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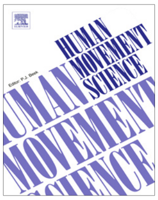

Full Length Article

# Contralateral pelvic drop during gait increases knee adduction moments of asymptomatic individuals

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ABSTRACT

*Purpose:* The current study purpose was to investigate the effects of contralateral pelvic drop gait on the magnitude of the knee adduction moment (KAM) within asymptomatic individuals.

*Methods:* 15 participants walked on a dual belt instrumented treadmill while segment motions and ground reaction forces were recorded. Participants completed typical gait trials and pelvic drop gait trials. The net external KAM was calculated using inverse dynamics. Peak and impulse were identified. Frontal plane hip abduction/adduction and pelvic drop were determined. Correlations and paired *t*-tests were used for statistical hypothesis testing (alpha = 0.05).

*Results:* Peak hip adduction angle reached 4° (±6°) during pelvic drop trials compared to 0° (±6°) in the typical gait trials ($p < 0.05$) equating to 4° of pelvic drop. KAM impulse was higher in the pelvic drop trial (0.16 Nm s/kg ± 0.04) compared to the typical gait trial (0.13 Nm s/kg ± 0.05) ($p < 0.001$). Peak KAM was higher in the pelvic drop trial (0.55 Nm/kg ± 0.15) compared to the typical gait trial (0.40 Nm/kg ± 0.109) ($p < 0.001$). Correlations between change in KAM and change in hip adduction moment and pelvic drop were $r > 0.80$ ($p < 0.001$).

*Conclusion:* Pelvic drop gait increased KAM peak and impulse. Results have implications for understanding relationships between frontal plane hip movement and the knee adduction moment during gait.

## 1. Introduction

Knee joint mechanics, particularly those that have implications for joint loading, have been crucial to the understanding of lower extremity injury and disease etiology and progression (Andriacchi, Koo, & Scanlan, 2009; Bennell et al., 2011). Of particular importance is the medial-lateral load distribution in the tibio-femoral compartment of the knee joint and its consequences for the prevalent disease of knee osteoarthritis (OA) (Andriacchi et al., 2009). The net external knee adduction moment (KAM) is used as a surrogate measure of knee compartment loading (Bennell et al., 2010; Chang et al., 2005; Mundermann, Asay, Mundermann, & Andriacchi, 2008; Rutherford, Hubley-Kozey, & Stanish, 2014; Takacs & Hunt, 2012) and has been shown to have a strong correlation with *in vivo* medial compartment knee loads (Zhao et al., 2007).

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A higher KAM is associated with an increase in pain (Thorp, Sumner, Wimmer, & Block, 2007), cartilage deterioration (Andriacchi et al., 2009) and joint space narrowing (Sharma et al., 1998). Longitudinal studies found that individuals with a higher baseline peak KAM (Miyazaki et al., 2002) and KAM impulse (Bennell et al., 2011) had an increased likelihood of OA progression. There is presently no cure for OA, however KAM reduction may reduce OA symptoms, but more importantly, improve joint mechanics to ensure continued joint function.

Over the past decade, numerous studies have attempted to understand the implications of hip abductor function (strength and activation) to control frontal plane knee mechanics during gait (Henriksen, Graven-Nielsen, Aaboe, Andracchi, & Bliddal, 2010; Pohl et al., 2015; Rutherford et al., 2014). Chang et al. (2005) and Mundermann, Dyrby, and Andriacchi (2005) provided the original rationale to support this relationship. Chang et al. (2005) found that a decreased hip abduction moment during gait at baseline increased the likelihood of ipsilateral medial knee OA progression from baseline to 18 months. Mundermann et al. (2005) observed that individuals with severe knee OA had lower hip abduction moments and higher KAM compared to age matched healthy controls. Authors theorized that the reduced hip abduction moments observed were the result of decreased hip abduction strength. Hip abduction strength has been found to be reduced in individuals with knee OA (Hinman et al., 2010), providing a plausible rational for previous conclusions. Studies have since focused on hip abductor strengthening (Bennell et al., 2010; Sled, Khoja, Deluzio, Olney, & Culham, 2010; Thorp et al., 2010), altering hip abductor function (Henriksen et al., 2010; Pohl et al., 2015), and electromyographic evaluations (Rutherford et al., 2014) to understand the potential relationship between these muscles and KAM features. Conclusions are varied and a consistent message is not apparent.

The inability of the hip abductors to generate sufficient torque to prevent excessive femoral adduction (i.e. pelvic drop) during the loading response of the gait cycle is generally associated with a contralateral pelvic drop (Trendelenburg (TB) gait) which in theory should increase the KAM (Mundermann et al., 2005). Takacs and Hunt (2012) examined the pelvic adduction angle and KAM during a unilateral standing task. They found that KAM was significantly increased with a contralateral pelvic drop compared to a level pelvis during single limb stance. However, they assessed the pelvic drop during a static condition. Since individuals rely on walking as a central mode of transportation, and gait has been used as a model to understand lower extremity pathomechanics associated with injury and disease, it is important to investigate these mechanics during dynamic conditions. Despite work completed to date on hip abductor function (strength and activation) during gait, we currently do not know if walking with an increased hip adduction angle during stance (i.e. pelvic drop) changes KAM amplitudes.

Therefore, the purpose of this study is to examine the effects of a contralateral pelvic drop gait pattern compared to a typical gait pattern on the magnitude of KAM, as measured by peak KAM and KAM impulse, within a healthy cohort and determine whether an association exists between the change in frontal plane hip angle and change in KAM. We hypothesize that ipsilateral peak KAM and KAM impulse will be higher in the contralateral pelvic drop trial compared to the typical gait trial. We also hypothesize that the change in KAM impulse and peak KAM will be strongly associated with the increase in contralateral pelvic drop angle.

## 2. Materials and methods

### 2.1. Participants

Healthy individuals between the ages of 18 and 35 were recruited using poster boards and email distributions from University and hospital communities. Individuals were included if they had no history of cardiovascular disease, neurological or cognitive diseases that would impair motor functioning or ability to follow instructions, no known musculoskeletal disease, no recent history of musculoskeletal injury, no lower limb surgery within the past year and able to walk independently. Written informed consent was provided in accordance with the institutional Research Ethics Board (NSHA-RS/2015-019).

### 2.2. Gait analysis

Data collection took place at the Joint Action Research Laboratory, School of Physiotherapy, Dalhousie University, Halifax, Nova Scotia, Canada. Participants changed into tight fitting shorts, a T-shirt and removed their footwear. Height, weight, age, sex, thigh circumference, and calf circumference were recorded. Participants completed five walking trials at a self-selected speed across the GaitRITE™ walkway to determine average walking speed (Rutherford, Moreside, & Wong, 2015). Following these walking trials, participants observed one or more of the investigators walk with a visually obvious unilateral contralateral pelvic drop during ipsilateral loading response. Participants then practiced as many times as needed to re-create the unilateral pelvic drop gait pattern during over ground walking. The initial standardized cue was "When your right heel first touches the ground, let your left hip drop down". The success of the contralateral pelvic drop was determined by visual observation as this would be consistent with a clinical evaluation of this movement pattern. This was completed by the three principal investigators and two physiotherapists. All evaluators agreed whether gait modifications were appropriate. If it was not deemed an appropriate amount or proper timing of the hip drop, additional individualized instructions and cues were provided in order for the participant to successfully perform the modification. These instructions and cues included not to lean their trunk over their ipsilateral hip (i.e. reverse Trendelenburg) and maintain knee flexion and extension motions as