebellar ataxic gait with a significant correlation to the ICARS [1] kinetic subscore. This shows that kinetic impairments can be detected in walking movements and are not only relevant for goal-directed visually guided movements, like tandem gait.

Introduction

Cerebellar dysfunctions can cause disturbances of gait by causing disequilibrium, and by altering the leg and trunk kinematics and interlimb coordination [2]. Such disturbances are characterized by an instable stumbling walking path, increased step width, and a high variability of gait. Quantifying the type of impairments based on classical gait features show a significant change only in balance-related parameters like reduced step length, increased step width or reduced peak joint angles [3–6]. No significant changes can be found for parameters related to deficits in inter-joint coordination or kinetics (dysmetria, hypometria, hypermetria). Based on this result it was suggested that kinetic impairments might be mostly relevant for visually-guided, goal-oriented movements, but not for walking [4,5]. We show that a accurate quantification of the spatio-temporal characteristics of movement trajectories makes it possible to detect correlates of kinetic impairments in walking.

Methods

To model such spatio-temporal characteristics we applied the method of HSTMMs [7,8]. In order to get a more precise description of the spatio-temporal patterns and its variability, a spatio-temporal correspondence between movement trajectories is established. The spatio-temporal correspondence is described by vectors of temporal and spatial displacements. By linear combination of these spatial and temporal correspondence fields, new trajectories can be modeled.

Results

We tested 14 patients suffering from a degenerative cerebellar disease analyzing 8–12 gait cycles per patient. Since we are interested in identify joint coordination impairments, we examine 16 feature sets consisting of different combinations of joint angles of lower limbs. In a first step we analysed the intra subject variability of joint angle coordination using the algorithm of spatio-temporal correspondence. The spatio-temporal variability of the inter joint coordination show a significant correlation (Spearman rank correlation: $r_s = 0.75$, $P < 0.01$) with the kinetic subscore of the common clinical ataxia scale ICARS [1]. This kinetic subscore quantifies impairments like movement decomposition, action and intention tremor. In a second step we want to identify systematic changes in joint coordination patterns by modeling trajectories through linear combination of prototypes. The prototypes consist of the trajectories of the other patients, using a Leave-one-out-paradigm. The resulting linear weights were mapped onto a score that describes the degree of cerebellar disease using nonlinear regression techniques (Support Vector Regression). These scores were again correlated with the ratings of the ICARS score and its subscores. The results shows significant correlations for different feature sets with the posture respectively with the kinetic subscore. Based on these analysis we can identify joint subsets which describe systematic joint pattern changes correlated with balance respectively kinetic deficits.

Discussion

The analysis of temporal shifts seems to be crucial for quantifying coordination deficits. An analysis of purely spatial displacements (like proposed in [9]) was not sufficient for the quantification of such deficits. The proposed method can be useful also for quantifying other movement disorders, especially when timing and coordination plays an important role.

Acknowledgement

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S7.6: Trunk and pelvis coordination and erector spinae activity during gait: effects of low back pain

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Summary

In normal walking, coordinated patterns of trunk-pelvis rotations and trunk muscle activity are important for the maintenance of dynamic equilibrium and to effectively deal with perturbations during locomotion. Compared to healthy controls, patients with low back pain (LBP) had a reduced ability to adapt trunk and pelvis coordination and erector spinae (ES) muscle activity to changes in walking velocity, and walked slower.

Conclusions

Detailed study of gait coordination and the variability of coordination patterns may help to elucidate the ability of patients to adapt to changes in walking velocity and the consequences of pain. Measures of coordination have a surplus value compared to more conventional measures such as step cycle parameters and mean amplitudes in that they more readily provide insight into the motor functioning of individuals with LBP.

Introduction

Under normal circumstances, walking is a highly flexible and adaptive activity that is continuously altered so as to meet both environmental and internal requirements. In healthy subjects the timing and coupling between trunk and pelvic rotations, as well as ES activity are adjusted to walking velocity in order to effectively deal with perturbations and to preserve an efficient and stable gait pattern [1–3]. It is conceivable that adaptations to LBP affect the coordination between trunk and pelvis and the level of gait efficiency [4]. The relationship between gait and LBP was examined by focusing on invariant and variant properties of coordination patterns, in order to better understand the consequences of LBP for gait and other daily life activities.

Patients/materials and methods

Nineteen patients with non-specific chronic LBP and 14 controls subjects participated. Angular movements of thoracic, lumbar and pelvic segments were recorded in the transverse and frontal plane and ES activity was recorded with surface electrodes during treadmill walking: (i) at a self-selected velocity; (ii) sequentially increased velocities (1.4 to maximally 7.0 km/h), and (iii) randomly changed velocities. Range of motion of the trunk and mean ES activity were calculated. The timing between rotations of the trunk and pelvis (relative Fourier phase) and the coupling strength was determined. Principal component analysis (PCA) was applied in its capacity as a data-driven filter to detect similarities and deviations between LBP and control subjects in trunk coordination and ES EMG activity patterns and to examine the relation between LBP and variability [5,6].

Results

The gait of LBP subjects was characterized by more rigid and less variable kinematic coordination in the transverse plane, and a less tightly and more variable coordination in the frontal plane, accompanied by poorly coordinated activity of the lumbar ES. Rotational amplitudes were not significantly different between LBP and control subjects, whereas stride length differed only at the lowest and highest velocity.

Discussion

The locomotory problems encountered by patients with LBP pain are primarily coordinative in nature. Changes in coordination and muscular control may reflect an attempt to stabilize the spine and prevent the occurrence of unexpected perturbations to which the patient cannot adequately respond. The slow preferred walking velocity can be interpreted as a strategy that LBP patients employ to enhance the control over their movements during walking, allowing them to deal with internal and external perturbations.

