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Effect of lateral wedge length on ambulatory knee kinetics

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ABSTRACT

Background: Lateral wedge insoles (LWI) were proposed to treat medial knee osteoarthritis through reductions of the ambulatory knee adduction moment (KAM). Limited attention was however paid to the LWI length, resulting in unclear understanding of its effect on KAM reductions. The knee flexion moment (KFM) was also shown to be important in knee osteoarthritis, but little is known about the effect of LWI length on it.
Research question: This study aimed to compare the KAM and KFM of healthy subjects walking with four different lengths of LWI, explicitly without LWI and with LWI below the hindfoot (HF), below the hindfoot and forefoot (HF + FF) and below the hindfoot, forefoot and hallux (HF + FF + HX) segments.
Methods: Nineteen healthy participants (63% male; 24 ± 3 years old) walked in an instrumented gait lab with LWI of four different lengths. Repeated one-way ANOVAs and post-hoc *t*-tests were used to compare knee kinetics among LWI lengths.
Results: The peak value of the KAM during the first half of stance and the KAM impulse differed with respect to the LWI length ($p < 0.001$). A length of at least HF + FF, but not necessarily longer, was needed to decrease both KAM parameters compared to walking without LWI. The LWI length had no effect on the peak value of the KFM during the first half of stance ($p = 0.86$).
Significance: The results in this study could contribute to better selections of LWI for medial knee osteoarthritis and suggested that the length of the LWI could be a critical factor that should be considered in future research.

1. Introduction

Knee osteoarthritis (OA) is a disease causing pain and functional disability in approximatively 8% of men and 16% of women [1]. Since no cure has been found for it, there is a critical need for therapeutic options to slow disease progression. Walking mechanics was shown to play an important role in OA development [2,3]. Specifically, for medial compartment knee OA, the most frequent form of the disease [4], the maximum value of the knee adduction moment (KAM) during the first half of stance (1st peak) and the KAM impulse have been consistently associated with pain as well as disease severity and progression [5–7]. Therefore, gait interventions reducing these kinetic parameters are sought as a means to treat medial knee OA patients.

Lateral wedged insoles (LWI) have been proposed to decrease the KAM, with studies reporting reduced 1st peak in healthy subjects and OA patients walking with LWI running from the heel until the tip of the metatarsals to the tip of the toes [8,9]. On the other hand, some studies have reported no significant decrease with rearfoot LWI [10,11]. Although comparing studies is difficult due to the large variations in KAM results, certainly related to varying methodology among studies, prior works suggest that the length of the LWI influences the modifications in KAM. Interestingly, while the effect of the wedging amplitude has been well described [12,13], little is known about the effect of LWI length. To the authors' knowledge, there has been one study comparing LWI of different lengths [14]. It reported reduction in the 1st peak with full-length but not with rearfoot LWI, confirming an effect of the LWI length on the KAM modifications. Additional research considering different LWI lengths is however necessary. Indeed, during walking, the foot functions primarily as three segments, the hindfoot (HF), forefoot (FF) and hallux (HX) [15–17], and the effect of LWI should be determined with respect to these segments. In comparison, the rearfoot LWI used in the prior study assessing the effect of LWI length included the HF and half of the FF. Determining the effect of LWI relative to the three primary segments would notably help selecting LWI for medial knee OA patients among the devices in the market. It would also provide a basis to interpret previous studies testing LWI of

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Fig. 1. Bottom view of the comfort insole with the four lengths of LWI used in this study.

varying lengths. Prior research put little focus on the KAM impulse, and a better description of the effect of LWI length on this parameter could likewise facilitate the selection among commercially available LWI and enhance the interpretation of LWI literature.

Better understanding the length of LWI, necessary to reduce the KAM 1st peak and impulse, could also have implications on the design of new footwear for medial knee OA (e.g., orthotics or shoes). In fact, normal walking includes a roll of the foot during stance phase, consisting in a succession of three rockers [18]. The third rocker, between FF and HX, requires a large dorsi-flexion of the toes which could be altered if the amount and/or stiffness of the footwear components below the HX segment are too high [19,20]. Disturbing the dorsi-flexion of the lesser digits could have important negative clinical implications. Therefore, there is a need to determine whether the LWI should run until the tip of the toes, or if LWI below the HF and FF segments are enough to reduce the KAM. This is important because LWI running until the tip of the toes are common in knee OA literature [8,9] and the only study assessing LWI length so far did not consider a LWI running below the HF and FF [14]. The possibility to shorten the LWI could also enhance comfort, notably regarding blisters [21], and thus improve compliance. The possibility of limiting the LWI to the HF and FF segments is particularly motivated by the fact that the toes are loaded late during stance compared to the occurrence of the KAM 1st peak and impulse [22].

Since the maximum value of the knee flexion moment (KFM) during the first half of stance (1st peak) has been shown to complement the KAM parameters in the assessment of the mechanical load acting on the knee during walking [23], it has been receiving a growing interest in the study of OA. Particularly, a larger KFM 1st peak was recently associated with faster progression of medial knee OA [7], suggesting that gait interventions, such as LWI, should not increase this parameter [24]. Data in literature seem to indicate no effect of LWI on KFM 1st peak [25,26], but a study describing the effect of LWI length on this kinetic parameter is missing.

The present work aimed to compare the KAM and KFM of healthy subjects walking with four different lengths of LWI, explicitly without LWI and with LWI below the HF, HF + FF and HF + FF + HX segments. This study specifically tested the hypothesizes that: 1) a minimum length of HF + FF is necessary for LWI to reduce the KAM 1st peak and impulse; 2) there are no differences in KAM parameters between LWI of lengths HF + FF and HF + FF + HX; 3) there are no differences in KFM 1st peak among the four LWI lengths.

2. Methods

2.1. Participants

Nineteen healthy subjects (12 males) without history of serious lower extremity injury took part in this study. Mean (± standard deviation) age, height and weight of the participants were 24 ± 3 years old, 1.76 ± 0.10 m and 71 ± 12.2 kg, respectively. A sample size calculation was performed using the effect sizes of LWI on KAM parameters in healthy subjects (Cohen's d > 1.2) reported in a prior review study [8]. To be conservative and consistent with preexisting data, the sample size calculation was based on multiple paired *t*-tests and lower effect size (Cohen's d = 1.0). With a power of 80% and an effective alpha level of 0.8%, a minimum of 16 participants was required for this study (G*Power, DE). This research was approved by the local ethics committee, and informed consent was obtained from all participants before data collection.

2.2. Gait analysis

Participants performed a series of gait trials at normal self-selected speed with LWI of four different lengths. Specifically, they walked with (1) neutral frontal plane stability shoes (gel-beyond, Asics, JP) as a control (i.e., with LWI length of zero) and with the same shoes when custom LWI were added below the (2) HF, (3) HF + FF and (4) HF + FF + HX segments. After reviewing multi-segment foot models [15–17], it was decided to separate the HF and FF at the basis of the metatarsals, and separate the FF and HX at the top of the metatarsals (Fig. 1). LWI were made of high density ethylene vinyl acetate (EVA) with a durometer of 60 (Shore C) and wedged at 5° following literature recommendations [12,13]. They were inserted between the comfort insole and the midsole in both, the left and right, shoes.

The kinetics of the right knee was measured during walking trials across a 10 m long walkway instrumented with a motion capture system (Vicon, Oxford, UK) and two ground-embedded force plates (Kistler AG,