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Effects of two different degrees of lateral-wedge insoles on unilateral lower extremity load-bearing line in patients with medial knee osteoarthritis

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ABSTRACT

Objective: The aim of this study is to assess the effect of 5 and 10° lateral-wedge insoles on unilateral lower extremity load carrying line in patients with medial knee osteoarthritis using the L.A.S.A.R. posture alignment system.

Patients and methods: Twenty subjects (10 females and 10 males, mean age 67.7 ± 5.4 years (range: 58–78) with bilateral medial knee osteoarthritis were included in the study. The laser line projected on the person by the L.A.S.A.R. posture alignment system showed joint load carrying line. The location of the joint load carrying line in static standing with one foot on the force plate was assessed with barefoot, and 5° and 10° lateral-wedge insoles. Displacement of the load carrying line was measured using a ruler placed tangentially to the patella at the level of joint line.

Results: The load carrying lines measured with 5° and 10° lateral-wedge insoles were significantly laterally located compared to that without wearing insole ($p < 0.001$). 10° lateral-wedge insole caused a significant more lateral shifting of the load carrying line than 5° lateral-wedge insole ($p < 0.001$).

Conclusion: Both wedge insoles was effective in moving of the unilateral lower extremity load carrying line to the lateral. Lateral wedged insoles are biomechanically effective and reduce loading of the medial compartment in patients with medial knee osteoarthritis.

Introduction

Knee osteoarthritis (OA) is a common medical problem which is a potential source of disability. In the general population, knee OA most commonly affects the medial compartment due to greater medial contact forces and knee joint adduction moment during weight-bearing activities.[1,2] Based on this pathophysiological mechanism, lateral-wedge insoles are utilized to unload weight from the medial compartment. Lateral-wedge insoles were shown to reduce knee joint adduction moment during gait by using a motion analysis system.[3–8] Knee adduction moment has been proposed as a surrogate measure for medial compartment load during gait, and a good correlation has been reported.[9] The effect of lateral-wedge insoles on reducing knee adduction moment may result from the more laterally shifted location of the center of pressure on the ground.[5] However, the effect of lateral-wedge insoles on knee load-bearing line has not been studied.

The L.A.S.A.R. posture alignment system (Laser Assisted Static Alignment Reference Posture, Otto Bock, Duderstadt, Germany) measures the vertical component of the ground reaction force acting on the force plate of the platform,[10] visualizing the load line while standing. The purpose of this study was to assess the effect of 5° and 10° lateral-wedge insoles on the unilateral lower extremity load-bearing line in patients with medial knee OA using the L.A.S.A.R. posture alignment system.

Patients and methods

Twenty subjects (10 females and 10 males) diagnosed with having bilateral medial knee OA and Kellgren–Lawrence grade of

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≥2[11] were included in the study. Mean age of the patients was 67.7 ± 5.4 years (range: 58–78 years), mean weight was 77.0 ± 7.7 kg (range: 62–87 kg), and mean body mass index was 28.7 ± 4.4 kg/m^2 (range: 24.1–33.3 kg/m^2). According to Kellgren–Lawrence grading scale, 8 patients had grade 2, 10 had grade 3, and 2 had grade 4 knee OA. The demographics of the subjects are presented in Table 1.

Exclusion criteria included flexion contracture of >5° at the knee joint, history of major trauma or surgery to the knee, infective or inflammatory pathologies of the knee joint, hip and ankle pathology, and involvement of the lateral compartment of the knee. Written informed consent of the participants was obtained. The study protocol was approved by the Institutional Review Board.

Unilateral lower extremity load-bearing line in patients with medial knee OA was documented using the L.A.S.A.R. posture alignment system. The patient's weight and location of the weight-bearing line in static standing with both feet on the force plate was determined. If the patient was standing with only 1 foot on the force plate, the force of that side and the resultant load line were measured. The system contained a force plate, a projection system, and electronics with a stepper motor, service, and display unit. The force plate included 4 sensor cells located in the corners. The microprocessor determined the center of the pressure and amount of the ground reaction force. The electronics triggered the stepper motor, whereupon it positioned a semiconductor laser to the center of the measured forces. The laser line was then projected on the subject, illustrating the location of center pressure. The location of the vertical ground reaction force was visibly indicated on the subject.[10]