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Session 8 (oral): 11:12 to 13:36
Methodology

S8.1: A simple method to calculate 2D induced accelerations

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Summary

A simple algorithm is presented to calculate the induced accelerations of body segments in human walking for the sagittal plane. The method consists of writing the Newton-Euler equations in the form of a 18 × 18 (swing) or 20 × 20 (stance) matrix and inverting this matrix in order to find induced accelerations and ground reaction forces resulting from moments due to muscle action. From the induced accelerations also the power flowing from a muscle to any segment can be calculated.

Conclusion

When a simple 2D model is used, induced accelerations due to muscle moments can be calculated very efficiently.

Introduction

In a number of recent papers the knowledge of the mechanics of human walking has considerably been increased [1–4]. These papers are based on complicated three-dimensional forward dynamics models including many muscles. Some of the methodological innovations are the concept of induced accelerations, the related power flows [2,5], and the subdivision of the ground reaction force into contributions of the separate muscles [4]. A problem is that these forward dynamics models are very complicated and computationally intensive.

Methods

The proposed method is based on a four-segment 2D model of the trunk and one leg of the human body [6]. The essential point of the proposed method is that the equations of motion are written in matrix form:

$$\boldsymbol{A}\boldsymbol{x} = \boldsymbol{c} \tag{1}$$

in which $\boldsymbol{x}$ is a vector of unknowns: intersegmental forces, linear (x- and y-) and angular accelerations and ground reaction forces, if present. Vector $\boldsymbol{c}$ is a vector of known quantities, gravity, centripetal accelerations, and joint moments. This set of equations is solved by inverting matrix $\boldsymbol{A}$:

$$\boldsymbol{x} = \boldsymbol{A}^{-1}\boldsymbol{c} \tag{2}$$

yielding the vector of unknowns $\boldsymbol{x}$. Matrix $\boldsymbol{A}$ is 20×20 in stance and 18×18 in swing, when no ground reaction forces are involved. It contains segment masses and moments of inertia, which are constant, plus distances from joints to centres of mass, which vary in the course of movement and which can be obtained from kinematic measurements (VICON, OPTOTRAK etc.).Power flowing to a segment can be calculated as

$$P = (m_{\text{segment}}\boldsymbol{a}_{\text{induced}}) \cdot \boldsymbol{v}_{\text{CoM}} \tag{3}$$

Results

As an example induced accelerations and power will be shown for gastrocnemius and soleus in walking. The results are qualitatively in agreement with [5]. Inversion of 20×20 matrices turned out to be performed very fast in standard programmes like MatLab and Excel.

Discussion

Although the proposed method comprises only part of the range of possibilities of a complete forward dynamics analysis, it can provide several interesting results of practical value at very little computational cost. An application example is in the interpretation of EMG data: what is the action caused by the activity of some muscle in a certain phase of the gait cycle?

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S8.2: Creating a baseline of dynamic muscle function from Induced acceleration analysis

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Summary

An induced acceleration (IA) model was utilized to establish a baseline of dynamic function for 36 lower extremity muscles during gait.

Conclusions

The dynamic function of lower extremity muscles in the gait of able-bodied subjects can be used as a reference for investigations into muscle dysfunction in patients with pathological gait. Until now, no such set of baseline data existed, significantly limiting the applicability of IA in clinical settings.

Introduction

The dynamic function of the individual muscles of the lower extremity during gait remains poorly understood. Historically, the function of these muscles has been implied by their anatomy, by clinical intuition, and by anecdotal observations of functional alterations that occur in their absence. It is difficult to ascertain the dynamic function of a muscle due to the anatomical, geometric, and mathematical complexity of the musculoskeletal system. In recent years, IA has been used as a tool to help understand this complex problem [1–3]. In this study, IA is used to assess dynamic function of 36 lower extremity muscles.

Materials and methods

This study used gait data previously acquired on able-bodied volunteers. Each subject ($N = 20$) was modeled as a seven segment, three-dimensional linkage system [1]. Each model was configured with subject-specific anthropometric parameters, and joint angles acquired from gait analysis. Foot-floor contact was treated as rigid during foot flat and as a point constraint located at the center of pressure otherwise [2,3]. Muscle architecture followed Delp et al. [4]. Unit muscle forces were applied, one at a time, at each instant of the gait cycle. The resulting joint, segment, and center of mass (COM) accelerations were derived using SD/FAST dynamics software (PTC, Needham, MA, USA).

Results

For each muscle, angular and linear accelerations of each body segment and joint were computed. Initial interest focused on the sagittal plane. Five IA graphs per muscle were produced to summarize the accelerations: hip, knee, and ankle angular accelerations in the sagittal plane, and COM linear accelerations in the vertical (support) and anterior/posterior (propulsion) directions. In each graph, acceleration is plotted versus the percentage of the total gait cycle (Fig. 1). Consistent patterns were found for many of the major muscles.

Discussion

Establishing a baseline of dynamic muscle function is an important step in advancing the clinical utility of IAA. Comparing subject IA data in relation to the IA baseline may further the understanding of pathological gait.

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S8.3: Quantitative computerized tremor analysis with graphic digitizing tablet: method validation

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Summary

This paper presents results of validation of new method of quantitative tremor analysis.

Conclusion

Quantitative tremor analysis with graphic digitizing tablet is precise and reliable measure of tremor frequency and intensity, correlating significantly with the results of other, clinical and physiological and EMG methods of tremor evaluation.

Introduction

Quantitative tremor analysis with graphic digitizing tablet (QTADT) is an easy to perform and low-cost method precisely assessing tremor parameters. Up to date, however, only few and incomplete validation studies are published.

Objective of the study was to compare tremor parameters assessed with quantitative computerized tremor analysis with graphic digitizing tablet against other tremor quantifying techniques in patients with extrapiramidal tremor (Parkinson Disease (PD) or Essential Tremor (ET)) and to demonstrate test-retest method reliability.

