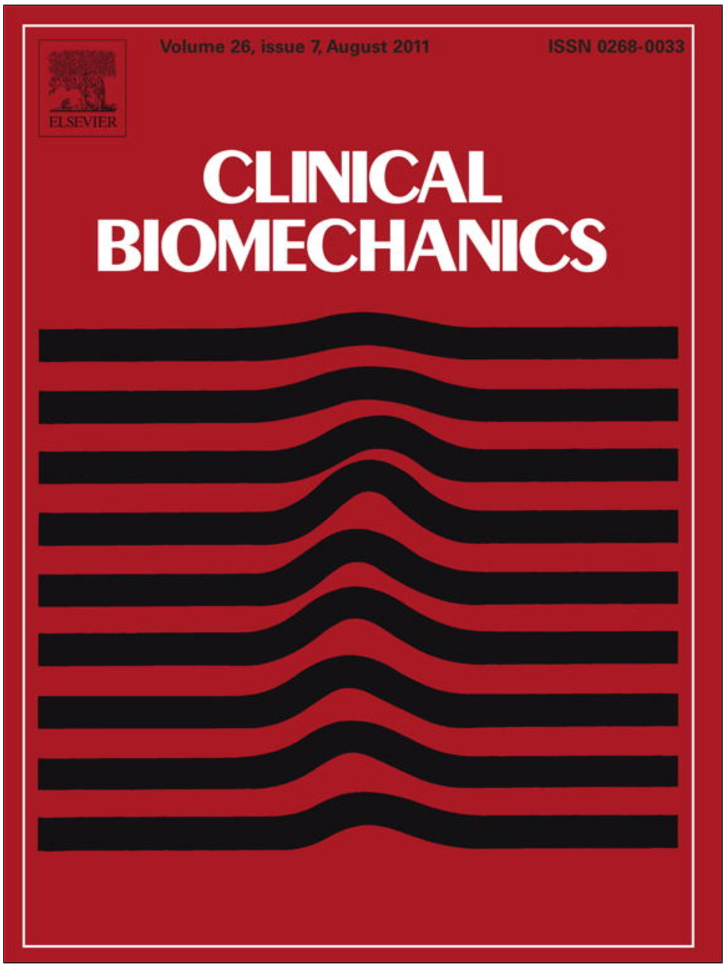
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Biomechanical changes accompanying unilateral and bilateral use of laterally wedged insoles with medial arch supports in patients with medial knee osteoarthritis

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ABSTRACT

Background: Laterally wedged insoles have controversial effect in treating medial compartment knee osteoarthritis. This study examined the effects of unilateral and bilateral use of insoles having medial arch supports and of different inclinations on the frontal plane external hip, knee, subtalar moments and pelvic alignment.

Methods: Kinetic and kinematic gait parameters were collected from 21 patients with primary medial knee osteoarthritis. The insoles' inclinations were 0, 6 and 11°, where each of the 6° and 11° was used once unilaterally and another bilaterally while the 0° was used bilaterally as a control.

Findings: The Multivariate Analysis of Variance revealed significant increase in the external subtalar eversion moment using either of the 6° or 11° laterally wedged vs the 0° non-wedged insole conditions ($P=0.003$). Moreover, there were significant increases in the external eversion moment using the 11° vs the 6° insole conditions ($P<0.05$). However, there were no significant differences for the remaining tested variables ($P>0.05$). The bivariate correlations revealed significant negative correlations between the subtalar eversion and knee adduction moments ($r=-0.409$, $P=0.000$) and the subtalar eversion and hip adduction moments ($r=-0.226$, $P=0.049$), and positive correlation between the hip and knee adduction moments ($r=0.268$, $P=0.019$).

Interpretation: The non-significant reduction in the external knee adduction moment may question the efficacy of using wedged insoles having medial arch supports in treating patients with medial knee osteoarthritis. Additionally, using such insoles did not produce appreciable mechanical effects on remote articulations as the hip and pelvis.

1. Introduction

Osteoarthritis (OA) is a potentially disabling disease that develops when the normal synovial joint structure or function is disrupted (Arden and Nevitt, 2006). It affects 13.9% of adults aged 25 and older and 33.6% of those older than 65 (Lawrence et al., 2008). It affects 240 cases for every 100,000 (Oliveria et al., 1995) with men having 45% lower incidence than women (Strikanth et al., 2005).