Firstly, the subject's weight was measured in static standing with both feet on the force plate. Subjects stepped onto the force sensor platform and placed their contralateral leg on the leveling step plate (Fig. 1). For an objective measurement of unilateral lower extremity load line, subjects were asked to adjust the pressure applied by the foot on the force plate, with on-screen monitoring to confirm that half of the total body weight was being measured. When the researcher was certain that patients could adjust half of their weight on the force plate, the measurements were calculated. The joint space of the knee was defined by palpation at the medial and lateral sides. The joint line was an imaginary line between these 2 points and perpendicular to the long axis of the tibia. A ruler on the arm of a goniometer was placed tangentially to the patella at the level of the joint line. The goniometer was fixed at 90° for proper tangential placement. The ruler formed a straight line corresponding to the joint line. The patients practiced using lateral-wedge and the L.A.S.A.R. posture alignment system. When they felt comfortable with the process, the measurements were taken. The projection of the medial margin of the joint line on the ruler was the reference point for the measurements (Fig. 2). The distance from the reference point to the load line was measured on the ruler. Subjects were evaluated first without wearing insoles. The measurements were repeated with the subjects wearing lateral-wedge insole inclined at 5° and 10°. All measurements were performed by the same investigator.

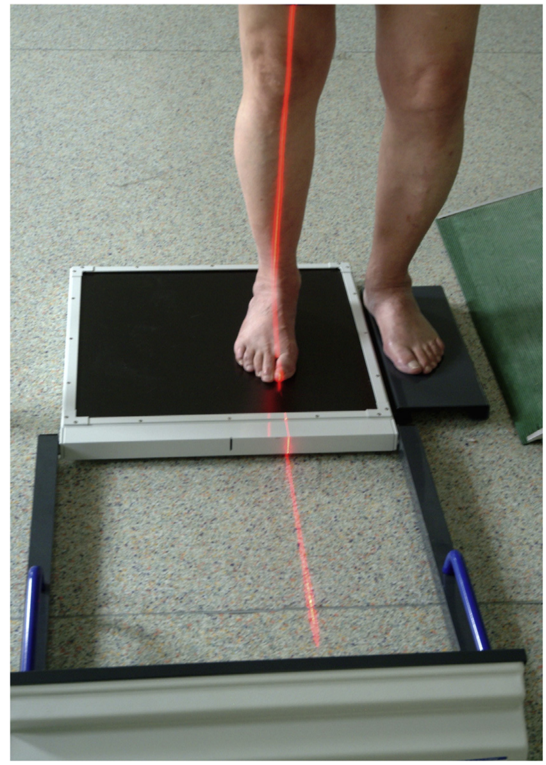

Fig. 1. L.A.S.A.R. posture alignment system.

Table 1
Patient characteristics.

Sex	
Male	10 (50%)
Female	10 (50%)
Age (years)[a]	67.7 ± 5.4 (58–78)
Height (m)[a]	1.64 ± 0.08 (1.55–1.78)
Weight (kg)[a]	77.0 ± 7.7 (69–94)
Body mass index (kg/m2)[a]	28.7 ± 4.4 (24.6–36.2)
Kellgren–Lawrence grade	
1	0 (0%)
2	8 (40%)
3	10 (50%)
4	2 (10%)

[a] Mean ± SD (range).

Results were expressed as the mean ± SD. Paired sample t-test was used to compare the measurements. Significance level was determined as $p < 0.05$. All statistical tests were performed using SPSS software (version 20.0, SPSS Inc., Chicago, IL, USA).

Results

The load-bearing lines measured with 5° and 10° lateral-wedge insoles were significantly moved laterally compared to those without wearing insoles ($p < 0.001$) (Table 2). Lateral-wedge insoles of 10° caused significantly more lateral shifting to the load-bearing line than 5° lateral-wedge insoles ($p < 0.001$) (Table 3).

Subjects with a range of knee OA severity according to Kellgren–Lawrence grading scale were compared in terms of lateral shifting of the knee load-bearing line with 5° and 10° lateral-wedge insoles. There was no significant difference between the groups ($p > 0.05$).

Discussion

The results of this study support the hypothesis that a lateral-wedge insole of either 5° or 10° laterally shifts the knee load-bearing line, indicating reduction of the loading of the medial compartment in patients with medial knee OA. In addition, the findings demonstrate the effect of 10° lateral-wedge insoles is greater than that of 5° lateral-wedge insoles.