Materials and method

Fifty patients with extrapiramidal tremor (PD or ET) were included into a study. Upper limbs tremor in both hands was evaluated using spectral analysis of spiral drawing on graphic digitizing tablet during three repetitive measurements. Autospectra for displacement, velocity and acceleration in 2–16 Hz frequency band were calculated and dominant tremor frequency was determined. Tremor intensity was quantified with max/mean Power Spectral Density ratio. Additionally, visual tremor rating of spiral drawing, volumetric method, Nine-Hole Steadiness Test, Groove-Type Steadiness Test, Nine-hole pegboard test and EMG tremor recording were performed.

Results

Tremor intensity assessed with QTADT correlated well with the tremor rating scores of spiral drawings in both dominant and non-dominant hand (Spearman's correlation $R = 0.65$, $P < 0.05$; $R = 0.65$, $P < 0.05$; respectively), volumetric methods ($R = 0.58$, $P < 0.05$; $R = 0.57$, $P < 0.05$), Nine–Hole Steadiness Test ($R = 0.73$, $P < 0.05$; $R = 0.73$, $P < 0.05$), Groove-Type Steadiness Test ($R = 0.60$, $P < 0.05$; $R = 0.59$, $P < 0.05$), and Nine-hole pegboard test ($R = 0.50$, $P < 0.05$; $R = 0.71$, $P < 0.05$). Dominant tremor frequency detected by QTADT technique did not differ significantly from peak EMG tremor frequency and both methods showed good correlation ($R = 0.57$, $P < 0.05$; $R = 0.67$, $P < 0.05$) (Fig. 1). QTADT test- retest reliability was significantly high (ANOVA).

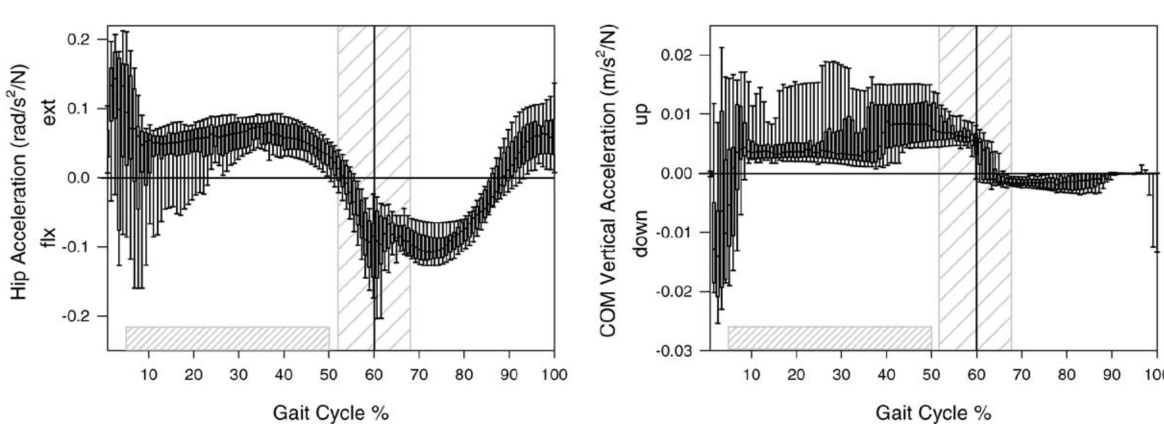

Fig. 1. Induced accelerations. A typical plot of the results showing the effect of a unit soleus force. Typical activation times are indicated by the horizontal bar above the abscissa. The range in toe-off can also be seen in the vertical hatched area. The plots show the middle 50% of results (grey boxes) along with the 5th and 95th percentile (vertical "error bars").

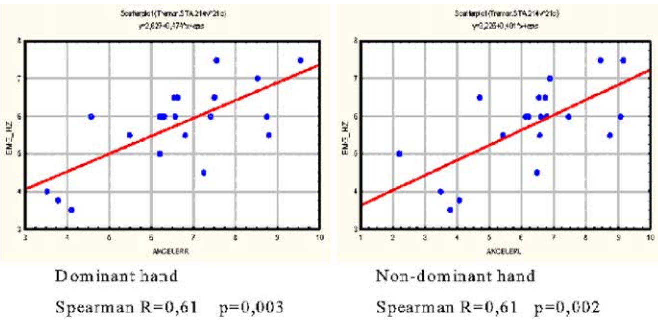

Fig. 1. EMG vs. QTADT tremor frequency.

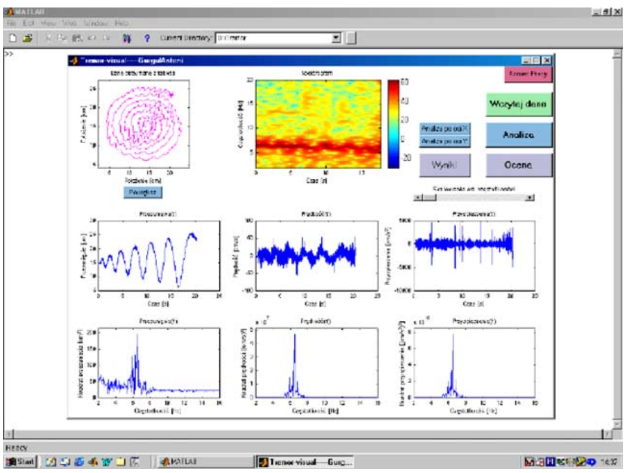

Fig. 2. Example a patient with ET.

Discussion

The reliable, low-cost and easy to perform method of tremor assessment is needed for many clinical and scientific purposes. In this study we found that the parameters of QTADT correlated well with other, often used in clinical practice methods and the tremor frequency and intensity assessed by QTADT method could be helpful in differential diagnosis as well as in monitoring disease progression and in the assessment of the efficacy of therapy. QTADT validation to accelerometry, the gold standard of tremor measurement in pathophysiological studies.