Patients with knee OA usually present with major involvement in only one compartment with the medial compartment being involved nearly 10 times more often than the lateral one (Ahlback, 1968). The unequal distribution of the transmitted load is due to the fact that the line of force acting at the foot passes medial to the knee joint (Johnson et al., 1980), producing knee adduction moment. The adduction moment tends to adduct the tibiofemoral joint providing a major contribution to the elevated medial compartment compressive load (Goh et al., 1993).

The increased medial compartment compressive load together with the induced lateral joint laxity produced via chronic stretching suggest that the knee adduction moment play a key role in the pathogenesis of knee OA (Goh et al., 1993). Additionally, the adduction moment is significantly correlated with radiographic disease severity (Mundermann et al., 2005; Sharma et al., 1998), where it is greater in patients than healthy subjects and in patients with severe OA than those with less severe OA (Baliunas et al., 2002; Hurwitz et al., 2002; Lewek et al., 2004). Longitudinal studies have also suggested that radiographic OA progression increases 6.46 times with a 1% increase in adduction moment (Miyazaki et al., 2002). Moreover, the higher knee adduction moment is related to the development of chronic knee pain on the long run, it remains unknown how this occurs. One possible hypothesis is that higher knee adduction moments may mediate knee pain by excessively loading the medial compartment. Increased loading on the medial compartment of the knee is likely to produce trauma and contusion to the subchondral bone, with subsequent pain (Amin et al., 2004).

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Because of the above findings and because it is difficult to measure the medial joint load directly, the knee adduction moment serves as an indirect measure of the medial joint loading (Prodromos et al., 1985; Schipplein and Andriacchi, 1991; Wang et al., 1990). Since the knee joint adduction moment is proportional to the combination of ground reaction force and its moment arm (Schipplein and Andriacchi, 1991), most of treatment strategies aim to reduce this moment through reducing the moment arm.

One of the forms of conservative treatment strategies developed for patients with medial compartment knee OA is using laterally wedged insoles. A laterally wedged insole (LWI) is a shoe insert with a thicker lateral border than medial thereby tipping the calcaneus into a valgus position (eversion). Reduction in lateral knee thrust (Ogata et al., 1997; Shimada et al., 2006), ligamentous tension (Yasuda and Sasaki, 1987) and pain together with improved function (Barrios et al., 2009; Fang et al., 2006; Toda and Segal, 2002) in patients with mild to moderate medial compartment knee OA have been consistently observed with the use of LWIs. This might be attributed to the change in the mechanical alignment of the lower limb to a more vertical position caused by the valgus correction of the calcaneus (Yasuda and Sasaki, 1987). It was theorized that these postural changes cause a lateral shift of the center of pressure (COP) which results in an increase in the subtalar eversion moment arm and a decrease in the knee adduction moment arm (Crenshaw et al., 2000; Yasuda and Sasaki, 1987).

While the use of LWIs began to attract attention, there is a lot of controversy in the literature regarding its efficacy in providing consistent reduction in knee external adduction moment (Butler et al., 2007; Hinman et al., 2008; Kakihana et al., 2004; Kakihana et al., 2007; Kerrigan et al., 2002; Maly et al., 2002; Nester et al., 2003). Moreover, it was noticed that almost all of the reported studies were restricted to studying the effects of these LWIs on the subtalar and knee joints only. To our knowledge, very few studies examined their effects on remote body regions knowing that postural changes in the calcaneus (caused by the LWIs) is expected to be associated with mechanical changes in remote body regions during closed kinematic chain activities as during gait (Gurney, 2002; Khamis and Yizhar, 2007).

