CONTENTS

STANDARD FOR HIP JOINT COORDINATE SYSTEM

RECOMMENDATIONS FROM THE ISB STANDARDIZATION COMMITTEE

Darryl D. D'Lima, MD

Alberto Leardini, M Eng

Hartmut Witte, MD

Sun G. Chung, MD, PhD

Luca Cristofolini, PhD

Ge Wu, PhD

INTRODUCTION

This is the recommendation of the *Hip Joint Working Group* of the *ISB Committee for Standardization and Terminology* for standardization in the reporting of hip joint kinematic data. For most areas of biomechanical research, the normal human hip joint is treated as a ball and socket joint, with the center of rotation defined as the center of hip, even if a measurable incongruity of ball and socket does exist.. Kinematics of the hip joint can therefore be described as motions of the femoral coordinate system relative to the pelvic coordinate system and the global coordinate system of the body. This allows a convenient system for describing three-dimensional joint position that is applicable to in vitro and clinical situations. The joint coordinate system (JCS) reported by Grood and Suntay for the knee has the distinct advantage of being easily described in clinical terms and is independent of the order in which the rotational transformations are used.[5] The JCS system corresponds to conventions using Euler angles in the following order: flexion, adduction-abduction and internal-external rotation of the moving segment coordinate system with respect to the fixed segment coordinate system. This report recommends a similar system for the hip.

General Definition of a Coordinate System

All coordinate systems proposed here are defined as right handed orthogonal triads. In general the X axis points anteriorly (in the direction of progression), the Y axis points cranially and the Z axis perpendicular to both X and Y, points to the right side of the body. The original ISB recommendation by Wu and Cavanagh has been retained as this ties together the coordinate systems for the rest of the joints.[9]

Pelvic Coordinate System

The recommendation is to set the hip coordinate system proximally with respect to the pelvis coordinate system as shown in Fig 1. The anterior superior iliac spines (ASISs) are used to set the origin (midpoint between right and left ASIS) of the pelvic coordinate system. The positive Z axis points from the origin to the right ASIS. The X axis lies in the plane defined by the ASISs and the midpoint of the posterior superior iliac spines (PSISs) and points ventrally (anterior, in the direction of progression) orthogonal to the Z axis. The Y axis is perpendicular to both X and Z, positive cranially (superiorly in the erect standing position).[3]

Hip Center of Rotation

The normal hip is assumed to be a ball and socket joint with a fixed center of rotation. The subject specific location of the hip center of rotation in the pelvic coordinate system has been estimated using either a "functional" or a "prediction" approach. The former method estimates the hip center as the pivot point of a three dimensional rotation between the femur and pelvis body segments.[2] An adequate hip joint range of motion is required for this method of determination of the mean center of rotation. The prediction approaches use regression equations based on standardized pelvic geometry.[1,4,7] However, in most of the reports, regression coefficients have been obtained on relatively small sample sizes of adult males. Bell[1] reported that the regression method was more accurate than the rotational method, while Leardini et al.[6] found that the functional method performed significantly better than any prediction approach. The recommendations to locate the hip center include the use of the functional approach with any standard optimization algorithms used to fit markers on the thigh to a sphere.

The method is suitable when there is an adequate range of motion possible in the hip joint being analyzed. Alternatively, any of the prediction methods may be used and, in fact, are especially recommended in patients with restricted range of motion of the hip joint. This may need to be addressed in more detail as a recent report demonstrated that inaccuracies in hip joint center estimates, as obtained with presently available methods, affect both angles and moments at the hip and knee.[8] Hip moments showed the largest propagation error, with the flexion-extension component being particularly sensitive to errors in hip joint location in antero-posterior direction. The abduction-adduction moment was the second largest affected quantity (for medio-lateral error).

Femoral Coordinate System

For the femur, the Y axis is defined along the line joining the hip center and the midpoint of the medial and lateral femoral epicondyles, pointing proximally. The Z axis is perpendicular to the Y axis, located in the plane defined by the hip center and both femoral epicondyles, pointing laterally to the right side of the body. The X axis is then perpendicular to both, pointing ventrally (anteriorly) [3]. It is hoped that this coordinate system will be consistent with that adopted for the knee.

Hip Order of Rotation

It is recommended that the coordinate system reported by Grood and Suntay[5] be utilized as this does not presume a specific order of rotation. Flexion would therefore be defined around the Pelvic Z axis, axial rotation around the Femoral Y axis, and adduction/abduction around the "floating" axis mutually perpendicular to the Pelvic Z and Femoral Y axes (Fig 1). For those

wishing to reconcile these rotations with Euler angles these rotations would correspond to ordered Euler angle rotations around Z, X and Y axes.