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S8.4: Biovariability: a key factor for motor evaluation in sport exercises

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Summary

This work investigates the intra/inter-variability of kinematic and kinetic parameters in vertical jump exercises, in order to better understand how to assess experimental protocols, treat data and interpret results for motor evaluation in sport applications. Despite the high homogeneity of the athletes analyzed, an appreciable variability resulted, both in inter and intra-subject kinematic and kinetic parameters.

Conclusion

Similar performance in competitions and in vertical jump exercises does not result from homogenuos motor strategies. Each subject seems to exploit different factors, following his own abilities and compensating his deficiencies. The potentialities of modern technologies could be fully used to support conditioning and reabilitative programs in sport, only when standardized test protocols, data collection procedures and methodologies for analysis of results will be defined. This paper tries to contribute to this process.

Introduction

Vertical jump (VJ, CMJ) exercises have been widely adopted in sport practice and biomechanics as an effective way to predict athletic ability, especially when lower limbs are required to produce explosive force (e.g. sprint events). Many scientists have focused their attention on VJ tests, discovering aspects of multijoint coordination and elastic properties of muscular activity. Nevertheless, previuos works use non-homogeneous experimental protocols and hypotheses which are to be verified. VJ test is generally used to discover common patterns among different people, and it's often referred as rather stereotyped within individuals. Among all the variables measured, the jumping height (H) is assumed to be the most valid performance index. Unfortunately, this parameter provides little information about the genesis of an efficient movement.

Patients/materials and methods

Twelve young sprinters (six males and six females: 16.4 ± 1.0 y.o., 1.71 ± 0.06 m, 59.4 ± 9.2 kg) of (inter)national class were asked to perform 10 double-legged maximal CMJ, their arms akimbo. 3D coordinates of the 10 retroreflective markers placed on anatomical landmarks of lower limbs (four-sticks per side modelization) were estimated by an automatic motion analyzer (Elite, BTS srl, Milan). Simultaneously, ground reaction force (GRF) of one foot was measured by a Kistler piezoelectric platform (the five GRF data for each side were collected in random order). Kinematic data were processed to estimate the 3D coordinates of joint centers and joint angles. Kinetic derivatives, joint moments and powers and selected parameters of each trial and subject were also estimated (after rejecting anomalous jumps). Basic statistics (means (μ), standard deviations (σ), coefficients of variation (CV), correlations with jumping height (r_H)) were applied for intra and inter individual analysis.

Results

Typical parameters of VJ (H, duration, peak of vertical GRF, . . .) showed little variability (CV < 10%). Most of the other parameters extracted (normalized maximum peak of joint moments and powers, time of occurrence of peaks, intervals between peaks, normalized work, positive–negative work ratio, . . .) gave evidence of less homogeneity (CV > 10%). Even considering males and females separately, there was no increase in uniformity within the groups. The intrasubjective variability followed the same trend, confirming what previously suggested by Rodano and Squadrone [1]. None of the parameters showed a significant r_H common to all the subjects.

Discussion

The little intra and interindividual variance in jumping height, duration of the jump movement or maximum vertical GRF, does not reflect the huge heterogeneity in the individual motor patterns. Results suggest a sensitive difference in kinematics and kinetics not only among different homogeneous subjects, but between different trials of the same subject, too. Thus, the classic approach based on the analysis of the individual "best jump" of a session, should be avoided; the mean of parameters taken from different jumps is much more advisable, at least in applications whose objective is the identification of peculiarities and time evolution. This "inductive" way, which starts from observation of individuals, has given clues of potentiality in preventing injuries, but it's a rather heavy task to be accomplished by a single lab: it needs cooperation and the definition of standards.

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S8.5: Gait analysis: a sound but selective outcome measure for cerebral palsy children having selective dorsal rhizotomy

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Summary

After careful and rigorous patient *selection*, 19 cerebral palsy patients were submitted to the SDR operation. All had gait analysis pre operatively, and the results of their function (step length and walking speed) plus other significant gait parameter measures improved at a follow-up analysis at an average of 1.5 years later.

Introduction

Surgical treatment by *Selective* Dorsal Rhizotomy (SDR) leads to a reduction in spasticity in cerebral palsy. Whether the procedure improves function is an on-going debate and evidence of improvement in post operative gait patterns is not readily available. Outcome measures lack standardisation and scales such as PEDI, Ashworth and GMFM have all been employed to evaluate SDR [1–3]. This study emphasises the use of measurable gait analysis changes before and after SDR.

Patients and methods

We have performed SDR on 19 children (13 boys, 6 girls average age 8.6 years) using careful selection criteria and employing gait analysis as an outcome measure. All children were assessed pre operatively and this included neurological and orthopaedic examination, video filming, 3D gait analysis with marker tracking, dynamic EMG of critical muscles and energy cost assessment. Only 13 children completed a full gait analysis, although all were able to comply with some parts of it. Post operative gait analysis was performed in all, on average 1.5 years after surgery. We compared pre and post operative data using paired *t*-tests where valid, otherwise Wilcoxon signed-rank tests were applied. All the changes reported below are significant ($P < 0.05$).

Results

Clinical improvements were seen in Hip extensor power, hip abduction range (increased by 6.6°), hidden flexion (Thomas) decreased by 8.1° and anteversion decreased by 7.7°. The Knee extensor power increased by 0.3 grades. At the ankle dorsiflexion range increased by 8.8° with the knee extended. The plantarflexion range decreased by 5.5° and dorsiflexor power increased by 0.5 grades.

The kinematic and kinetic data from gait analysis are entirely consistent with the clinical changes found and will be demonstrated graphically and by video. At the knee joint there was a marked increase in knee extension. This was observed by an 9.8° decrease in knee flexion at initial contact and a 12.8° increase in the maximum extension angle during stance phase. The transition into swing phase became much freer with an increased rate of knee flexion by 83°/s.

