Comparison of level and up-hill gait after gastrocnemius / soleus muscle flap

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Introduction: Muscle flap techniques are utilized in treatment of open tibial fractures, chronic infections or severe soft tissue injuries of the shank. The local treatment of these conditions is successful in most cases. However, not much attention has been paid to the functional deficit that may be induced by depriving the donor muscle of its function. This study investigates if a "donor deficit" is present during level gait and during more demanding tasks such as up-hill walking.

Methods:. The subjects for this study were selected from a group of 36 Patients who were treated with a muscle flap procedure between 1983 and 1991 due to severe injury of the lower leg. Five subjects met the inclusion criteria for gait analysis: They did not suffer from any additional gait impairments, unrelated to the muscle flap. In two subjects the medial gastrocnemius muscle and in three subjects the soleus muscle was used as flap. Kinematic analysis was performed utilizing a VICON System. Ground reaction forces were sampled during level gait by two Kistler force plates. Level gait was recorded while the subjects walked at a free and a fast walking speed. A ramp with 10° inclination was placed in the middle of the walkway to measure up-hill gait. The data was further processed by a biomechanical analysis package (ANALYZE) allowing for the calculation of 3d- segment positions and the individual joint angles with numerical and graphical representations.

Results:

Level gait: The free gait velocity was on the lower side of normal, (mean 1.27 m/sec, range 1.18 to 1.4 m/sec). Two subjects shortened the unaffected step length slightly, with a side to side difference of less than 3 cm (less than 5%). One of them had a slightly shorter stance duration on the affected side (side difference 6%). All the other subjects did not demonstrate a significant asymmetry of step length or stance duration. Two subjects, with symmetrical time/ distance parameters, had a tendency to a calcaneal gait pattern, with slightly increased dorsiflexion towards the end of single limb stance on the affected side. This was accompanied by a slight reduction of the vertical peak force during push off in one of them (side difference 6%). All the others had a symmetrical motion pattern and symmetrical ground reaction forces.

Fast gait: All subjects were capable of increasing their gait velocity (mean 1.89 m/sec, range 1.58 to 2.43 m/sec). Asymmetry of the time/ distance parameters did not increase. However, in three subjects the second vertical peak force was reduced on the affected side more than 5% (side difference 7% to 12 %). The tendency to a calcaneal gait pattern remained in two subjects.

Up-hill gait: During up-hill gait, all subjects shortened the unaffected step length: mean side to side difference 3.9 cm (range 2.2 to 6.2 cm). In three subjects the calcaneal gait pattern was obviously more pronounced during up-hill walking.

Discussion:

Gait analysis revealed only minor deficits during level walking after a muscle flap procedure for treatment of severe injury of the lower leg. In more demanding tasks, such as walking at a higher velocity or up-hill walking the deficit due to the functionally missing portion of the calf muscle became more obvious. This was seen by an increase of asymmetry of the second vertical peak force, step length asymmetry and an increasing calcaneal gait pattern during up-hill gait.

CROUCH GAIT IN CEREBRAL PALSY-THE EFFECTS OF PSOAS LENGTHENING

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The purpose of this study is to assess changes in hip function due to intramuscular psoas lengthening over the pelvic brim (IMPL) in patients with crouch gait due to spastic cerebral palsy. We evaluated the pre- and post- operative kinematic and kinetic data of 62 patients who had undergone multiple simultaneous lower extremity surgeries to improve ambulatory function. 42 patients whose treatment included IMPL were compared to a group of 20 patients who underwent a comparable set of surgeries except that no psoas surgery was performed. In order to determine the effect of femoral derotational osteotomy (FDO), we subdivided the psoas group according to whether simultaneous FDO was done (Group II) or not (Group I).

