REPRODUCIBILITY OF TWO DIFFERENT BIOMECHANICAL MODELS TO QUANTIFY KNEE KINEMATICS

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INTRODUCTION

Human movement is variable [1], thus results from gait analysis vary between different test situations. Besides natural variation of human gait, different sources of errors are attributed to the total amount of observed variability during movement, such as biological errors, measurement errors, and errors induced from sources external to the organism [1]. Knowledge of the total variability is important for the interpretation of clinical results and the evaluation of a measurement set-up.

The aim of the present study was to quantify test-retest reproducibility of kinematic data of the knee joint, and to evaluate whether reproducibility differs between varying biomechanical models.

METHODS

Reproducibility was quantified on two consecutive days. Distinctive kinematic variables of the knee joint were analysed in the stance-phase of barefoot walking at a normal speed in 10 healthy subjects (KO) and 12 subjects with knee osteoarthritis (OA). An analysis was performed using two different biomechanical models: Model (FA) used functionally determined joint axes and joint centers and further techniques to reduce errors in segment definition. Model (PA) constructed joint axes relative to anatomical landmarks. A single comprehensive marker-set was defined allowing the use of exactly the same gait cycles for both protocols. A 12-camera Vicon MX5 system collected data at 100 Hz. Five force plates were used to detect gait events. 3 variables in the transversal plane and 5 variables in the sagittal plane were compared (Table 1). Results of 5 trials were averaged for each subject. Reproducibility between days was quantified using Root Mean Square Error (RMSE) [2]. A useful way of presenting measurement error is the repeatability, which is 2.77 x RMSE. The difference between two measurements for the same subject is expected to be less than this value ($\alpha=0.05$) [2]. A two-factorial ANOVA (day X group) was used to analyze whether the underlying population had an effect on differences between test days.

RESULTS AND DISCUSSION

The underlying population had no relevant influence on the reproducibility of data.

Absolute values for RMSE were similar for sagittal and transversal plane variables. However, relative RMSE was larger for measures in the transversal plane. Reproducibility of joint excursions was better compared to specific joint angles.

Reproducibility for sagittal plane kinematics was comparable between models. For variables in the transversal plane, absolute RMSEs were smaller in FA (Table 1). Larger values for relative RMSE for ROM transversal plane were caused by smaller transversal plane motions in FA compared to PA. The use of well-positioned marker clusters and functionally determined joint axes and centers in FA may reduce additional movement due to soft tissue artifacts in the transversal plane. It may also contribute to reduced measurement errors and increased reliability in absolute data (3).

Values between 2.3° and 4.9° for repeatability (Table 1) illustrate the potential magnitude of subject specific differences between test days which are solely attributed to the circumstance of a repeated measure.

CONCLUSIONS

Improved accuracy and segment definition in clinical gait analysis can increase reproducibility for out-of-sagittal plane motion. However, decreased reproducibility of transversal plane motions queries their use in research and daily routine. Measures describing joint excursions are less affected by measurement errors and are therefore recommended to be used for test-retest designs.

Common users of clinical gait analysis should be sensitized to the variability of clinical outcome measures derived from different test sessions to allow a valid interpretation of the results of clinical gait analysis before and after an intervention program.

REFERENCES

1. James CR in Stergiou (Ed.): *Innovative Analyses of Human Movement*, Human Kinetics, 2004.
2. Bland JM et al. *BMJ* **312**:1654, 1996.
3. Della Croce et al. *Gait and Posture* **21**:226-237, 2005.

Table 1: RMSE for PA and FA in °. Relative RMSE for ranges of motion (ROM) is in brackets as % ROM.

Variable	RMSE PA [°]	RMSE FA [°]	Repeatability PA [°]	Repeatability FA [°]
maximum external rotation	1.3	0.9	± 3.6	± 2.5
maximum internal rotation	1.6	1.1	± 4.4	± 3.0
ROM transversal plane	1.2 (10%)	1.1(13%)	± 3.3	± 3.0
initial extension	1.7	1.6	± 4.7	± 4.5
maximum extension in midstance	1.5	1.5	± 4.2	± 4.2
initial flexion maximum	1.8	1.7	± 4.9	± 4.6
initial flexion ROM	0.9 (7%)	0.8 (7%)	± 2.4	± 2.3
extension ROM in midstance	1.2 (7%)	1.2 (7%)	± 3.3	± 3.4