There was also a significant increase in post operative step length (increased by 0.1 m) and walking speed (increased by 0.15 m/s) indicating that the gait changes described had a functional and not purely cosmetic impact. Our primary goal was to improve the children's gait and we feel that our promising results are a reflection of careful patient selection.

Discussion

There are measurable kinematic and kinetic differences in gait analyses performed before and after SDR. Spatial and temporal gait parameters also appeared to improve, after due allowance was made to normalise for growth. It is believed that these changes represent an important method of measuring the outcome of patients subjected to SDR in the same way as scalar measures such as the GMFM, PEDI, etc.

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S8.6: Correlation between the normalcy index and the edinburgh gait score in patients with cerebral palsy

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Summary

The Edinburgh Gait Score (EGS) and the Normalcy Index (NI) were computed for 106 legs of 53 subjects with cerebral palsy. Correlation coefficients were calculated between the two scores for each leg, and also for each subject.

Conclusions

All correlation coefficients were found to be strong and highly significant. This supports the claim that both scores are valid quantitative measures of the quality of gait in patients with cerebral palsy.

Introduction

The Edinburgh Gait Score [1] and the Normalcy Index [2] both seek to quantify the quality of a subject's gait with a numerical value. The NI is calculated from a set of uncorrelated variables which are derived from kinematic data using Principle Component Analysis. In contrast, the Edinburgh Gait Score was developed as simple gait assessment tool for use with video recordings when sophisticated computerised gait analysis techniques are not available. The aim of this study was to examine correlation between the Normalcy Index and the Gait Score.

Patients/materials and methods

Gait Scores and Normalcy Index values were obtained for 106 legs of 53 patients with cerebral palsy who attended the Anderson Gait Laboratory for clinical gait analysis. Ages ranged between 5 and 39 years (mean age 12 years 4 months). Only barefoot data were used and NI was computed as the average of between three and seven kinematic trials. Pearson's product moment correlation coefficient was used to correlate the EGS and NI for each leg, and also for each subject by summing the left and right leg scores. Similar correlations were also computed between the EGS and the square root of the NI. Spearman's rank correlation coefficient was also computed between the EGS and NI for each leg and for each subject.

Results

The following correlation coefficients were obtained.

Correlation type	EGS variable	NI variable	Correlation coefficient (r)
Pearson	EGS for each leg	NI for each leg	0.79
Pearson	EGS for each leg	Square root of NI for each leg	0.83
Pearson	EGS for each subject	NI for each subject	0.85
Pearson	EGS for each subject	Square root of NI for each subject	0.89
Spearman	EGS for each leg	NI for each leg	0.83
Spearman	EGS for each subject	NI for each subject	0.89

Discussion

The strong correlations are in accordance with the hypothesis that both scores provide a quantitative assessment of the quality of gait in patients with cerebral palsy, despite the fundamental differences between them. The stronger correlations found when the square root of the NI was used may be because the NI is the square of the Euclidean distance between the subject and the normal reference in the uncorrelated coordinate system. The similarity of the rank correlation coefficients values with Pearson values computed when the square root of the NI is used suggests that the square-law is probably the best model for the relationship between the two scores. The stronger correlations produced from combined left and right scores may reflect cancelling of errors in some instances.

References

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S8.7: The practicality of functional model calibration in a clinical setting

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Summary

The functional method for model calibration described by Schwartz and Rozumalski [5] was successfully implemented as part of the standard testing protocol in a clinical gait laboratory.

Conclusions

The use of functional methods is practical in the clinical setting.

Introduction

Functional model calibration (FMC) is the use of patient motions to estimate joint parameters (centers/axes of rotation). Many FMC methods exist, such as those described by Capozzo [1], Gamage [2], Halvorsen [3], O'Brien [4], and Schwartz [5]. These methods have been shown to be reliable, precise, and accurate. The perception exists, however, that FMC is not practical for every day use. The concerns commonly voiced include: need for separate marker sets, increased time necessary to acquire the needed range of motion (ROM) trials, inability of patients to carry out the ROM trials, and difficulty in transitioning from the standard model to a new one. This study provides a qualitative description of one clinical gait laboratory's experience implementing FMC. This study does not address the issues of accuracy and precision since they have been described in the literature [1–5].

Patients, materials, and methods

In order to implement FMC the following steps were taken:

1. A marker set was developed that allowed simultaneous collection of standard and FMC data (Fig. 1).
2. A ROM protocol was developed that took <10 min. Patients could perform the ROM trials on their own, or with the assistance of the gait lab staff.
   a. *Hip ROM trials*: patient performs marching-in-place and lateral stepping. Patients unable to perform these tasks approximate the motions with aid from a physical therapist.
   b. *Knee ROM trials*: patient stands on a slightly elevated platform while a physical therapist flexes and extends the patient's knee.
3. ROM data was processed using the method described by Schwartz and Rozumalski [5].
4. FMC and standard gait data were reported together for comparison during the clinical review.

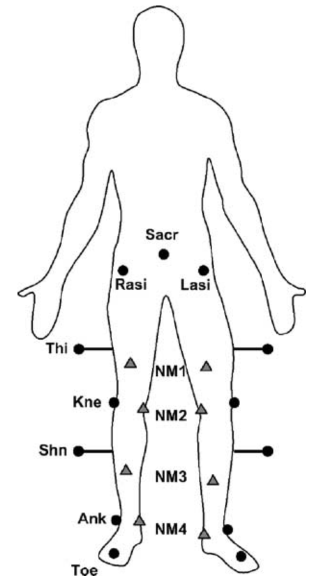

Table 1. Patient diagnoses and sub-diagnoses

Cerebral palsy	385
Triplegia (10%)	
Hemiplegia (14%)	
Quadriplegia (18%)	
Diplegia (58%)	
Myelomeningocele	17
Normal	14
Traumatic/acquired brain deficit	14
Developmental variants	13
Other	80
Total	523

Beginning on 1 January 2002, the Gillette Children's Specialty Healthcare Center for Gait and Motion Analysis began using steps 1–4 as part of the standard protocol for *every* patient referred for gait analysis. During the subsequent 12 months, 523 patients were seen.

