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Letter to the editor

ISB recommendation on definitions of joint coordinate system of various joints for the reporting of human joint motion—part I: ankle, hip, and spine

Abstract

The Standardization and Terminology Committee (STC) of the International Society of Biomechanics (ISB) proposes a general reporting standard for joint kinematics based on the Joint Coordinate System (JCS), first proposed by Grood and Suntay for the knee joint in 1983 (J. Biomech. Eng. 105 (1983) 136). There is currently a lack of standard for reporting joint motion in the field of biomechanics for human movement, and the JCS as proposed by Grood and Suntay has the advantage of reporting joint motions in clinically relevant terms.

In this communication, the STC proposes definitions of JCS for the ankle, hip, and spine. Definitions for other joints (such as shoulder, elbow, hand and wrist, temporomandibular joint (TMJ), and whole body) will be reported in later parts of the series. The STC is publishing these recommendations so as to encourage their use, to stimulate feedback and discussion, and to facilitate further revisions.

For each joint, a standard for the local axis system in each articulating bone is generated. These axes then standardize the JCS. Adopting these standards will lead to better communication among researchers and clinicians.

1. Introduction

Since November 1993, the Standardization and Terminology Committee (STC) of the International Society of Biomechanics (ISB) has begun its journey of developing a set of standards for reporting joint motion. Headed by Drs. Peter Cavanagh and Ge Wu in 1993, an initial decision was made to adopt the Joint Coordinate System (JCS), first proposed by Grood and Suntay in 1983 (Grood and Suntay, 1983), as the standard. This decision was publicized to the biomechanics community via Biomech-L, an electronic discussion network. With the enormous amount of support received from the Biomech-L subscribers, the STC then decided to move forward with this decision. A group of volunteers was recruited via Biomech-L who would like to participate in the effort of developing the JCS for each of the major joints in the body. To date, nine subcommittees involving a total of 25 people have been established and, so far, eight proposals have been completed. They include ankle, hip, spine, shoulder, elbow, hand and wrist, TMJ, and whole body.

There are two main reasons as to why these JCSs are established. First, there is a lack of standard for reporting joint motion in the field of biomechanics for human movement. This makes the comparisons among various studies difficult, if not impossible. Secondly, the use of JCS as proposed by Grood and Suntay has the advantage of reporting joint motions in clinically relevant terms. This makes the application and interpretation of biomechanical findings easier and more welcoming to clinicians.

Although all of the JCS recommendations have been published in various forms, such as in previous ISB Newsletters, and on the ISB Home Page, only a few of them have been test-used and subsequently revised. The purpose of this paper is to present these JCS definitions to the biomechanics community so as to encourage the use of these recommendations, to provide first hand feedback, and to facilitate the revisions. It is hoped that this process will help the biomechanics community to move towards the development and use of a set of widely acceptable standards for better communication among various research groups, and among biomechanists, physicians, physical therapists, and other related interest groups.

2. Overview of JCS

All recommendations of JCS for various joints follow the similar procedures as proposed by Grood and

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articulates with the first of the sacral vertebrae (sacral vertebrae are fused together to form the sacrum). The sacrum articulates with the two innominate bones, also known as ilia that in turn have a flexible articulation with each other at the pubic symphysis. The ilia also include the acetabula that articulate with the femora.

This proposed standard concerns the intervertebral motion between adjacent vertebrae, but the principles can be extended to regional and overall spinal motion. The intervertebral articulations have six degrees of freedom (three translations and three rotations) each of which has a measurable stiffness. Therefore, there are six independent parameters of motion (three displacements and three rotations). The load-displacement characteristics of these joints has been described by a stiffness matrix (Panjabi et al., 1976). This stiffness matrix has off-diagonal ('coupling') terms as well as diagonal terms. Therefore the pattern of motion that occurs between two vertebrae depends on the combination of forces applied, and it is only possible to define an instantaneous axis of rotation, since no fixed joint axis exists. The helical axis of motion is as alternative to the three rotations and three translations description of intervertebral motion. Using the helical axis of rotation, the motion is described by the position and direction of an axis of motion, together with a scalar translation along this axis and a scalar rotation around it.

5.2. Vertebral coordinate system—XYZ (proximal) and xyz (distal) (Fig. 4)

O(o): The origin is the intersection of the axes Y and y in the reference, neutral position (see Fig. 5a. The neutral position must be specified, and must be in a position where the vertebral axes Y and y are coplanar. If Y and y are parallel (do not intersect at the common origin O) the Y- and y-axis are constrained to be colinear, and the origin O is the mid-point between adjacent endplates (see Fig. 5b).

Y(y): The line passing through the centers of the vertebra's upper and lower endplates, and pointing cephalad.

Z(z): The line parallel to a line joining similar landmarks on the bases of the right and left pedicles, and pointing to the right.

X(x): The line perpendicular to the Y- and Z-axis, and pointing anteriorly.

It should be noted that other axis conventions have been described. White and Panjabi (1978) have X left; Y cephalad, Z anterior. ISO 2631, SAE J-211, and the Scoliosis Research Society (Stokes, 1994) have X anterior, Y left and Z cephalad.

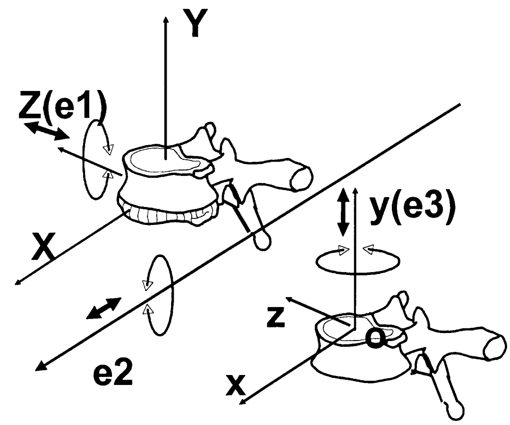
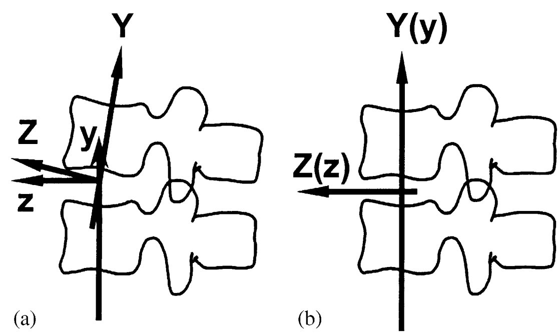


Fig. 4. Illustration of a proximal vertebral coordinate system (XYZ), a distal vertebral coordinate system (xyz), and the corresponding JCS.



(a) (b)

Fig. 5. Location of the common origin of axes: (a) the general case; (b) the specific case of Y and y being parallel. Note: the Y-and y-axis must be coplanar in the reference position of the two vertebrae.

5.3. JCS and motion for the spine (Fig. 4)

e_1: The axis fixed to the proximal vertebra and coincident with the Z-axis of the proximal vertebra coordinate system.
Rotation (α): flexion or extension.
Displacement (q_1): mediolateral translation.

e_3: The axis fixed to the distal vertebra and coincident with the y-axis of the distal vertebra coordinate system.
Rotation (γ): axial rotation.
Displacement (q_3): proximo-distal translation.

e_2: The floating axis, the common axis perpendicular to e_1 and e_3.
Rotation (β): lateral bending.
Displacement (q_2): antero-posterior translation.

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