To the best of our knowledge, this is the first study evaluating the changes in unilateral lower extremity load-bearing line with lateral-wedge insoles in patients with medial knee OA by using the

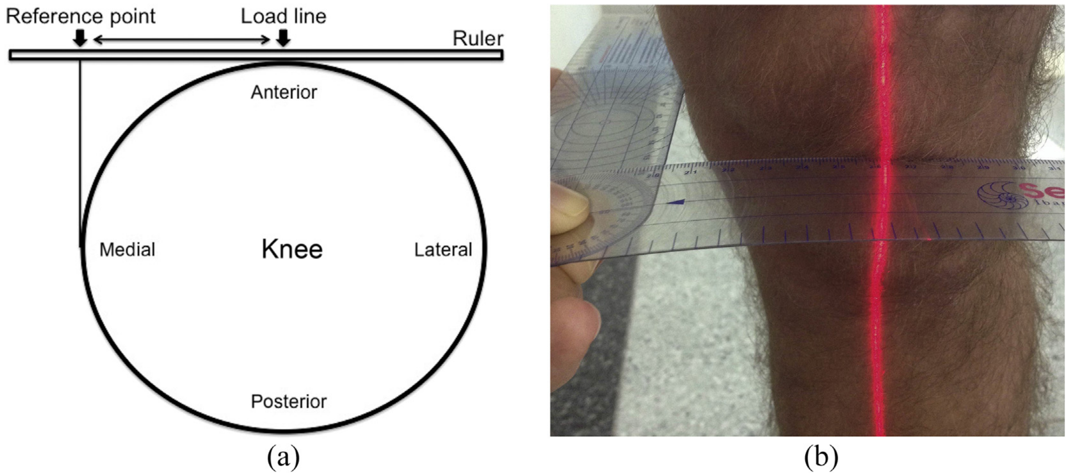

Fig. 2. Diagram **(a)** of the knee joint in transverse plane shows placement of the ruler on the arm of a goniometer that was placed tangentially to the patella at the level of joint line. The projection of the medial margin of the joint line on the ruler was the reference point for the measurements. The distance from the reference point to the load line was measured on the ruler. The photograph **(b)** shows the placement of the goniometer fixed at 90° for proper tangential placement.

Table 2
Distances between the medial end point of the knee joint line and the load line without wearing insoles and with 5° and 10° lateral-wedge insoles.

	Right side	p-value	t-value	Left side	p-value	t-value
Barefoot[c]	2.27 ± 0.53 cm			2.20 ± 0.41 cm		
5° lateral-wedge insole[c]	3.50 ± 0.45 cm	<0.001[a]	−13.322[a]	3.53 ± 0.58 cm	<0.001[a]	−11.546[a]
10° lateral-wedge insole[c]	4.59 ± 0.65 cm	<0.001[b]	−16.006[b]	4.62 ± 1.03 cm	<0.001[b]	−10.812[b]

[a] Barefoot vs 5° lateral-wedge insole.
[b] Barefoot vs 10° lateral-wedge insole.
[c] Mean ± standard deviation (range).

Table 3
Comparison of lateral shifting of the load line with 5° and 10° lateral-wedge insoles.

	5° lateral-wedge insole[a]	10° lateral-wedge insole[a]	p-value	t-value
Right side	1.28 ± 0.38 cm	2.37 ± 0.63 cm	<0.001	−11.733
Left side	1.34 ± 0.52 cm	2.42 ± 1.00 cm	<0.001	−7.252

[a] Mean ± standard deviation (range).

L.A.S.A.R. posture alignment system. Previous studies on the subject have investigated the mechanical effect of orthotics in people with medial knee OA by using the knee adduction moment as an indirect measure of medial compartment loading. Crenshaw et al[3] used 3-dimensional gait analysis to examine the kinetics of the use of lateral wedges with healthy subjects. Kinetics at the knee demonstrated reduced adduction moment. Kerrigan et al[4] used gait analysis to determine the effect of a lateral-wedge insole on knee adduction moment. A reduction in knee adduction moment was noted with both wedged insoles compared with non-wedged insoles in early and late stance. Using a 3-dimensional motion analysis system, Kakihana et al[5] showed that a 6° lateral-wedge insole significantly reduced knee adduction moment during gait compared with the no-wedge insole.