Results

The patient population encompassed a broad range of diagnoses (Table 1). Of the 523 patients seen in the lab, there were only two for which the functional calibration was unsuccessful. The increase in test time was minimal, so there was no need to decrease the case load. The method performed as expected based on prior studies with able-bodied volunteers, and has now become a vital part of the gait analysis and interpretation protocol in the center at which this study was conducted.

Discussion

This study refutes the widely held belief that FMC, while theoretically sound, is not practical for day-to-day clinical gait analysis. Many options exist for functional model calibration. The method used in this study is just one member of this ever-expanding family. The authors strongly urge other centers to implement functional methods as part of their regular protocol!

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S8.8: Procedures for the classification of movement analysis data in early diagnosis of a developing spasticity in newborns with icp

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Summary

At the Helmholtz-Institute, a methodology has been developed, which allows the three-dimensional acquisition of unconstrained movement in newborn babies. In this paper, the results of two different classification approaches are presented. These classification approaches discriminate between healthy babies and newborns at risk of developing spasticity due to infantile cerebral palsy (ICP), and is based on parameters extracted from the three-dimensional movement analysis data recorded during spontaneous motor activity. This procedure permits a forecast of a spasticity developing to be predicted already at the age of newborn infants.

Conclusion

The classification algorithms presented allow a reliable discrimination between healthy and affected subjects. Best results are achieved utilising quadratic discriminant analysis with a cost function. Sensitivity as well as specificity reach detection values of around 75%. These values are expected to rise with increasing patient and norm collective database size.

Introduction

One year ago, a new procedure for reliably retrieving 3D motion analysis data in newborn babies was presented at the ESMAC congress [1]. In a further step all parameters of the movement were identified, that best describe the differences between healthy and affected subjects. By asking experienced physicians in the field of neuropediatrics for their methodology of visual assessment, altogether 125 quantitative parameters could be extracted from the patient's 3D movement data. These included parameters regarding movement speed, trajectory smoothness, periodicity, range of motion, acceleration and distance between trajectories. Considered individually, each of these parameters does not permit a conclusive statement to be made as to whether or not the patient is at risk. Therefore optimized parameter combinations were used and the subjects' movement was preferably arranged in homogeneous classes as "healthy" or "at risk", respectively, by an adequate classification procedure. Two different ways of classification were tested for their feasibility.

Methods and patients

The first technique (methodology A) tries to discriminate between healthy and affected subjects by utilising five selected parameters. To find the optimal combination of parameters, cluster analysis based on Euclidian distances was used. A measurement trial is then used to verify if these five parameters are within the range of the standard deviation for the norm collective with respect to each of the parameters. Depending on the number of parameters within or outside the standard deviation, classification is effected. The second, more complex approach utilises quadratic discriminant analysis with eight parameters and a cost function (methodology B). Here, the selected parameter values of a measurement trial are compared with all corresponding parameter sets in a database, for which the classification of each parameter set – healthy or affected – is already known. The classification for the parameter set showing the greatest similarity with the measurement trial is then adapted to the measurement trial itself. The patient collective consisted of 8 preterm newborns with cerebral hemorrhage for the pathologic group. The norm collective consisted of 16 normal newborns. Measurements were carried out during the first, the third and the fifth month of life, calculated with respect to the target date of delivery.

Results and discussion

A comparison of the two classification procedures shows that the quadratic discriminant analysis with eight parameters and a cost function partly achieves substantially higher sensitivities in relation to methodology A. On the other hand specificity, which depends upon the variant of the cost function, is on the same level or only slightly below. Summarizing quadratic discriminant analysis based on eight parameters proves to be the best classification procedure. Depending upon the selected cost function, detection rates of 70% for healthy babies (specificity) and of over 80% for affected subjects (sensitivity) are reached.

Reference

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Orthopaedics

S8.9: Long term follow-up of gross motor function after uncemented total hip prosthesis using Harris hip score (HHS)

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Summary

A long term follow-up of locomotor performance after total hip joint replacement (THR) is presented using the Harris Hip score (HHS) [1]. The interdependence of gross motor function, hip range of motion (ROM), pain and deformity was analysed over 1 year.

Conclusions

Within the study population, increased HHS is found, documenting improved clinical status. Initial improvement is related to reduction of pain. Only thereafter, gross motor function (GMF) improves, initiating a combined improvement of pain, gross motor function and range of motion.

Introduction

The long term effect of total hip joint replacement on motor function is scarcely documented. However, validated tools are available to asses clinical outcome after total hip joint replacement [1]. HHS scores gross motor function (walking distance, use of walking aid, ability to climb stairs, presence of limping, ...), hip range of motion, pain and deformity (contractures and leg length discrepancy).The present study aims to document the temporal interdependency of changes in these subitems in a long term follow-up (12 months) after uncemented THR.

Patients/materials and methods

Thirty-eight patients, aged 21–79 (average 48), were examined 1 day before surgery (T1), 6–8 weeks (T2), 12–14 weeks (T3), up to 1 year after surgery (T4). All patients received a primary, uncemented custom made total hip prosthesis [2]. The HHS was calculated for each time point. The score is given on a rating scale with a maximum of 100 points including four topics: pain (max. 44 points), gross motor function (max. 47 points), range of motion (max. 5 points) and deformity (max. 4 points). The total HHS and subitems were analyzed using an ANOVA for Repeated Measures (Statistica 6.1). Tucky HSD post hoc test was used to determine the significance if the differences between the time points. Significance level was set to $P \leq 0.05$.

Result

A significant improvement in HHS is found after surgery (47.4–86.0). Although, improvement in pain score is prominent during the first 6–8 weeks after surgery (13.9–34.6), a minor decrease in motor function is present (24.8–24.5). Thereafter, a significant increase of GMF is seen until 1 year post-op (24.5–37.2).

