Medializing Center of Plantar Pressure Reduces Peak Knee Adduction Moment

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Introduction: The knee adduction moment (KAM) is higher than normal in individuals with medial compartment knee osteoarthritis (OA) [1] and has been implicated in both OA severity [2] and progression.[3] Typically, the KAM curve has two maximum values, or peaks, with the first occurring during early stance and the second occurring closer to terminal stance. Peak KAMs have been successfully reduced in some individuals by walking with altered gait patterns such as “medial thrust” gait;[4] however, individuals vary in their load response. Altered plantar pressure distributions (PPD), including medialized or lateralized shifts in center of plantar pressures (COP), have been proposed as one mechanism behind the successful KAM reductions, however a relationship of COP shifts with KAM changes have not been demonstrated. The aim of this cross-sectional study is to determine if reductions in peak KAM during medial thrust gait correlate with a medial shift in COP.

Methods: 12 healthy subjects (mean age 27±6.3 years, 7 males, 5 females) participated in a single session gait test. Each subject completed a total of 10 barefoot walking trials per limb including 5 trials of normal gait and for 5 trials of medial thrust gait. The same physical therapist trained all subjects in performing medial thrust gait. Data were obtained for both legs; in this abstract left leg data are reported. For simultaneous COP and 3-D ground reaction force acquisition, a pressure platform (Emed, Novel, Munich, Germany) was mounted onto a force plate (Bertec, Columbus, OH, USA) and the stacked assembly was leveled with the walkway. Lower extremity kinematics were obtained using 12 optoelectric cameras (Qualysis, Gothenburg, Sweden) and reflective markers on bony landmarks. Knee joint moments were calculated from ground-reaction forces and knee kinematics using inverse dynamics. All 3 capture systems were run at a frequency of 100 Hz to allow for accurate syncing of stance phase, KAM peak and impulse, and the corresponding plantar pressure. COP was quantified by determining the Medial to Lateral Pressure Index (MLPI), which compares the COP line during gait to the anatomical center line of the foot. This longitudinal line was defined as a line connecting the midpoint of the tip of the 2nd toe and the centroid of the heel (Figure 1). All COP tracing data points medial to the longitudinal line were considered negative while COP data points lateral to the longitudinal line were considered positive. The sum of the distances resulted in a either a negative (medialized) or positive (lateralized) shift in MLPI. The first peak KAM was paired with the first half of the MLPI and the 2nd peak KAM was paired with the 2nd half of MLPI. We also assessed the change in knee adduction angular impulse (KAI), a marker of medial knee loading throughout stance, [5] and compared it with the change in the entire stance MLPI. Linear regression analysis was used to compare the change in each peak KAM and KAI with the corresponding change in MLPI.

Results: 75% of tested subjects (9/12) reduced their first peak moment when asked to execute thrust gait. All of those individuals medialized their COP line. Out of the three subjects whose first peak KAM increased, two subjects lateralized their COP line. The change in first peak KAM and medial shift of COP were highly correlated (R²= 0.814, p<.001) as shown in Figure 2a. The 2nd peak KAM was reduced in 3 subjects, all of whom medialized their COP. However, 2nd peak KAM and COP shift were not correlated. The knee adduction angular impulse was reduced in 8 subjects, with 7 of those subjects medializing their COP (R²=0.413, p=.024).

Discussion: This study establishes that reduced first peak KAMs using a gait modification strategy are highly correlated with medialized COPs. The 1st peak KAM and the corresponding MLPI were highly correlated while the 2nd peak and its corresponding MLPI were not correlated. The first peak reductions are consistent with previous studies showing that medial thrust gait reduces the first peak much more consistently than the second peak. These finding suggest that subjects who successfully medialize their COP early in stance are also the candidates most likely to reduce their KAM thus redistributing load across the tibiofemoral joints. Only three subjects were able to reduce the 2nd peak KAM using thrust gait as modification. Interestingly, the COP was medialized in those subjects as well. PPD has been used extensively to characterize foot postures and foot disorders but has not been used to predict or change knee loading patterns in knee OA. Predicting load distribution across the tibiofemoral joint currently requires a gait laboratory, which is not practical for most health care centers, unlike a PPD measurement system such as a pressure plate that is more realistic in a clinical setting.

Significance: The results of this study demonstrate that plantar pressures are consistently medialized in subjects who successfully reduce their peak KAM during thrust gait. Therefore, COP changes may serve as a marker to predict changes in KAM.

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**Figure 1.** Medial-Lateral Pressure Index. Distances from each data point on the Center of Pressure Line (COP) to the Longitudinal Reference Line (LRL) were summed, with COP data points lateral to the LRL positive and those medial to the LRL line negative. In this example, the Normal Walk had roughly equal lateral and medial COP data points resulting in a MLH near 0.0mm, while the Medial Thrust Walk resulted in most COP data points positioned medial to the LRL, resulting in a MLH near -4.0mm.

**Figure 2.** The change (between normal gait and medial thrust gait) in peak knee adduction moment (KAM) during early stance versus the corresponding change in medial-lateral pressure index (MLH). Figure 2b: The change in peak KAM during late stance versus the corresponding change in MLH.

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