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Comparison of distinctive gait variables using two different biomechanical models for knee joint kinematics in subjects with knee osteoarthritis and healthy controls

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ABSTRACT

Background: Gait analysis is an important instrument in clinical research and results should be objective. The purpose of this study was to quantify clinical outcomes of two biomechanical models with different anatomical coordinate systems and angle decomposition strategies for knee joint kinematics.
Methods: The study was designed to compare a functional approach and a predictive approach with a single comprehensive marker set. 10 healthy subjects and 12 subjects with knee osteoarthritis were analysed. Distinctive gait variables were averaged across five trials. Agreement between methods was illustrated with the so-called levels of agreement. Differences between models were quantified using a paired *t*-test or Wilcoxon-Signed Rank test in case of non-normality (Shapiro–Wilk test). Unpaired t-tests/Wilcoxon tests were used to compare gait variables between healthy subjects and subjects with knee osteoarthritis, and to examine whether statistical analysis of this comparison would yield different data interpretations when using different models.
Findings: Outcome variables differed between the functional and predictive approaches in the sagittal plane (0.1–3.1°), and transverse plane (1.0–3.7°). With respect to the range of motion in the given movement plane, variables in the sagittal plane of the knee were more consistent between methods. The functional approach was more sensitive for detecting differences between groups for sagittal plane kinematics. Statistical analysis for transverse plane kinematics differed substantially between models.
Interpretation: Sensitivity to detect differences of kinematic data between population groups can vary between biomechanical models. Rotational gait variables are inconsistent between models and should not be used as clinical outcome variables in daily routine.

1. Introduction

Gait analysis is an important instrument in various fields of clinical research and its protocols are intended to make kinematics interpretable for clinicians (Ferrari et al., 2008). In subjects with knee or hip osteoarthritis, deficits with regard to strength, postural control and bodily pain can influence gait stability, which cannot be adequately described with disease specific questionnaires such as the WOMAC score alone (Lindemann et al., 2006). Clinical gait analysis is often used to describe pathologic gait patterns or to quantify the efficacy of a therapeutic intervention. In this respect, spatio-temporal variables and gait parameters, such as ranges of motion, and joint excursions, are used (Al-Zahrani and Bakheit, 2002; Astephen et al., 2008; Brandes et al., 2008; Maly et al., 2006; Mundermann et al., 2005; Schmitt et al., 2006; Weidow et al., 2006; Yavuzer et al., 2005).

Objectivity of gait analysis is a prerequisite to guarantee high quality in research and clinical practice. Attempts have been made to standardise procedures for instrumented gait analysis (Wu et al., 2002); however, there is still a variety of different approaches being used in clinical research. Protocols differ in the underlying biomechanical model, associated marker-sets, and data recording and processing. The former defines properties of the modelled joints, the number of involved segments, the definitions of joint centres and axes, the used anatomical and technical reference frames, and the angular decomposition technique to calculate joint angles. Despite apparent differences of the outcome measures derived from different gait protocols, data of different studies are compared and interpreted (i.e. Ryu et al., 2006).

Several comparisons of gait protocols have already been described in previous studies. Ferrari et al. (2008) compared five current protocols in gait analysis along the gait cycle. Movements in the sagittal plane showed good correlation and a small bias between protocols. Out-of-sagittal plane rotations revealed worse correlations. One subject with a prosthesis restraining any movement in the coronal plane showed joint ranges of up to 35° for one protocol. Although this work

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is outstanding with respect to the choice and number of compared protocols, comparisons are only based on three subjects (Ferrari et al., 2008). Variability of clinical gait analysis conducted in four different laboratories was quantified in eleven subjects with spastic cerebral palsy. However, three of the four laboratories used the same protocol and therefore variability was mainly affected by the different investigators (Noonan et al., 2003). Cappozzo et al. (2005) compared time series and angle values during level walking in one subject using different concepts to describe relative movements between two bony segments. They reported only minor differences for knee flexion/extension angles, but substantial differences for knee abduction/adduction and internal/external rotation angles.

In summary, previous studies have already focused on differences between gait protocols and biomechanical models. However, conclusions are based on results from very few subjects or specific populations. Studies mainly quantify variability of angle-time-histories and do not allow a statement on discrete variables, which are important for quantifying efficiency of therapeutic interventions or differences between healthy subjects and subjects with knee or hip osteoarthritis. Furthermore, differences are not quantified in the unit of interest (degree).