Although a positive trend can be observed, the changes in the hip ROM score were not significant over time (4.5–4.9).

The deformity score remained constant over time (4.0).

Discussion

Positive outcome after THP is documented, with improvements up to 1 year after surgery. Monitoring of the different subitems over time reveals initial pain reduction to be the immediate effect after surgery. Only after 12–14 weeks, an effect on gross motor function and hip ROM was found. Our findings seems to suggest that when monitoring changes in gross motor function after THR, timing is crucial and only of limited use when applied during the first 6–8 weeks after surgery.

References

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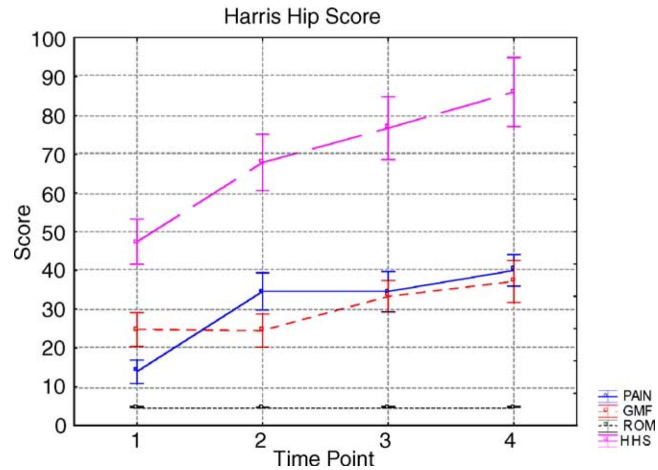

Fig. 1. Marker set suitable for both FMC and the standard gait model.

S8.10: An RCT of functional outcome up to 2 years following total knee arthroplasty with and without patella resurfacing

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Summary

This study measured active, sagittal, knee joint motion prior to and up to 2 years following total knee arthroplasty (TKA) using a system of electrogoniometry. Two randomised group of patients one with and one without patella resurfacing were compared to a group of normal age matched subjects.

Conclusions

Patella resurfacing did not result in an increase in the functional range of movement after knee arthroplasty in the subjects studied. While patella resurfacing may be appropriate in some individuals, it should not be carried out routinely in patients with osteoarthritis of the knee in an attempt to improve knee function.

Introduction

The need for patella resurfacing remains an area of controversy in total knee replacement surgery [1,2]. The authors in a previous report of knee arthroplasty subjects [4] indicated that knee motion is limited following joint arthroplasty across a portfolio of functional activities. However there is no similar reported evidence on the effect on knee function as measured by functional range of movement in patients undergoing knee arthroplasty with and without patella resurfacing [3].

Patients/materials and methods

The study design was a blinded, randomised, prospective, controlled trial. The knee joint functional ranges of movement of a group of patients ($n = 50$, mean age = 70 years) with knee osteoarthritis were investigated prior to and following (4 and 18–24 months) total knee arthroplasty along with a group of normal subjects ($n = 20$, mean age = 67). Patients were randomly allocated into two groups, those who received patella resurfacing ($n = 25$) and those who did not ($n = 25$). Flexible electrogoniometry was used to measure the flexion–extension angle of the knees with respect to time in eleven functional activities (Gait, Ascending a slope, Descending a slope, Ascending stairs, Descending stairs, Sitting down to a low chair, Standing up from a low chair, Sitting down to a standard chair, Standing up from a standard chair, Getting into a bath, Getting out of a bath).

Results

For each of the eleven functional activities a single cycle was identified and the minimum, maximum and change in knee joint angle (excursion) of both knees were calculated. Repeat measures analysis of variance (ANOVA) was used to test for differences between means. A General Linear Model was used involving one within subjects factor with three levels (pre-operative, 4 months post-operative and 18–24 months post-operative) and one between subjects factor (patella resurfaced or patella not resurfaced). No statistically significant differences (alpha level 0.05) in joint excursion of the affected knee were found between patients who received patella resurfacing and those who did not. However all patient groups showed significant reductions in joint excursion compared to the age matched normal subjects for all eleven functional task recorded (t-test, $P < 0.004$).

Discussion

The patients showed significant limitation of active knee excursion during all functional activities prior to surgery and little improvement following surgery in knee motion. Two years after operation they used only approximately 75% of the knee angulation seen in normal subjects. However there was no evidence to suggest that this situation was made better or worse by the use of routine patella replacement and hence this procedure should be reserved for situations in which there are clear clinical indications for replacing the patella surface.

References

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Table 1. Outcome measures

	DFEO with PTA		DFEO only		PTA only	
	Pre	Post	Pre	Post	Pre	Post
KF contracture (°)	18 (9)	1 (4)[a]	21 (6)	7 (8)[a]	5 (8)	0 (4)[a]
KF at initial contact (°)	48 (11)	28 (12)[a]	48 (19)	37 (14)[a]	38 (9)	26 (10)[a]
KF min. in mid stance (°)	42 (13)	10 (12)[a]	43 (17)	31 (13)[a]	31 (13)	13 (15)[a]
KF range of motion (°)	28 (11)	49 (12)[a]	24 (9)	28 (9)	35 (18)	48 (18)[a]
Norm speed	0.271 (0.1)	0.237 (.09)[a]	0.274 (0.11)	0.246 (0.11)	0.265 (.13)	0.268 (.11)
Koshino index deviation	0.135 (0.12)	−0.164 (.18)[a]	0.138 (.23)	0.002 (.19)	.007 (.13)	−.171 (.10)[a]

[a] Indicates statistical significance of pre-post changes at the $P < 0.05$ level.

S8.11: Distal femoral extension osteotomy and patellar tendon advancement for treatment of persistent crouch gait in individuals with cerebral palsy

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Summary

A retrospective study design was used to evaluate the effectiveness of distal femoral extension osteotomy and/or patellar tendon advancement surgery for the treatment of a persistent crouch walking pattern in individuals with cerebral palsy.

