3-2013

Medial knee joint loading during stair ambulation and walking while carrying loads

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ABSTRACT

Carrying loads while walking or using stairs is a common activity of daily living. Knee osteoarthritis is associated with increased external knee adduction moment (KAM) during walking, so understanding how the additional challenges of stairs and carrying loads impact these moments is of value. Sixteen healthy individuals performed three types of MOTION (walking, stair ascent, stair descent) under three LOAD conditions (no load, carrying a 13.6 kg front load, carrying 13.6 kg load in a backpack). Three-dimensional gait analysis was used to measure KAM. Results of ANOVA showed a significant main effect of both MOTION and LOAD on peak KAM ($p<0.001$), but no significant MOTION x LOAD interaction ($p=0.250$). Peak KAM during stair ascent was about two-times those seen in stair descent ($p<0.001$) and was significantly higher than those seen in walking ($p<0.001$). Conditions with LOAD generated significantly greater KAM as compared to the no-LOAD conditions ($p<0.001$). These findings suggest that carrying a load of moderate magnitude while climbing stairs significantly increases the peak KAM – a risk factor associated with knee osteoarthritis.

This is an author's manuscript of an article from, Gait & Posture37 (2013): 460-462, doi: 10.1016/j.gaitpost.2012.08.008.

INTRODUCTION

Manual carriage of loads is integral to many occupational, recreational, and household tasks [1]. Epidemiological studies have associated physically demanding tasks, such as carrying loads, with knee osteoarthritis [2]. In particular, the external knee adduction moment (KAM) is indicative of medial knee joint loading, the site most commonly affected by osteoarthritis. Studies have observed that during walking, higher peak KAM magnitudes are related to the development of knee pain [3] and with a 6.5-fold increase in risk of knee OA progression for every one percent increase in KAM (normalised by body weight x height) [4]. Accumulating cross-sectional evidence indicates an association between peak KAM and medial tibial cartilage degradation in people with knee OA [5, 6]. These studies highlight the clinical relevance of assessing peak KAM during everyday tasks.

The KAM has been described during stair use and walking [7, 8] with the highest peak KAM found during stair ascent as compared to stair descent and walking [8]. Furthermore, studies have also investigated biomechanical effects of external load carriage during walking and stair use [9-11]. However, to the authors' knowledge, no research has described the effect of carrying an external load on peak KAM during stair use or walking. Therefore, we investigated how carrying loads affects peak KAM during stair ascent, stair descent, and walking. Specifically, two carrying techniques involving 13.6 kg (30 lbs) were assessed: a container held in front of the body with two hands (front load) and a backpack. The chosen mass approximates mass used in previous research (15kg) [1].

These tasks were selected based on their applicability to everyday situations and occupations. It was hypothesised that firstly, the peak KAM would be highest during stair

ascent when compared to stair descent and walking and secondly, that carrying an external load would significantly increase peak KAM during stair use and walking.

METHODS

Sixteen healthy adults (nine males; age 26 $\pm$ 3 years; height 1.73 $\pm$ 0.08 m; mass 69.3 $\pm$ 9.4 kg) with no musculoskeletal complaints participated. The Institutional Review Board approved the study, and participants provided written informed consent prior to participation. A three-step staircase (step height 18.5 cm, tread depth 29.5 cm) and a 10 m walkway were used. Kinematic and kinetic data were sampled at 160Hz and 1600Hz respectively. Retro-reflective markers (1.9 cm diameter) were placed bilaterally over the malleoli, heel dorsifoot and lateral aspect of the foot, acromion processes, anterior and posterior superior iliac spines, greater trochanters, anterior thighs, medial and lateral femoral condyles, anterior shanks and sacrum [11]. Data were processed using a forth order, symmetric Butterworth filter applied to the kinematic data and ground reaction force (GRF) data with a low-pass cut-off frequency of 6 Hz.

Two independent variables were assessed: MOTION (three levels: walking, stair ascent, and stair descent) and LOAD (three levels: no load, front load, and backpack load). The dependent variable was peak KAM. Participants performed five trials of each condition at a self-selected pace while barefoot, and conditions were randomly presented. Using inverse dynamics, peak KAM (normalised by body mass) was found during the stance phase of walking and on the first and second stair steps of stair ascent and descent. Stance phase was defined as previously described [12]. Paired t-tests determined no statistical difference between peak KAM during the first and second stair step of stair ascent or stair descent.