In addition, reviewing the literature revealed that most of the studies that reported knee adduction moment reduction used the LWIs unilaterally on the affected side (Butler et al., 2007; Fang et al., 2006; Giffin et al., 1995; Kerrigan et al., 2002).The unilateral use of these insoles was found to cause an increase in the subtalar eversion (pronation) which is a possible cause of postural asymmetry with one foot being more pronated than the other(Botte, 1981; Kakihana et al., 2005; Rothbart and Estabrook, 1988). Asymmetrical foot pronation, with a difference exceeding 2° of stance phase pronation between both limbs is associated with increasedtibial and femoral internal rotation, anterior pelvic tilt (Botte, 1981; Khamis and Yizhar, 2007; Parker et al., 2008; Pinto et al., 2008; Rothbart and Estabrook, 1988) together with functional leg length discrepancy (Botte, 1981; Cibulka, 1999; Gurney, 2002; Rothbart and Estabrook, 1988). These postural changes increase the risk for musculoskeletal disorders development which may include plantar fasciitis and calcaneal spur (Lutter, 1982), inflammation of the Achillis tendon (Clement et al., 1990), chondromalacia, sacroiliac dysfunction, low back pain, sciatica (Botte, 1981; Hammer, 1992; Rothbart and Estabrook, 1988) and scoliosis (Aebi, 2005; Gurney, 2002). This implies the necessity of comparing the effects of unilateral vs bilateral application of LWIs on other body segments' postures and mechanics.

Additionally, most of the studies conducted in this field examined the insoles that had no arch supports. Un-supporting the medial arch of the foot while placing the foot in a more pronated position with LWI use is expected to increase the tension on the medial aspect of the foot, the perceived discomfort (Butler et al., 2007; Rubin and Menz, 2005) and the local peak pressures on the sole of the foot while walking (Tsung et al., 2004).

So, the purpose of the present study was to compare the effects of unilateral vs bilateral application of laterally wedged insoles with medial arch supports on frontal plane lower limb joints' moments together with frontal plane pelvic alignment. This is in addition to investigating the inter-relationships among the frontal plane lower limb joints' moments with the use of these insoles.

2. Methods

2.1. Subjects

Upon approval of Cairo University's supreme council of postgraduate studies and research, twenty-one female patients with primary medial compartment knee OA were recruited for this study. Their mean (SD) age, weight and height were 54.1 (7.42) year, 84.19 (8.75) kg and 1.57 (0.06) m respectively. They were referred by an orthopedist and a rheumatologist who were informed of the criteria of subject inclusion and exclusion. Medial compartment knee OA was diagnosed according to the criteria of the American College of Rheumatology (Altman et al., 1986). The criteria involved a radiographic evidence of medial femorotibial OA on plain weight-bearing standing X-rays, medial knee pain for most days in the past month, pain of at least 30 mm on a 0–100 mm Visual Analog Scale (VAS) following physical activities during the previous two days and at least one of the following items: age greater than 50 years, morning stiffness of less than 30 min duration or crepitus on active knee joint motion.

In the present study, patients had radiographic evidence of grade II or III medial knee OA determined by Kellgren and Lawrence (1957) OA severity grading scale. Patients also had a lateral femorotibial angle (FTA) of 176–180° indicating varus knee alignment (Goker and Block, 2007; Khan et al., 2008). Subjects were excluded if they had: serious clinically active inflammatory disease (mainly rheumatoid arthritis), limitation in the hip, knee or subtalar joints' ranges of motion, previous knee joint trauma or surgery or intra-articular corticoid injection within the past month, significant foot deformity especially forefoot valgus deformity, structural leg-length discrepancy, inability to walk independently without the use of assistive devices for at least 20 min and concurrent use of any insoles or other custom-made orthotics in the shoes.

2.2. Instrumentation

A six-camera 3D Motion Analysis System (120 frames/sec; Pro-reflex, Qualisys, Inc, Gothenburg, Sweden) with an AMTI (Advanced Mechanical Technology Inc., USA) force plate with a sampling rate of 1200 Hz were used to measure the concerned kinetic and kinematic parameters. The measured variables were: the external hip adduction, knee adduction and subtalar eversion moments together with the maximum degree of lateral pelvic tilt (pelvic obliquity) on the tested lower extremity (the affected limb in patients with unilateral knee OA affection and the most symptomatic limb in patients with bilateral knee OA affection) during the stance phase. Values for frontal plane moments were recorded at the first peak knee adduction moment occurring mostly in the midstance phase of the gait cycle (40–54% of the stance phase) as defined by (Andrews et al., 1996) and were normalized by body weight.