Conclusion

The combination of patellar advancement with distal femoral extension osteotomy is an effective treatment for persistent crouch gait in individuals with cerebral palsy. A distinction of outcome of distal femoral extension osteotomy is noted depending on whether or not advancement of the patella is included in the procedure. The patellar tendon advancement only group exhibits differences from the other two groups pre-operatively reflecting less severe crouch.

Introduction

Persistent crouch gait is a common problem in adolescents and young adults with cerebral palsy (CP). Soleus insufficiency from previous interventions, lever arm dysfunction, and/or decrease in the power to mass ratio during adolescence can all be precipitating factors. Increased patellofemoral pressures likely contribute to increased pain which often leads to a discontinuance of ambulation. Traditional treatment typically addresses the muscle tightness component but not the muscle insufficiency. Effective treatment may need to address both components to reduce pain and maintain ambulation into adulthood.

Patient/materials and methods

IRB approval was granted for this study. Subjects consisted of 35 adolescents and young adults with a diagnosis of cerebral palsy (55 knees) who had previously undergone either (i) distal femoral extension osteotomies with patellar tendon advancement (DFEO + PTA), (ii) distal femoral extension osteotomy without patellar tendon advancement (DFEO only), or (iii) patellar tendon advancement alone (PTA only). All had pre- and post-operative 3D gait analysis. Community function was assessed pre-and post-operatively as well using the Gillette FAQ and the PODCI parent report measures [1,2]. Patellar position was measured on X-ray using the Koshino Index [3]. All had at least one additional procedure performed simultaneously. Findings were analyzed using a one-way ANOVA between groups and paired *t*-tests within groups.

Results

The average age of the individuals across all groups was 13.2 (10.0–30.25) years. Average duration between surgery and post-operative assessment was 1.06 (.58–2.08) years. Fourteen individuals had DFEO + PTA (21 knees), 10 had PTA only (18 knees), and 11 had DFEO only (13 knees). The average time duration between the surgical procedures and the post-operative assessment was 1.06 years. All subjects had at least one additional procedure performed simultaneously (see Table 1).

References

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S8.12: Effect of selective dorsal rhizotomy on gait in children with CP: the risk of including soleus and gluteus rootlets in the SDR procedure

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Summary

Objective gait analysis indicate that carefully selected children with spastic diplegia ($N = 18$) significantly improve their kinematic and kinetic profiles 10 months and 2 years post SDR. Children who received rhizotomy of soleus and gluteus rootlets ($N = 6$) have a higher risk for pelvic anterior tilt and for crouch than children who received SDR, preserving the soleus and gluteus rootlets ($N = 6$).

Conclusions

SDR results in a significantly improved gait 10 months and 2 years post surgery. The results further suggest that when including the soleus roots by not monitoring the soleus and gluteus-muscles in the selection procedure of SDR, there is a risk for increased pelvic anterior tilt and for limited knee and hip extension in stance. By preserving the roots for the soleus and gluteï, the children develop more pelvic and knee control in stance.

Introduction

Only a few previous studies evaluated the effect of SDR on a carefully selected patient group, including only children with spastic diplegia, and there are no studies reported on the change in kinetics post SDR. The aim of the study was to evaluate the changes in gait pattern 10 months and 2 years post SDR and to define the risk for pelvic instability and crouch gait. We hypothesized that SDR would significantly improve gait, especially when soleus and gluteus rootlets were preserved in the SDR procedure.

Methods

The group consisted of 18 children with spastic diplegia, (age range 4.8–12.3 years), with periventricular leucomalacia, ambulant, with good strength and selectivity, and without previous orthopaedic surgery. Sensory rootlets of L1 to S2 were stimulated, and the selection procedure was based on observation of abnormal EMG and clinical patterns, resulting in an average SDR of 29.9%. Two subgroups of six children were selected. For the first group, soleus and gluteus medius rootlets were included in the selection procedure when pathological patterns were observed during the surgical procedure. For the second group, soleus and gluteus rootlets were preserved in the SDR procedure, to prevent crouch and pelvic instability. Each child underwent a comprehensive pre-operative evaluation including clinical examination and 3D gait analysis with joint kinematics, kinetics and surface EMG of 8 lower limb muscles, in the month before SDR, and 10 months and 2 years post-operatively. Ninety gait parameters were assessed blind by the same kinesiologist at the different evaluation times. Repeated measures analysis of variance was used to assess the differences over time for continuous data and the wilcoxon signed rank test was used to compare interval data, with a critical *P*-value of 0.005 (with Bonferroni correction).

Results

At 10 months and 2 years post SDR, all children significantly improved for ankle kinematics at initial contact, terminal stance and during swing ($P < 0.005$). Ankle moments and power improved significantly at loading response and terminal stance ($P < 0.0001$). Knee extension at initial contact improved for all children ($P < 0.001$) at 10 months and 2 years post SDR and knee and hip extension at terminal stance improved significantly at 10 months post SDR. However, the originally improved knee and hip extension was lost at 2 years post surgery for the children who received SDR with soleus rootlets. Children who received SDR without selection of soleus and gluteus roots, preserved the improved extended position in stance until 2 years post SDR. All children gained pelvic stability in the sagittal plane ($P < 0.001$), but improved pelvic anterior tilt and increased ankle power generation at terminal stance was more frequently observed for the children who received SDR without selecting soleus and gluteus roots. Changes in time and distance parameters were similar for all children and were mainly seen 2 years post-SDR.

Discussion

The results of our study demonstrate that SDR is successful in improving the walking performance in children with spastic diplegia, however, the selection of patients and the fine-tuning of the SDR procedure is of primary importance when functional improvement is the goal. Our objective gait data document that crouch and pelvic instability post SDR can be prevented by preserving soleus and gluteus rootlets in the SDR procedure.