Therefore, peak KAM was averaged for step one and step two, and used in subsequent analyses. A two-way (3×3) repeated measures ANOVA was used to explore the effects of MOTION and LOAD and their interaction on peak KAM. Statistical analyses were performed using SPSS (SPSS, Chicago, IL). Significance was set at $p<0.05$.

RESULTS

There were significant main effects for MOTION ($p<0.001$) and LOAD ($p<0.001$), but no significant MOTION x LOAD interaction ($p=0.250$). Both front load and backpack load showed an increased peak KAM compared to the no load condition (29% and 31% greater than no load, respectively; $p<0.001$) (Figure 1). However, LOAD location (front vs. back) did not have a significant effect ($p=0.690$). For MOTION, stair ascent had greater peak KAM compared to walking ($p<0.001$) and stair descent ($p<0.001$) (Figure 2). Peak KAM during stair ascent was more than twice the value seen in stair descent and was more than 30% greater than walking.

DISCUSSION

This study considered the relatively under-explored area of the biomechanics of carrying loads when using stairs and walking. These are common occupational tasks of daily living, and developing an appreciation for the effects of these tasks on knee loading is warranted considering the association between the KAM and knee pathology.

Our study is the first to highlight that carrying loads equivalent to approximately 20% body weight (BW) during common daily activities considerably elevates the peak KAM, which is reflective of increased medial knee joint loads. Specifically, peak KAM was approximately 30% greater while carrying an external load during all motions, and peak KAM was over 50%

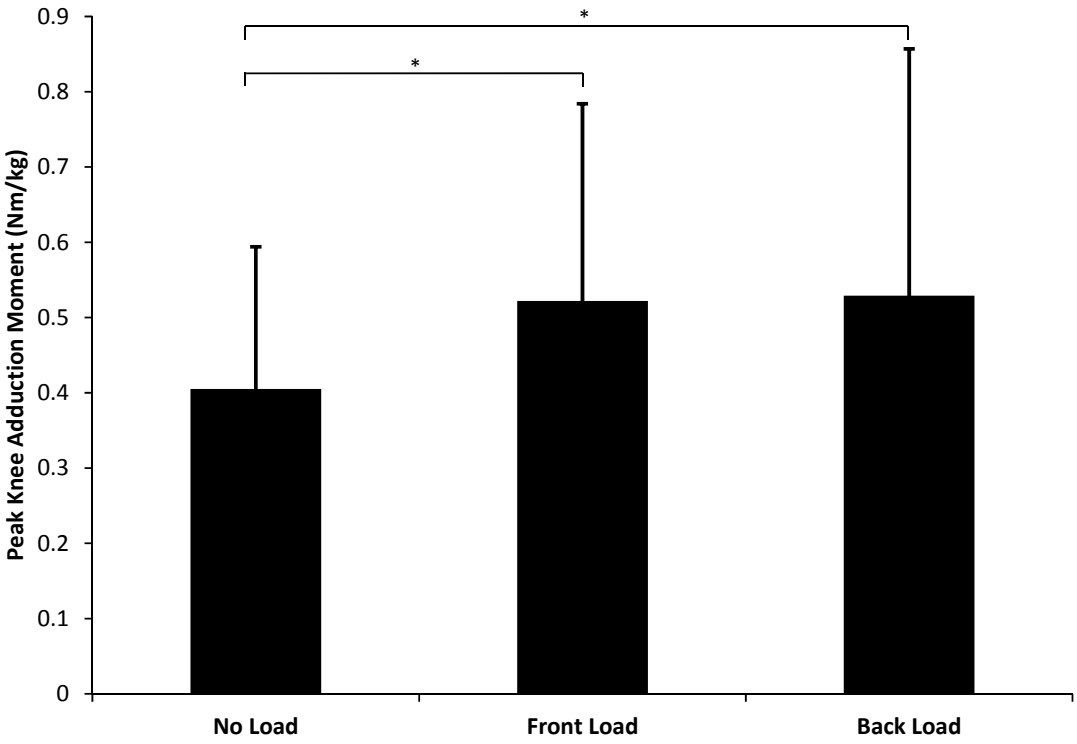
and 30% greater during stair ascent compared to stair descent and walking, respectively. In a clinical context, these magnitudes of peak KAM relative to walking while carrying no load are potentially harmful. For example, persons post-meniscectomy are at increased risk of developing knee OA [13]. A large cross-sectional study of individuals post-APM found an 11% increase in peak KAM during walking when compared with healthy matched controls [14]. It is widely believed this elevated peak KAM contributes to the onset of knee OA in this population. While an 11% increase in peak KAM is likely to have greater detrimental consequences post-meniscectomy, we infer that 30% increases in peak KAM for healthy individuals carrying loads (~20% BW) puts the medial knee joint under potentially pathological stress, particularly while climbing stairs.