2.3. Insole description and application

Two types of removable insoles were tested in this study; non-wedged and wedged. The non-wedged insoles formed a 0° lateral inclination while the wedged ones formed 6.2° and 11.2° lateral inclinations (6° and 11° for the sake of simplification). Both the non-wedged and wedged insoles were made of a 3-mm even thickness sheet of rubber foam. The wedged insoles had additional laterally wedged sheets of Pedilin and Plastazote. The lateral heights of the 6°

and 11° LWIs, excluding the rubber foam height, were 6.55 mm and 11.95 mm respectively after considering the compressibility of the Pedilin and Plastazote. These lateral heights correspond to angles of 6.2° and 11.2° respectively using a heel width of 60 mm (that same width of the studied insoles) (Fig. 1).

All insoles (non-wedged and wedged) had medial arch supports and were covered with two layers of leather on both sides. The tested arch support was prefabricated. Its length was 33% of the insole length and width 45% of the insole width at the level of the peak height of the arch which was 1 cm (excluding the rubber foam height).The insoles were all trimmed and manufactured to fit inside unified, light-weight, thin and flexible-soled shoes which were provided for all patients tested in the study. The shoes bodies were made of stretchable material to fit adequately to the patient's foot (Fig. 2). The insoles were supplied in several sizes to accommodate the differences in shoe size among the patients. The thin flexible-soled shoes were tested so the loads on the force plate would not be dampened by thicker, inflexible ones. In this way, the maximum effect of the wedged insoles on the recorded moments at the tested joints would be most evident (Crenshaw et al., 2000).

The 0° non-wedged insoles were applied bilaterally and were used as the control (0°×0°). However, each of the 6° and 11° laterally wedged insoles was applied once bilaterally (6°×6° and 11°×11° respectively) and another unilaterally on the tested limb with a concomitant 0° non-wedged insole on the untested limb (6°×0° and 11°×0° respectively).Using the non-wedged insole on the untested limb aimed to neutralize the effect of the 3 mm height of the 3 mm even thickness rubber foam sheet that was used as a basis in all the laterally wedged insoles. Hence, ensuring that the effects produced by the insoles were confined to the degree of insole inclination only.

2.4. Procedures

Each patient was allowed to randomly select one from five folded papers located in a container and representing the five tested insole conditions. Insoles were tested according to this selection order. Then, twenty infra-red reflective markers were attached by the same investigator bilaterally to the acromion process, anterior superior iliac spine, greater trochanter, superior border of the patella, lateral knee joint line, tibial tuberosity, lateral malleolus, posterior aspect of the calcaneus (corresponding to the level of the forefoot marker), and the forefoot 1-cm proximal to the space between the second and third metatarsal heads placed on top of the comfortable shoes (Fig. 3). The last two markers were attached to the 12th thoracic and 2nd sacral vertebrae. Patients were allowed to acclimate to the testing procedure by walking with the inserted insoles at a self-selected speed for few minutes along a 10-m walkway prior to data collection (Crenshaw et al., 2000). Then, three successful trials of foot force plate contact were captured for averaging. Each time the LWI condition changed, patients were asked to take two practice walks to ensure the insoles were properly placed. Because it was intended to determine whether the LWIs were effective through a mechanical effect rather than neuromuscular adaptation, the study investigated only the immediate mechanical effect of these interventions instead of the long term one (Maly et al., 2002).

Fig. 2. A pair of thin flexible-soled comfortable shoes used during the testing process.

As mentioned earlier, values for frontal plane moments were recorded at the first peak knee adduction moment occurring mostly in the midstance phase of the gait cycle (40–54% of the stance phase) and were normalized by body weight.

2.5. Data analysis

All statistical measures were performed through the statistical package for social sciences (SPSS) version 17 for windows. Initially and prior to final analysis, data were screened for normality assumptions, homogeneity of variance and presence of extreme scores as a prerequisite for parametric calculations of the analysis of difference and analysis of relationship measures. Multivariate analysis of variance (MANOVA) was used to assess the effects of laterally wedged insole inclinations (0°×0°, 6°×0°, 6°×6°, 11°×0° and 11°×11°) on the tested variables of interest. Finally, Pearson product moment correlation coefficient was used to determine the interrelationships among the external hip adduction, knee adduction and subtalar eversion moments where the difference scores between the experimental and control conditions were taken into account instead of using the raw scores. The level of significance for each of the MANOVA and the correlation was set at an alpha level of 0.05 (Fig. 4).