The preoperative kinematic status of the psoas and no psoas groups was different consistent with the preoperative impression regarding psoas function. If the psoas was felt to be shortened or overactive (and therefore in the psoas group), the anterior tilt of the pelvis was increased and pelvic motion was excessive. The pelvic range of motion decreased in both psoas groups. The mean pelvic tilt improved in Group II. There was no change without psoas surgery. Preoperative hip motion was skewed toward flexion in all patients but to a greater extent in the psoas group than in the no psoas group. Maximum hip extension in preswing was decreased in all groups but more so in the psoas groups. Postoperatively, psoas surgery significantly improved these parameters representing decreased crouch. There was no change if psoas surgery was not done.

Hip kinetics showed corresponding preoperative deviations in the psoas groups including an increased peak hip extensor moment which occurred later in the gait cycle than normal. The hip moment crossover point from extension to flexion was also delayed in the psoas groups. The peak hip flexor moment was similarly decreased and delayed compared to normal. Postoperatively, these findings were improved only if the psoas was lengthened.

Hip joint powers were also abnormal preoperatively in all three groups. Postoperatively, the H1 generation peak was normalized in the psoas groups. Most importantly, the H3 hip flexor power generation was not diminished with psoas lengthening.

These patients were found to have increased walking velocity with diminished oxygen consumption and oxygen cost revealing overall improvement in their walking function with surgical intervention. This study shows that psoas lengthening over the brim of the pelvis significantly improves hip kinematics and kinetics in nearly all aspects without sacrificing essential hip flexor power generation.

A long-term follow-up of the effects of heel cord surgery on the ankle in persons with cerebral palsy.

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Introduction: Examination of the effects of heel cord surgery on ankle motion in persons with cerebral palsy (CP) have generally been limited to follow-up at about one year after surgery (Rose, 1993). The long-term effects of heel cord surgery in terms of clinical measures and joint kinematics are unknown. It is the purpose of this prospective study to determine if the effects of heel cord surgery seen at one year post surgery are maintained approximately 6 years post surgery.

Methodology: A total of 36 patients (57 sides) with pre operative (P0) and post operative (P1) gait analyses were identified and re analyzed at 6±1 years after surgery (P2). A detailed description of the methods used has been previously published (Davis, 1991). All patients had a diagnosis of CP, ten patients with unilateral involvement and the remainder bilateral involvement. All patients underwent an intramuscular lengthening of the gastrocnemius (Baker technique) and all but one had other surgery (not at the ankle) considered appropriate at the time of the treatment decision. In 6 sides, other surgery was completed at the ankle including 3 posterior tibialis procedures, 2 bony procedures and one peroneal lengthening. The average age at surgery was 10±5 years. All tests included collection of temporal and stride, joint kinematic and clinical range of motion and strength data. The group was evaluated as a whole and separated into two subgroups based on walking velocity with a slower group (N=22) under 80 cm/s and a faster group (N=35) 80 cm/s or more. Selected ankle kinematics and clinical measures were used for evaluation. Differences were evaluated using a repeated measures analysis of variance with post hoc testing. Significance level was set at $p < 0.01$.

Results: Clinical range of motion data (Table 1) for the whole group, showed significant improvements in the maximum ankle dorsiflexion with the knee at 0° from P0 to P1 (2°±11° to 14°±10°) and a significant decrease in this measure (to 8°±8°) at P2. Maximum ankle dorsiflexion with the knee at 90° showed a significant improvement at P1 in comparison to P0 (10°±10° to 18°±9°) which declined slightly at P2 (15°±8) in comparison to P1 but was not significant. Evaluation of these measures in the slower and faster walkers showed similar trends irrespective of the groups.

Table 1: Comparison of selected kinematic and clinical examination measures between the pre operative (P0), first post operative (P1) and second post operative tests (P2) for all sides (N=57). (d.fl. = dorsiflexion, p.fl. = plantar flexion, gc = gait cycle, deg = degrees, norm = normal, [1] indicates significance between P0 and P1, [2] indicates significance between P1 and P2 and [3] indicates significance between P0 and P2 all at P<0.01)

