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Localization and Inverse Dynamic Simulation in determining Joint Moments

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INTRODUCTION

The slip-induced fall accidents continue to be a very serious problem. An analysis of data in 1986 found that falls were the leading cause of accident death in senior citizens (Rice et al. 1989). More than 17% of all work-related injuries in 1988 and 12% of all worker fatalities in 1992 resulted from falls (The National Safety Council 1993). The annual direct cost occupational injuries due to slips, trips and falls in the USA has been estimated to be in excess of US $6 billion (Courtney et al., 2001). However, understanding what causes slip-induced fall accidents is challenging because of biomechanics, psychophysical and physiological factors involved.

Joint moments obtained from gait analysis are commonly used as one of the major variables of lower extremity kinematics. It has been generally accepted that the preferred manner for determining joint moments is using inverse dynamics and standard motion analysis methods. Segmental kinematics required of inverse dynamics is typically based on the motion of retro-reflective tracking targets attached to the leg (K. Manal et al., 2002).

While these inverse solutions to determine joint moments have been proven effective, there exist several limitations. First limitation is that few calculation methods are based on localized coordinate system. This may lead to inaccurate result interpretation. Second limitation is the dependence on force plat-form measurement, which limits the available duration for joint moment calculation.

The objectives of the current study were to compare the difference in joint moments under different coordinate system, global and localized. Also, another approach in determining joint moments through inverse dynamic simulation was presented and compared with the results from digital calculation.

METHODOLOGY

Ten (five males and five females) healthy subjects divided equally by gender were recruited for slip/fall experiments. Their ages range from 19 to 78 years (mean 41.3 years, SD 26.56 years) and weight from 51.8 to 86.7 kg (mean 69.92, SD 9.30). Written informed consent approved by the Institute Review Board of Virginia Tech was obtained prior to any testing.

The ground reaction forces of the subjects were collected using two force-plates (BERTEC # K80102, TYPE 45550-08, Bertec Corporation, OH 43212, USA) and sampled at a rate of 1200Hz. A six-camera ProReflex system (Qualysis) was used to collect the three-dimensional posture data of the subjects as they walked over the test surfaces normally. Kinematics data were sampled and recorded at 120Hz. MATLAB program was used for digital processing joint moments. ADAMS (Automatic Dynamic Analysis of Mechanical Systems) Simulation Package (Mechanical Dynamics, Inc.) and its plug-in LifeMOD (Biomechanics Research Group, Inc.) were utilized to perform inverse dynamic simulation.

Ankle, knee and hip moment were calculated based on ground reaction forces, body kinematics and body segmental properties derived using Dempster's anthropometry data (Dempster, 1955). Global coordinate frame was identical with the coordinate adapted in motion capture system. Segmental local coordinate systems were constructed based on anthropometry landmarks and Gram-Schmidt orthogonalization process (Bradley, 1975). Lower extremity joint moments were normalized to the subject's body weight.

Using two subjects' datasets, human models were constructed in ADAMS with assistance of LifeMOD to perform inverse dynamic simulation. Subjects' anthropometry data and 3D posture data were integrated in simulation without using ground reaction forces. Motion Agents were employed to drive the human model following the motion spline defined by posture data. Joint moments were derived using angular history.

RESULTS

In terms of ankle external/internal rotation and inversion/eversion, ankle joint moments under global coordinates and localized coordinates differ significantly both in pattern and in magnitude. While for ankle dorsiflexion/plantar flexion, both patterns and magnitude are very similar. A one-way ANOVA was performed to compare the peak values of flexion as well as the locations of the peak value, which indicated no significant difference ($p>0.05$) found under different coordinate systems.

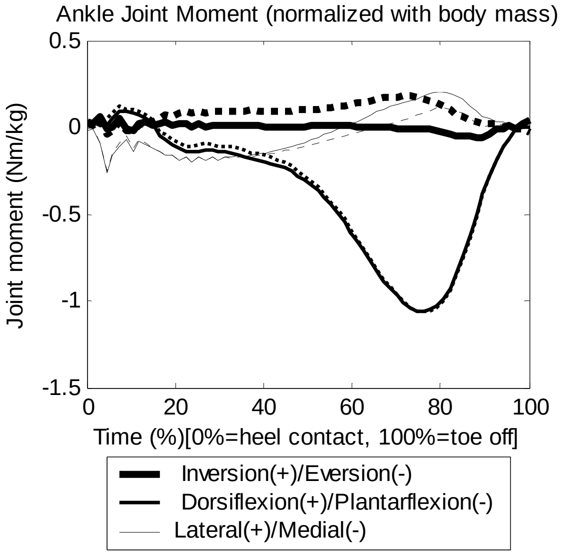

Figure 1: Profile of ankle joint moment

(<u>Dotted</u>: Global based; <u>Solid</u>: Segmental based)

	Global		Local	
Subject#	Peak	Location	Peak	Location
1	1.1486	78.05%	1.1796	78.05%
2	1.1375	77.01%	1.1535	77.01%
3	1.1638	77.66%	1.1443	77.66%
4	1.0832	76.04%	1.0677	76.04%
5	1.2325	78.67%	1.1522	80%
6	1.0619	77.61%	1.0626	76.12%
7	1.2383	80%	1.1987	80%
8	1.0815	76.92%	0.9865	76.92%
9	0.9199	75.79%	0.8761	75.79%
10	1.2202	77.78%	1.1901	77.78%

Table 1: Summary of sagittal plane results

(Normalized with body mass)

Results from inverse dynamic simulation shows similar pattern compared with localized results. Ankle joint moment in sagittal plane corresponding the duration of heel contact to toe off was shown below (Figure 2). However, significant difference in magnitude between localized results and inverse dynamic simulation was observed, which revealed limitations in current simulation.

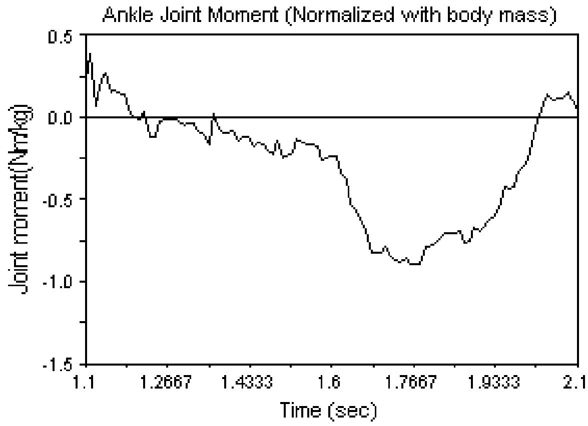

Figure 2: Ankle joint moment in sagittal plane from inverse dynamic simulation**.**

CONCLUSIONS

Current study proves global coordinate based calculation to be as effective as localized approach because, in general, sagittal plane motion attracts most of the attention in studying ankle joint moment. Further, in more simplified situation, 2D condition, global approach can be safely utilized. However, additional comparison in other lower extremity joints, i.e. knee and hip, are going to be examined in order to verify and generalize this conclusion.

Current study also reveals the feasibility of determining joint moments through inverse dynamic simulation. However, this approach is susceptible to errors caused by limited simulation quantities, assumptions in modeling parameters, anthropometric estimations. Future improvement will focus on accurate reflection of subject's parameter in modeling process.

ACKNOWLEDGEMENTS

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REFERENCES

Dempster, W.T., Space Requirements of the Seated Operator, WACD-TR-55-159, Aerospace Medical Research Laboratories, Dayton, Ohio, 1955.

Bradley, G.L. (1975). A Primer of Linear Algebra. Englewood Cliffs, NJ: Prentice Hall.