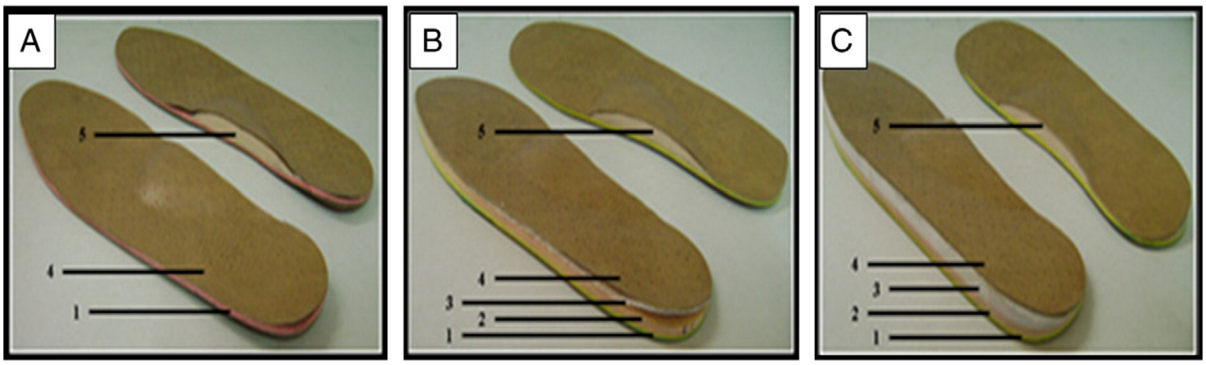

Fig. 1. The construction of the tested insoles (A: 0° non-wedged, B: 6° laterally wedged, and C: 11° laterally wedged insoles); 1 – a basic uniform layer of rubber foam (3 mm in all insoles), 2 – a laterally wedged layer of Pedilin (initial lateral height was 5 mm in both the 6° and 11° LWIs), 3 – a laterally wedged layer of Plastazote (initial lateral heights were 2 mm in the 6° LWI and 8 mm in the 11° LWI), 4 – a layer of leather, and 5 – a medial arch support.

Fig. 3. Flexible shoes with the reflective markers place on top.

3. Results

Statistical analysis revealed that MANOVA was significant at $P=0.003$ and the Post Hoc tests revealed that the external subtalar eversion moment increased significantly in each of the ‘$6°\times0°$, $6°\times6°$, $11°\times0°$ and $11°\times11°$’vs the ‘$0°\times0°$’ insoles and in the $11°\times0°$ vs $6°\times0°$, $11°\times0°$ vs $6°\times6°$ and $11°\times11°$ vs $6°\times6°$ insoles ($P<0.05$). However, there were no significant differences for the remaining tested variables ($P>0.05$) among the five tested insole conditions (Tables 1 and 2).

Finally, the bivariate correlations among the hip adduction, knee adduction and subtalar eversion moments revealed a significant positive correlation between the hip and knee adduction moments ($r=0.268$, $P=0.019$) with a regression equation of (knee adduction moment $=-0.054+0.305$ * hip adduction moment). However, there were significant negative correlation between the knee adduction and subtalar eversion moments ($r=-0.409$, $P=0.000$) with a regression equation of (knee adduction moment $=-0.02-0.672$ * subtalar eversion moment) and significant negative correlation between the hip adduction and subtalar eversion moments ($r=-0.226$, $P=0.049$) with a regression equation of (hip adduction moment $=0.01-0.259$ * subtalar eversion moment. The following figure presents the correlations mentioned ahead.

4. Discussion

In an attempt to solve the controversy towards the effectiveness of LWIs with medial arch supports in reducing external knee joint adduction moment, the effects of using LWIs of different inclinations (6° and 11°) on knee and subtalar moments were tested. The rationale for using the 6° and 11° inclinations was that they are similar to the second least and highest inclinations reported to significantly reduce the knee joint adduction moment based on several studies conducted in this field (Kakihana et al., 2004; Kakihana et al., 2005; Kakihana et al., 2007; Toda et al., 2004; Toda and Tsukimura, 2006). Findings reported a non-significant difference in the magnitude of the knee adduction moment among the five tested insole conditions ($P>0.05$). However, the subtalar eversion moment was found to increase significantly with the increase in the degree of lateral wedging ($P=0.000$). Our findings are supported by those reported by Nester et al. (2003)who compared a 10° LWI with usual footwear; however their increase in the subtalar eversion moment was insignificant.