Malalignment influences how mechanical load is transferred. Malalignment affects the contact stress that occurs in a particular compartment of the knee. Consequently, the force cannot be dissipated uniformly. Knee varus loading increases contact stress across the cartilage of the medial compartment, causing cartilage degeneration.[12] Lateral-wedge insoles help correcting the location of knee load line by increasing subtalar valgus and decreasing knee varus.

Measuring alterations in knee joint loading due to lateral-wedge insole has been considered difficult using conventional gait analysis methods. One study showed that pressure distribution at the foot may allow for predictions of changes in joint moments with the use of foot wear modifications but cannot predict magnitude changes.[13] Shelburne et al[14] used computer modeling and simulation to show decreased knee adduction moment and medial compartment load with lateral displacement of the center of pressure of the ground reaction force. The L.A.S.A.R. posture alignment system is a relatively easy technique to show knee joint loading.

Lateral-wedge insoles of 10° were found to have greater effect on lateral shifting of the load-bearing line than 5° insoles in the present study. Previous studies found that 5°, 6°, and 10° lateral-wedge insoles were effective in reducing knee adduction moment in patients with knee OA.[4,5] However, 3° lateral-wedge insoles were found to be ineffective.[5] The optimal degree of incline for lateral-wedge insoles has not yet been determined. Ideally, the insole should effectively reduce the disease progression and provide with good compliance. Butler et al[7] studied the effect of a subject-specific amount of lateral-wedge on knee joint kinematics. The prescribed wedge amount was the minimal wedge amount that provided the maximum amount of pain reduction during a lateral step-down test. Their results demonstrated that a custom lateral-wedge insole was able to reduce knee adduction moments, which may increase compliance. Future studies are needed to confirm the degree of incline for the most comfortable and most beneficial lateral-wedge insoles.

There are some biomechanical issues present in this study. The lateral-wedge insole might alter the joint biomechanics in not only the knee joint but also the ankle and subtalar joints. In other words, the change in the measurement data with the L.A.S.A.R. posture alignment system reflects the change in alignment of the ankle and subtalar joint as well. Lower limb alignment was not assessed due to the lack of long leg standing X-ray in the study. Future studies may investigate the relationship between radiological leg alignment and load line excursion with a lateral-wedge insole. This correlation, if indicated, could suggest the clinical value of the L.A.S.A.R. posture alignment system as a tool to assess weight-bearing leg alignment in a simple and less-invasive manner.

There are several limitations in the present study. The L.A.S.A.R. posture alignment system allows a static assessment of the weight-bearing line. A dynamic assessment of the knee load-bearing line when wearing insole would be preferential, as possible through gait analysis systems. This study investigated load line excursion in only the medial–lateral plane, and lack of loading analysis in the anterior–posterior plane is a limitation in assessing the effect of lateral-wedge insole on the knee joint. While the patients were instructed to adjust the pressure applied to the force plate by monitoring it on the system display unit, this visual feedback method might be insufficient for equal distribution of body weight on both sides. To compensate for this limitation, each subject was carefully observed during weight-bearing, and measurements were taken when the investigator was satisfied with the equal distribution of body weight. Although the divergence distance was measured with a ruler that was placed tangentially to the patella as opposed to on the skin, the knee joint size may have some effect on the measurements obtained. The lack of intra- and inter-observer reliability of the measurements is another limitation for the study. Pain intensity level that could be reduced with use of lateral-wedge insole was not measured in this study, nor was knee function of the patients assessed. Establishing correlation between functions and unilateral lower extremity load-bearing line would provide results on static assessment and have clinical and functional value. Future studies may consider pain and function level of the knee as outcome measures.

In conclusion, the findings of the present study demonstrate that both 5° and 10° wedge insoles are effective in shifting the unilateral lower extremity load-bearing line laterally and that wedged insoles are biomechanically effective in reducing the loading of the medial compartment in patients with medial knee OA. Lateral shifting of the knee load-bearing line is related to reducing knee adduction moment. While gait analysis was not used to measure knee adduction moment in this study, the results might still be assessed as consistent with previous reports in the literature that showed the reducing effect of lateral-wedge insoles on knee adduction moment.

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No.

Conflict of interest

None declared.

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