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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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KAdM) i.e. not imposing a kinematic strategy, is more effective than feedback via an explicit kinematic target, i.e. the internal hip angle.
One of the kinematic changes that is related to the decrease in knee loading as reflected in the decrease in the KAdM Impulse, is the increased toe-in angle. This parameter has also been suggested in literature to use for retraining of KOA patients. Future studies should focus on the applicability of such techniques in KOA patients, and the long term effects of gait retraining, and patient specific preferences for feedback on different parameters.
Our findings demonstrate the potential of gait analysis and real-time visual feedback for conservative treatment of KOA patients by KAdM reduction, potentially postponing knee replacement.

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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 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 yrs; 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 (KMadd) and flexion peak (KMflex) during stance were extracted. The magnitude of the adduction and flexion moments was calculated as the vectoral sum of both moments. The peak magnitude (KMmag) and angle (KMang) 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 (KMmag) 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 KMmag and KMang are illustrated in a 2D plot in Figure 2, while depicting the relationship between KMmag, KMang and the adduction 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 knee 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 KMmag and KMang in an osteoarthritic population.

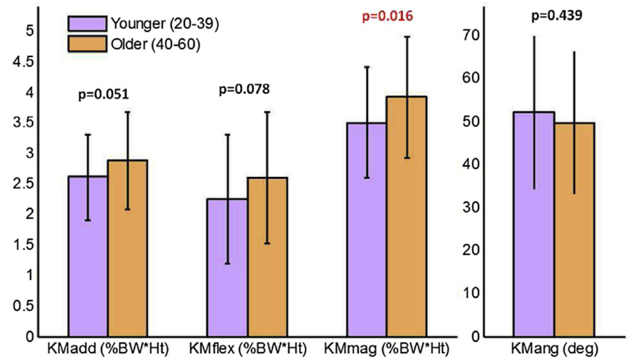

Figure 1. The magnitude of the knee moment in the transverse plane (KMang) is more sensitive to loading differences that occur with age than the peak adduction (KMadd) and peak flexion (KMflex) moments.

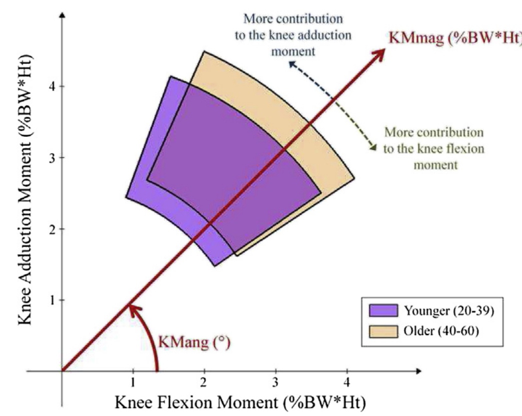

Figure 2. The transverse plane vector is represented as a magnitude (KMmag) and angle (KMang) that describe the contribution of the adduction and flexion moments.

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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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Purpose: Three-dimensional (3D) gait analysis is widely used in the quantitative evaluation of gait. However, 3D gait analysis produces a large volume of data, and simplifying such complex data into a single measure of patients overall gait 'quality' would be valuable in clinical practice. The Gait Deviation Index (GDI), used to evaluate treatment in children with cerebral palsy, has been proposed as such a measure. The experience with GDI in osteoarthritis (OA) patients following total hip arthroplasty (THA) is unknown. The aim of our study was to use the GDI to evaluate post-operative gait quality changes in patients with hip OA following two types of THA.
Methods: A total of 38 patients (11 females and 27 males, age 56 ± 5.6, BMI 27.8 ± 3.6) with unilateral end-stage primary hip osteoarthritis were evaluated pre-operatively, two- and six-months after total hip arthroplasty, using 3D gait analysis while walking at self-selected speed. Upon completion of the pre-operative assessment, the patients were randomly assigned to either resurfacing hip arthroplasty (RHA) or conventional total hip arthroplasty(THA). All patients were allowed early postoperative weight-bearing, and had rehabilitation supervised by an in-hospital physiotherapist. All patients completed the gait evaluation at each follow-up. From the entire variability in kinematic