Similarly, Maly et al.(2002)declared that wearing either a 5° LWI or a 5° valgus modified custom orthosis had not only produced a non significant difference in the peak knee adduction moment but also had produced a non significant difference in mediolateral center of pressure (COP) displacement. However, the researchers used heel wedging only not full-length foot wedging as we did in the present study. This might be responsible for the lack of any significance.

Controversially, our findings of insignificant difference in the knee adduction moment were opposed by the significance reported by Kerrigan et al. (2002). However, it should be pointed out that their examined patients used their own comfortable shoes. However, we preferred to unify the footwear for all of the examined patients to exclude any shoes characteristics that might interfere with the measured variables (Kerrigan et al., 2005).

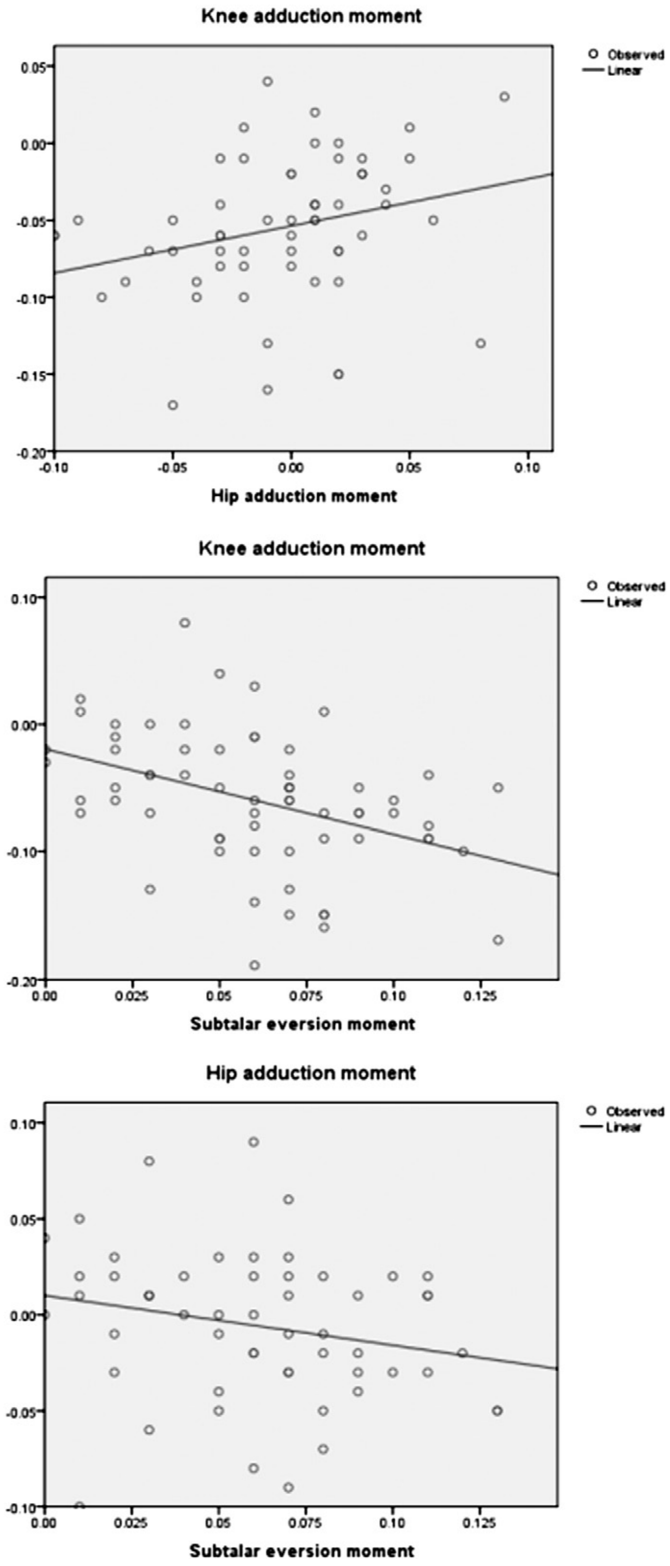

Fig. 4. Scatter plot for the bivariate correlation between the external hip adduction, knee adduction and subtalar eversion moments in patients with medial knee osteoarthritis.