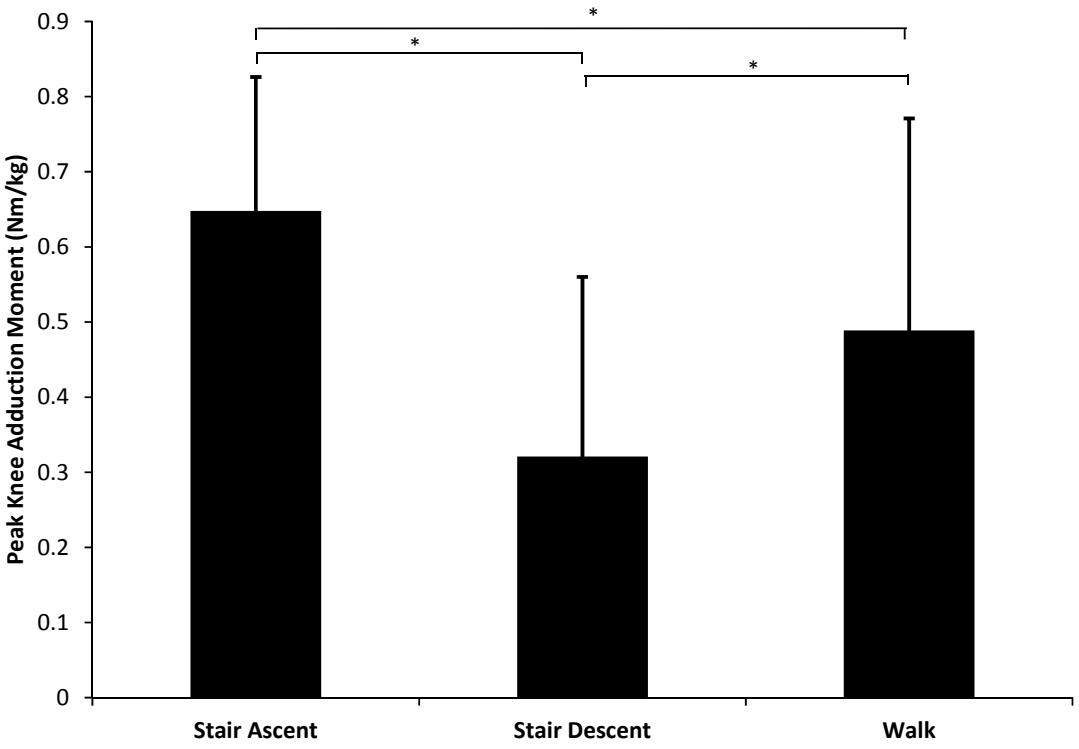
.Future studies should further consider the relationship between peak KAM and external load mass. The peak KAM possibly increases linearly with external load, as BW was found to account for 33% of KAM variance during walking [15]. In light of our findings, we recommend that individuals should monitor time spent carrying loads while walking and using stairs, particularly loads of 20% BW or greater during stair ascent.

Acknowledgements:
The authors would like to thank Mr. Eric Sterner for his contribution to the study design and data collection.

Figure 1. Mean (with standard error bars) peak knee adduction moment as a function of LOAD. * indicates $p<0.001$.

Figure 2. Mean (with standard error bars) peak knee adduction moment as a function of MOTION. * indicates $p<0.001$.


0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Peak Knee Adduction Moment (Nm/kg)
*
*
No Load
Front Load
Back Load



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