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ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion—Part II: shoulder, elbow, wrist and hand

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Abstract

In this communication, the Standardization and Terminology Committee (STC) of the International Society of Biomechanics proposes a definition of a joint coordinate system (JCS) for the shoulder, elbow, wrist, and hand. For each joint, a standard for the local axis system in each articulating segment or bone is generated. These axes then standardize the JCS. The STC is publishing these recommendations so as to encourage their use, to stimulate feedback and discussion, and to facilitate further revisions. Adopting these standards will lead to better communication among researchers and clinicians.

Keywords: Joint coordinate system; Shoulder; Elbow; Wrist; Hand

1. Introduction

In the past several years, the Standardization and Terminology Committee (STC) of the International Society of Biomechanics has been working to propose a set of standards for defining joint coordinate systems (JCS) of various joints based on Grood and Suntay's JCS of the knee joint (Grood and Suntay, 1983). The primary purpose of this work is to facilitate and

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encourage communication among researchers, clinicians, and all other interested parties.

The STC has established a total of nine subcommittees, involving nearly 30 people who have extensive experience (either research or clinical) in joint biomechanics, and had developed proposals for nine major joints in the body. These joints include: foot, ankle, hip, spine, shoulder, elbow, hand and wrist, TMJ, and whole body. The proposals are based on the ISB standard for reporting kinematic data published by Wu and Cavanagh (1995). The first set of these standards for the ankle joint, hip joint, and spine was published in Journal of Biomechanics in April 2002 (Wu et al., 2002). A response to comments to this set of standards was later published in 2003 (Allard et al., 2003).

In this publication, the proposed standards for the shoulder joint, elbow joint, and wrist and hand are included. For each joint, the standard is divided into the following sections: (1) Introduction, (2) Terminology, (3) Body segment coordinate systems, and (4) JCS and motion for the constituent joints. It is then up to the individual researcher to relate the marker or other (e.g. electromagnetic) coordinate systems to the defined anatomic system through digitization, calibration movements, or population-based anatomical relationships.

The two major values in using Grood and Suntay's JCS are: (1) conceptual, since it appears easier to communicate the rotations to clinicians when using individual axes embedded in the proximal and distal segments and (2) the inclusion of calculations for clinically relevant joint translations. Some confusion, however, has arisen over their statement that the JCS is sequence independent, whereas Euler or Cardan angle representations are not. It should be noted that the Grood and Suntay's convention, without the translations, is simply a linkage representation of a particular Cardan angle sequence; the floating axis is the second, i.e. rotated, axis in the Cardan sequence (Small et al., 1992; Li et al., 1993, Baker, 2003). The angles are independent because the sequence is defined by the mechanism; a Cardan or Euler sequence is equally "independent" once the sequence is defined.

2. JCS for the shoulder

2.1. Introduction

Standardization of joint motions is very important for the enhancement of the study of motion biomechanics. The International Shoulder Group (ISG) supports the efforts of the ISB on this initiative, and recommends that authors use the same set of bony landmarks; use identical local coordinate systems (LCS); and report motions according to this recommended standard.

The starting point for the shoulder standardization proposal was a paper by Van der Helm (1996). More information can be obtained at: http://www.internationalshouldergroup.org.

The standardization of motions is only described for right shoulder joints. Whenever left shoulders are measured, it is recommended to mirror the raw position data with respect to the sagittal plane ($z = -z$). Then, all definitions for right shoulders are applicable.

Rotations are described using Euler angles. For a clearer interpretation of these angles it is suggested that the coordinate systems of the proximal and distal body segments are initially aligned to each other by the introduction of 'anatomical' orientations of these coordinate systems. The rotations of the distal coordinate system should then be described with respect to the proximal coordinate system. If both coordinate systems are aligned, the first rotation will be around one of the common axes, the second rotation around the (rotated) axis of the moving coordinate systems, and the third rotation again around one of the rotated axes of the moving coordinate system. This last axis is preferably aligned with the longitudinal axis of the moving segment. This method is equivalent to the method of Grood and Suntay (1983) using floating axes. They also describe the first rotation around an axis of the proximal coordinate system and the last rotation around the longitudinal axis of the moving segment. The second axis is by definition perpendicular to both the first and third rotation axis.

For joint displacements, a common point in both the proximal and distal coordinate systems should be taken, preferably the initial rotation center (or a point on the fixed rotation axis in the case of a hinge joint). For most shoulder motions the rotation center would be only a rough estimate, since only the glenohumeral joint resembles a ball-and-socket joint. The definition of the common rotation centers of the sternoclavicular joint and acromioclavicular joint are left to the discretion of the researcher. Displacements should be described with respect to the axes of the coordinate system of the segment directly proximal to the moving segment to represent true joint displacements.

2.2. Terminology

2.2.1. Anatomical landmarks used in this proposal (Fig. 1)

Thorax:	C7:	Processus Spinosus (spinous process) of the 7th cervical vertebra
	T8:	Processus Spinosus (spinal process) of the 8th thoracic vertebra
	IJ:	Deepest point of Incisura Jugularis (suprasternal notch)