Inspite that our findings of a significant increase in subtalar eversion moment is supported by Kakihana et al. (2004), their findings of a significant decrease in knee adduction moment opposes ours. However, their examined sample incorporated healthy adult

Table 1
Descriptive statistics of frontal plane hip, knee and subtalar moments (in Nm/kg) together with pelvic obliquity (in degrees) in patients with medial knee osteoarthritis during the five tested insole conditions.

	0°×0°	6°×0°	6°×6°	11°×0°	11°×11°
Hip adduction moment (Nm/kg)	0.89 (0.13)	0.91 (0.18)	0.91 (0.17)	0.91 (0.19)	0.89 (0.21)
Knee adduction moment (Nm/kg)	0.66 (0.16)	0.6 (0.14)	0.63 (0.16)	0.63 (0.15)	0.61 (0.15)
Subtalar eversion moment (Nm/kg)	0.04 (0.03)	0.1 (0.04)*	0.09 (0.04)*	0.13 (0.05)*†‡	0.13 (0.05)*‡
Pelvic obliquity (°)	4.38 (2.38)	3.5 (2.18)	4.02 (2.18)	4.4 (2)	4.05 (2.2)

(*) Significant vs the control condition, (†) significant vs the unilateral 6° condition, (‡) significant vs the bilateral 6° condition. The significance is set at the 0.05 level.

individuals, not elder patients as ours. Healthy young individuals may have greater adaptability to altered footwear than those with knee OA (Winter, 1991). Moreover, patients with knee OA are reported to have greater knee laxity than healthy controls (Lewek et al., 2004). This might have reduced the effect of LWIs in reducing knee adduction moment in patients with knee OA compared with healthy individuals.

The varied response to LWIs between healthy individuals and patients with medial knee OA was reported by Kakihana et al. (2007). The examined patients had smaller decrease in the knee adduction moment and smaller increase in the subtalar eversion moment than the healthy individuals using 6° LWIs. Moreover, it seems that the healthy individuals adapt faster to footwear changes as we proposed previously. It was found that the knee adduction moment significantly decreased and the subtalar eversion moment significantly increased in all the healthy individuals and only in the majority of the patients. It was shown that 17.6% (9/51) of patients had reversed changes; increased knee adduction moment, decreased or unchanged eversion moment. This is in addition to the varied response among the patients themselves to the LWIs as reported by Hinman et al. (2008). The researchers showed that although most of the examined patients had significant reduction in the first peak knee adduction moment using a pair of 5° LWIs, this reduction was not consistent across the cohort. The magnitude of the reduction ranged from 0.1% to 18.2%. The inconsistent individual's response to LWIs use was additionally supported by Butler et al. (2007).

In addition to the examined biomechanical effects of LWIs on the frontal plane knee and subtalar joints' moments, we decided to study their effects on the frontal plane hip joint moment and pelvic alignment. To our knowledge, Nester et al. (2003) were the only researchers who examined these latter effects during gait. They reported that a bilaterally applied pair of 10° LWIs did not produce a significant difference in either the hip adduction moment or the pelvic excursion. These findings come in accordance with ours which revealed insignificant difference in the magnitude of external hip adduction moment and the degree of pelvic obliquity among the five tested insole conditions.

Having a look at the characteristics of the insoles used throughout the previous studies and ours, it was noticed that the presence or absence of medial arch supports might have affected the findings greatly. In our study and the one conducted by Nester et al. (2003), the insoles incorporated medial arch supports as opposed to all the previously reported studies. A medially applied arch support might have interfered with the effect of LWI in producing foot pronation that is accompanied by lower limb postural changes responsible for reducing knee adduction moment as proposed by Yasuda and Sasaki (1987). Based on this postulation, the authors do not recommend the use of medial arch supports with laterally wedged insoles. However, it worth mentioning that if the insoles were to be used without medial arch supports for long periods of time, they will be exhaustive to the patients and might cause discomfort due to the increased tension on the medial aspect of the foot. Moreover, it was reported that flat insoles are associated with increased local peak pressures on the sole of the foot much more than the contoured ones (Tsung et al., 2004).