Therefore, the aim of the present study was to compare distinctive gait variables of knee joint kinematics derived from two different models in subjects with knee osteoarthritis and healthy controls. Protocols vary regarding the anatomical coordinate system, the angular decomposition,

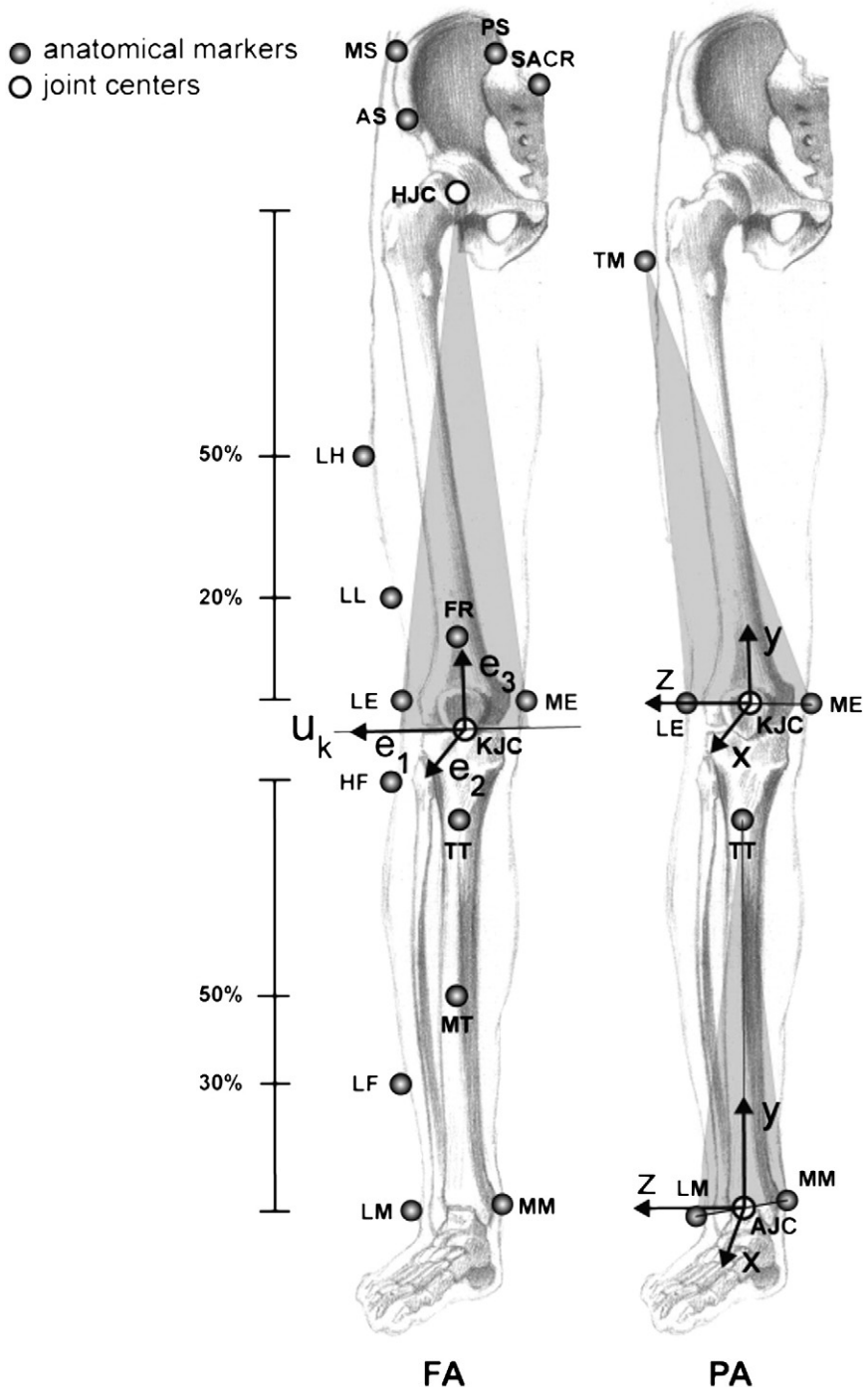

Fig. 1. Location of markers and the joint coordinate systems for the functional approach (FA) and prediction approach (PA) models.