Can Gait Deviation Index be used effectively for the evaluation of gait pathology in total hip arthroplasty An explorative randomized trial

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Published in:
Osteoarthritis and Cartilage

Publication date:
2014

Document version
Tidlig version også kaldet pre-print

Citation for published version (APA):

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THE MAGNITUDE OF THE KNEE MOMENT IN THE TRANSVERSE PLANE IS A SENSITIVE METRIC TO DIFFERENCES IN AMBULATORY KNEE LOADING

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Purpose: The first peak knee adduction moment during gait is often discussed in the context of osteoarthritis and many disease interventions have focused exclusively on reducing this peak in order to reduce one’s risk for disease progression. However, this peak does not completely characterize the knee’s loading environment during gait; it has recently been shown that the combination of the knee adduction and flexion moments provides a more complete description of the loads that act on the knee. Thus there is a possibility to introduce new metrics for the knee loading based on both the adduction and flexion moments. In this study, the adduction and flexion moments were combined in a manner that is described by a single vector with magnitude and direction, defined in the transverse plane of the tibial anatomical frame. We aimed to characterize this measure in an asymptomatic population in order to gain a better understanding of its capacity to differentiate knee loading. We hypothesized that the magnitude and angle of the transverse plane kinetic vector are more sensitive to differences in knee loading that occur with aging than the peak adduction or flexion moment.

Methods: Following an IRB-approved protocol, 127 healthy subjects (63 females; age: 37.2 ± 11.4 vs; BMI: 26.8 ± 5.7 kg/m²) were tested for gait mechanics using a 10-camera motion capture system (Qualisys, Sweden) and a floor-embedded force plate (Bertec Corp, OH). The knee adduction and flexion moments were calculated using an inverse dynamics method. The first adduction (K Madd) and flexion peak (K Mflex) during stance were extracted. The magnitude of the adduction and flexion moments was calculated as the vectoral sum of both moments. The peak magnitude (K Mmag) and angle (K Mag) of this signal during the first half of stance was determined. The subjects were allocated to a younger group (39 females; age: 29.1 ± 4.7 yrs; BMI: 27.0 ± 6.1 kg/m²) or to an older group (24 females; age: 50.1 ± 5.6 yrs; BMI: 26.5 ± 5.0 kg/m²). Group differences in KMadd, KMflex, KMmag, and KMang were assessed using a two-sample t-test, with statistical significance set at p ≤ 0.05. Statistics were done with MATLAB.

Results: It was found that the older group had a higher KMadd (p = 0.051), but slightly above statistical significance. The results also suggest that the older group’s KMflex was higher, but the difference was not statistically-significant (p = 0.078). The magnitude of the unified measure (KM mag) was significantly higher in the older group (p = 0.016) but its associated angle KMang was not found to be different between the two age groups (p = 0.439). Group comparisons for all measures are shown in Figure 1 and group differences of KM mag and KMang are illustrated in a 2D plot in Figure 2, while depicting the relationship between KM mag, KM ang and the addition and flexion moments.

Conclusions: These results suggest that the combination of the knee adduction moment and flexion moment can generate a combined knee moment whose peak magnitude (but not angle) is more sensitive to changes in knee loading than the peak adduction moment or the peak knee flexion moment. The new measure represents an elegant way to describe multiple knee moments during gait, where the magnitude is related to the absolute load at the knee, and the angle represents the relative contribution of the adduction and flexion moments. As shown in Figure 2, an increased KMang indicates a larger contribution of the knee adduction moment. This measure could be useful as a single target measure for gait interventions to treat osteoarthritis. Further studies should focus on characterizing the behavior of KM mag and KM ang in an osteoarthritic population.

Figure 1. The magnitude of the knee moment in the transverse plane (KM mag) is more sensitive to loading differences that occur with age than the peak adduction (KMadd) and peak flexion (KMflex) moments.

Figure 2. The transverse plane vector is represented as a magnitude (KM mag) and angle (KM ang) that describe the contribution of the adduction and flexion moments.
Weight-bearing posterior-anterior (PA) bent knee (30 degree) radiographs were taken 5 years after ACLR and graded using the Kellgren-Lawrence system. Presence of OA was defined as a grade ≥ 2 in the medial compartment.

Fisher’s exact test and independent t-tests were performed to test differences in demographics, pkMC, PKFM, PKAM, and KAMI between those with and without radiographic OA in the medial compartment (OA, nonOA) 5 years after ACLR.

Results: Nine subjects had OA in the index knee 5 years after ACLR, 5 did not. The OA and nonOA groups were not different with respect to BMI, sex, age, pre-injury activity level, time from injury to pre-training, graft type, or concomitant injuries (p > 0.10). In general, the OA patients walked slower (1.58 m/s) than the nonOA patients (1.73 m/s).

There was no difference in pkMC between groups at baseline (p = 0.209, nonOA: 2.97 ± 0.96 BW, OA: 2.45 ± 0.31 BW) (Figure 1). After pre-operative training, the OA group had significantly lower pkMC than the nonOA group (p = 0.032, nonOA: 3.41 ± 1.00 BW, OA: 2.49 ± 0.29 BW). Six months after ACLR the lower pkMC persisted in the OA group (p = 0.038, nonOA: 3.24 ± 0.63 BW, OA: 2.31 ± 0.61 BW). Two years after ACLR, there were no longer significant differences between groups as the OA group loading increased (p = 0.598, nonOA: 3.06 ± 0.60 BW, OA: 2.94 ± 0.16 BW).

No significant differences between groups in any kinetic measures were present at any time point. However, both KAM and KAMI demonstrated similar trend of loading to pkMC (Figure 2).

Conclusions: An association existed between early medial compartment unloading and the presence of radiographic medial knee OA 5 years later. pkMC demonstrated superior ability to differentiate between the presence of OA 5 years after ACLR compared to kinetic measures, although both KAM and KAMI did demonstrate similar patterns of loading to pkMC. The more comprehensive approach undertaken by the musculoskeletal model to estimate joint loading, including use of frontal and sagittal plane kinetics along with co-contraction estimates via EMG input, may provide enhanced insight into the development of OA as compared to kinetic measures alone.

Patients with OA had lower involved joint contact forces (unloading) relative to the uninjured before and 6 months after ACLR, with loading becoming similar between groups 2 years after ACLR. This persistent (months) unloading followed by reloading as evidenced by 2 year pkMC data may be a perfect storm for the development of knee OA after ACL injury and reconstruction, and the time frame between injury and 6 months after ACLR may represent a critical period during which articular cartilage health is highly sensitive to joint unloading and cartilage deconditioning.

Figure 1. Peak joint contact force at the medical compartment during stance phase of walking. Asterisk represents p<0.05 between groups. Bars represent ±1 SD.