Considering the insignificant difference reported for the maximum degree of lateral pelvic tilt, the presence of the medial arch supports can provide an explanation for this lack of significance. Laterally wedged insoles are supposed to produce functional limb shortening through directing the calcaneus towards eversion and directing the talus medially and downwards towards inversion and planter flexion respectively. This causes a collapse of the medial longitudinal arch and consequently results in functional limb shortening (Cibulka, 1999; Gurney, 2002; Rockar, 1995). A functionally shortened limb is therefore expected to be associated with an increase in the degree of lateral pelvic tilt towards this side. Using the medial arch supports might have prevented the medial longitudinal arch from collapsing and consequently has hindered the effects of the LWIs on increasing the degree of lateral pelvic tilt from taking place.

Being interested in comparing the biomechanical effects of unilateral vs bilateral application of LWIs, the findings revealed a non significant difference between the unilaterally and bilaterally applied insoles using either degree of insole inclinations for the tested variables. Pinto et al. (2008)examined the effects of unilateral and bilateral increases in calcaneal eversion on pelvic alignment. They found that standing on a 10° laterally wedged board that was placed unilaterally with a simultaneous non-wedged board on the other side produced a significant increase in calcaneal eversion together with a significant increase in the degree of lateral pelvic tilt towards the side of increased eversion (functionally shortened). The average lateral pelvic tilt was 1.46°. On the other side, standing on bilaterally placed 10° wedged boards hasn't produced postural changes in the pelvic

Table 2
Post-hoc analysis for the multiple comparison between the five tested insole conditions for the subtalar eversion moment.

Dependant variable	(I) Insole condition	(J) Insole condition	Mean difference (I–J)	Sig	95% confidence interval	
					Lower bound	Upper bound
Subtalar eversion moment	1	2	−0.0578	0.001[a]	−0.0905	−0.0252
		3	−0.0475	0.004[a]	−0.0797	−0.0153
		4	−0.0932	0.000[a]	−0.1264	−0.0601
		5	−0.0875	0.000[a]	−0.1207	−0.0543
	2	3	0.0103	0.498	−0.0200	0.0406
		4	−0.0354	0.027[a]	−0.0667	−0.0041
		5	−0.0297	0.063	−0.0610	0.0017
	3	4	−0.0457	0.004[a]	−0.0766	−0.0149
		5	−0.0400	0.012[a]	−0.0708	−0.0092
	4	5	0.0057	0.721	−0.0261	0.0376

[a] The mean difference is significant at the 0.05 level.

alignment. However, it should be noticed that they used flat wooden boards, without medial arch supports and examined the individuals in static standing postures.

Finally, being interested in investigating the relationships among the frontal plane hip, knee and subtalar moments, the current study examined such correlations through the Pearson Product Moment Correlation Coefficient (r). The aim was to detect whether a decrease in the knee adduction moment, if any, would be associated with an increase in nearby joint moments. An increased moment about a joint implies that this joint is subjected to an increased risk of undergoing degenerative changes resulting from the increased joint reaction forces especially when LWIs were to be incorporated in walking activity. Findings revealed the presence of a significant positive correlation between the external hip and knee adduction moments which were recorded in the midstance phase of the gait cycle (40–54% of the stance phase). This might be attributed to their occurrence at almost the same timing with the GRFV located medial to the axes of both joints (Andrews et al., 1996; Hunt et al., 2006).

Additionally, findings revealed the presence of significant negative correlations between the external subtalar eversion moment and either of the hip or knee adduction moment. These findings are supported by those reported by (Kakihana et al., 2004; Kakihana et al., 2005).These negative correlations may verify the proposed mechanism of action of LWIs of being able to successfully shift the COP laterally. However, it should be noted that this may increase the demand on the internal invertors to counteract such shift leading to consequent pathomechanical changes to the foot.

4.1. Limitations

The external validity might be threatened by the inability to infer the findings to male population with the study being conducted on female participants.

5. Conclusion

The use of LWIs with medial arch supports did not lead to significant reduction in the frontal plane knee adduction moments when used either unilaterally or bilaterally. On the contrary, the current results support the proposed mechanism of the lateral shift of the center of pressure secondary to the use of such insoles. Such lateral shift did not lead to significant mechanical effect on remote body regions as the knee, hip and pelvis. Accordingly, the authors do not support the use of such insoles with medial arch supports in treating patients with OA.

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