	Ankle angle 98%gc (deg)	Peak d.fl. stance (deg)	Peak d.fl. % gc (deg)	Peak p.fl swing (deg)	Peak p.fl. swing (%gc)	Peak d.fl. swing (deg)	Range of motion 100%gc (deg)	Angle d.fl. knee 0° (deg)	Angle d.fl. knee 90° (deg)
P0	-7±11	5±12	26±17	-17±15	67±6	-7±13	24±10	2±11	10±10
P1	-1±6[1]	15±7[1]	41±11[1]	-6±10[1]	67±6	5±7[1]	23±8	14±10[1]	18±9[1]
P2	0±7[3]	15±7[3]	39±13[3]	-5±10[3]	68±4	4±8[3]	22±7	8±8[2,3]	15±8[3]
norm	0±6	14±3	36±8	-18±7	63±2	3±5	32±6		

Evaluation of the kinematic data showed significant improvements in ankle angle just prior to initial contact (-7°±11° to -1°±6°), peak dorsiflexion in stance (5°±12° to 15°±7°), time of peak dorsiflexion as % of the gait cycle (26%±17% to 41%±11%), peak plantar flexion in the initial third of swing (-17°±15± to -6°±10) and peak dorsiflexion in mid swing (-7°±13° to 5°±7°) at P1 in comparison to P0, which were all maintained at P2. The time of peak plantar flexion and dorsiflexion in swing and the dynamic ankle range of motion remained unchanged among the three tests. Examination of these parameters in the slower and faster walking groups showed similar results as mentioned above with significant changes in the peak dorsiflexion in stance, time of peak dorsiflexion as % of the gait cycle in stance, peak plantar flexion in the initial third of swing and peak dorsiflexion in mid swing in both groups. The time of peak plantar flexion and dorsiflexion in swing and the dynamic ankle range of motion remained unchanged among the three tests in both the slow and fast groups.

Discussion: These results suggest that ankle motion shows improvement in certain variables at the initial post operative test which is maintained long-term (6±1 years post surgery). The increased dorsiflexion at initial contact assists in improved prepositioning of the foot for initial contact. The improved timing and degree of the peak dorsiflexion in stance indicates improved modulation with elimination of premature plantar flexion which is a common gait deviation in persons with CP (Rose, 1993). Improved peak dorsiflexion in swing suggests improved clearance although ankle motion alone does not determine clearance. Passive ankle dorsiflexion with the knee at 0° showed significant improvement initially with a decrease in motion from the P1 to P2 tests. This result is similar to the results previously reported looking at the long-term effect of surgery at the knee with a decrease in popliteal angle from P1 to P2 while maintaining knee extension during gait (Murray, 1995). This result may suggest that the effects of a large increase in mass between P1 to P2 (35 to 51 kg) in comparison to P0 to P1 (31 to 35 kg) may minimize the effects of increasing shortness in muscle length and cause more dorsiflexion during gait. These results suggest the limitation of using the clinical examination alone in determining the need to perform a heel cord procedure. The peak passive dorsiflexion with the knee flexed at 90° showed a significant improvement that was maintained. To determine if these effects were seen primarily in the more functional walkers as compared to the less functional ones, the patients were divided into two groups: slower and faster walkers. Results show that significance seen in parameters in the group as a whole was also seen in both the slow and fast walkers. These data suggest that ankle motion due to heel cord surgery can be improved and maintained for less functional and functional walkers. This is not consistent with the findings at the knee where the faster walkers showed better improvements and maintained these long-term while the slow walkers failed to show any improvement (Murray, 1995).

The mean knee angle in stance was also assessed for the faster and slower groups. In the slow group, the mean knee angle in stance did not significantly change from P0 to P1 and P2 indicating that the increased dorsiflexion in stance was not associated with increased crouch. In the fast group, the mean knee angle in stance showed a significant reduction (decrease in crouch) from P0 to P1 which was maintained at P2 indicating that the increased dorsiflexion again did not result in crouch.

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References

Davis RB. et al., Human Movement Science, 10:575-587, 1991.
Murray T. et al., Developmental Medicine and Child Neurology, 37(8):26-27, 1995.
Rose S. et al., Journal of Pediatric Orthopaedics, 13:727-732, 1993.