Gait deviation index by surgical treatment and limb at each time-point ($n = 38$ patients, 76 limbs)

	pre-operative	Two-months	Six-months	Treatment effect (95% CI)
All, mean (SD)	83.4 (10.8)	83.8 (11.0)	88.0 (8.9)	4.9 (2.1 to 7.9)
Surgical treatment:				
Resurfacing hip arthroplasty (RHA)	82.8 (11.3)	82.9 (10.1)	85.6 (6.9)	
Conventional hip arthroplasty (THA)	83.9 (10.4)	84.9 (12.0)	90.0 (10.0)	1.8 (-2.8 to 6.4)
Limb:				
Operated	81.5 (9.6)	83.1 (10.0)	87.1 (8.9)	
Non-operated	85.3 (11.6)	84.6 (12.1)	88.9 (9.0)	2.5 (0.1 to 4.8)

variables across a gait cycle, rather than a small number of discrete parameters, the GDI was calculated for each limb ($n = 76$ limbs). The normative mean and standard deviation (mean = 94.7; SD = 8.4) from our age-matched controls ($n = 20$) were used as reference. A fixed-effects multilevel regression model was employed to evaluate the treatment effects.

Results: No interaction was observed between treatment and time ($p = 0.33$) or limb and time ($p = 0.53$). The pre-operative GDI mean value was 83.4 ± 10.9, showing patients had a moderate deviation from normative gait before surgical treatment (Table 1). After surgical treatment, the GDI score improved significantly by 4.9 [:95CI: 2.1 to 7.9] equal to a 0.8 average increase in GDI per month of follow-up. There was no difference in GDI scores between the two surgical treatments groups; 1.8 [:95CI: -2.8 to 6.4]. However, the GDI score for the non-operated limb was higher than the GDI score for the non-operated limb; 2.5 [:95CI: 0.1 to 4.8].

Conclusions: Our results show that, THA and RHA patients recovered equally well from the respective treatments. The GDI increased significantly after THA surgery, which indicates an overall improvement in gait quality for both treatment groups. The difference between the operated and the non-operated limb showed that asymmetrical gait pattern do not disappear following THA. Further research is required to establish the clinical relevant difference for the GDI score, and to determine the association with pain and OA severity.

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ASSOCIATION OF JOINT MOMENTS AND CONTACT FORCES WITH EARLY KNEE JOINT OSTEOARTHRITIS AFTER ACL INJURY AND RECONSTRUCTION

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Purpose: Knee joint osteoarthritis (OA) is common following anterior cruciate ligament (ACL) injury and reconstruction (ACLR). Abnormal joint loading is one key mechanism in the development of OA, and evidence of altered loading has been demonstrated following ACL injury and ACLR. Identifying a link between joint loading and OA is a critical step in better understanding and preventing early onset knee joint OA. Therefore, the purpose of this study was to determine whether knee joint moments and contact forces early after injury and surgery were associated with radiographic knee OA 5 years after ACLR.

Methods: Fourteen patients (6 F, 8 M, age 32.5 ± 12.0 yrs) with acute, unilateral ACL injury participating in cutting and pivoting activities were included in this study. All underwent ACLR using a hamstring autograft or soft tissue allograft.

Testing consisted of gait analysis with electromyography (EMG) at 4 time points: pre-operatively after ROM, effusion, and pain were resolved (baseline), immediately following 10 sessions of pre-operative rehabilitation (post-training), 6 months after ACLR following criterion-based rehabilitation (6 months), and 2 years after ACLR (2 years). Standard motion analysis methods were used to obtain stance phase kinematics and kinetics during walking at a self-selected speed. Kinetic measures of interest included external peak knee flexion moment (PKFM), peak knee adduction moment (PKAM), and knee adduction moment impulse during the first 50% of stance (KAMI).

Knee joint contact forces were derived using an EMG-driven Hill-type musculoskeletal model to estimate muscle forces. Muscle forces were used to calculate peak medial compartment contact forces (pkMC) during stance phase.

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 ($p = .209$, 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 ($p = .032$, nonOA: 3.41 ± 1.00 BW, OA: 2.49 ± 0.29 BW). Six months after ACLR the lower pkMC persisted in the OA group ($p = .038$, 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 ($p = .598$, 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 uninvolved 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.

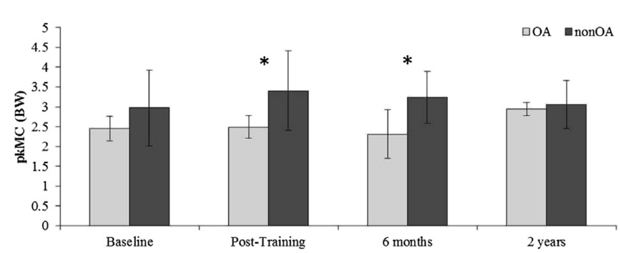

Figure 1. Peak joint contact force at the medical compartment during stance phase of walking. Asterisk represents $p<0.05$ between groups. Bars represent ±1 SD.