Hip Translations

In a stable hip any translation is assumed to be due to measurement error in locating the center of the hip or due to relative motion of skin markers. However in an unstable hip, including pathologic conditions such as a dislocating hip or an excision arthroplasty, there could be true translation. To maintain consistency with the above described system of hip rotations, mediolateral translation is measured along Pelvic Z axis, proximo-distal translation along the femoral Y axis and antero-posterior translation along the mutually perpendicular “floating” axis.

FIGURE 1

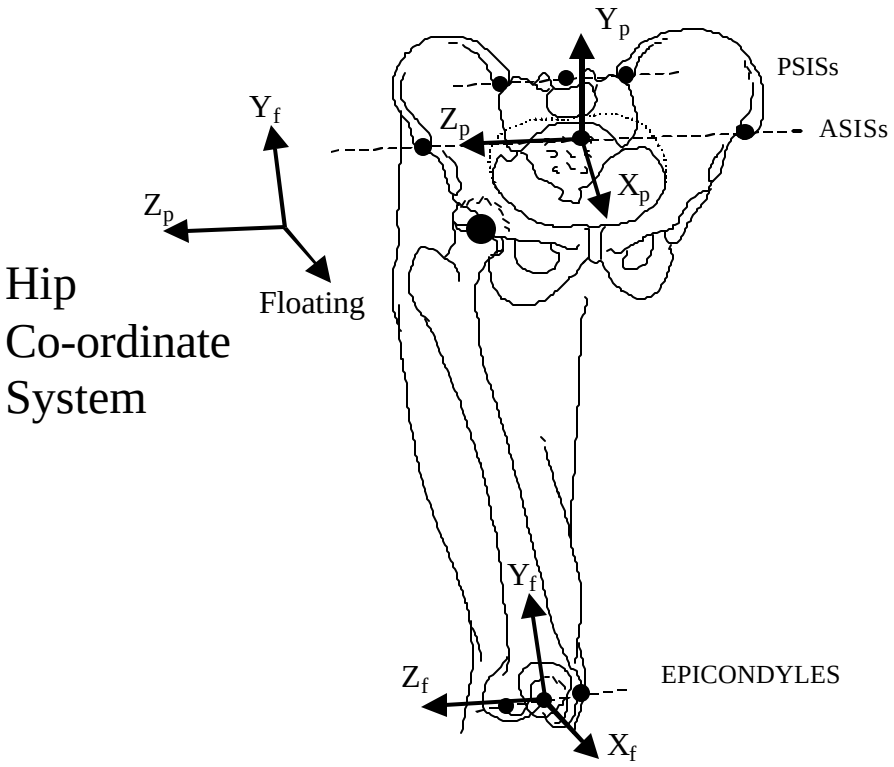

Figure Legend: Diagram of pelvis and right femur depicting the coordinate systems. X_p, Y_p and Z_p are the pelvic orthogonal axes, while X_f, Y_f and Z_f are the femoral orthogonal axes. The hip coordinate system is derived from the pelvic Z axis (Z_p), the femoral Y axis (Y_f) and the mutually perpendicular floating axis.

REFERENCES

1. Bell AL, Pedersen DR, Brand RA: A comparison of the accuracy of several hip center location prediction methods. J Biomech 23:617-621, 1990.
2. Cappozzo A: Gait analysis methodology. Hum Mvmt Sci 3:27-54, 1984.
3. Cappozzo A, Catani F, Della Croce U, Leardini A: Position and orientation of bones during movement: anatomical frame definition and determination. Clin Biomech 10:171-178, 1995.
4. Davis RB, Ounpuu S, Tyburski D, Gage JR: A gait analysis data collection and reduction technique. Hum Mvmt Sci 10:171-178, 1991.
5. Grood ES, Suntay WJ: A joint coordinate system for the clinical description of three-dimensional motions: application to the knee. J Biomech Eng 105:136-144, 1983.
6. Leardini A, Cappozzo A, Catani F, et al: Validation of a functional method for the estimation of hip joint centre location. J Biomech 32:99-103, 1999.
7. Seidel GK, Marchinda DM, Dijkers M, Soutas-Little RW: Hip joint center location from palpable bony landmarks--a cadaver study. J Biomech 28:995-998, 1995.
8. Stagni R, Leardini A, Benedetti MG, Cappozzo A, Cappello A: Effects of hip joint centre mislocation on gait analysis results. J Biomech In press:2000.
9. Wu G, Cavanagh PR: ISB recommendations for standardization in the reporting of kinematic data. J Biomech 28:1257-1261, 1995.