The Effects of Different Angles of Wedged Insoles on Knee Varus Torque in Healthy Subjects

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Abstract

The purpose of this study was to examine the effect of the angle of a wedged insole on knee varus torque during walking. Fifteen healthy subjects were recruited. Knee varus torque was measured using three-dimensional motion analysis (Elite). Knee varus torque was normalized to gait cycle (0%: initial contact; 100%: ipsilateral initial contact) and stance phase (0%: initial contact; 100%: ipsilateral toe off). The average peaks of knee varus torque during the stance phase of the gait cycle according to the different insole angles (10 or 15 degrees) were compared using one-way ANOVA with repeated measures. The results showed that in the early stance phase, the average peak knee varus torque increased significantly for both the medial 10 and 15 degree wedged insole conditions and decreased significantly for both the lateral 10 and 15 degree wedged insole conditions as compared with no insole (p<.05). However, there were no significant differences between the 10 and 15 degree wedged insole conditions with either the medial or lateral wedged insole (p>.05). In the late stance phase, the average peak knee varus torque increased significantly for the medial 10 and 15 degree wedged insole conditions (p<.05), but not for the lateral 10 and 15 degree wedged insole conditions as compared with no insole (p>.05). We suggest that these results may be beneficial for manufacturing foot orthotic devices, such as wedged insoles, to control medial and lateral compartment forces in the knee varus-valgus deformity. Further studies of the effects of wedged insole angle on knee varus torque in patients with medial-lateral knee osteoarthritis are needed.

Key Words: Knee osteoarthritis; Knee varus torque; Medio-lateral wedged insole.

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Introduction

Knee osteoarthritis (OA) is the most common joint disorder, in which prevalence increases with age (Davis et al, 1989). Patients with knee OA usually present with major involvement in only one compartment of the 3 knee components, with the medial compartment involved nearly 10 times more often than the lateral compartment (Cooke et al, 1994; Huch et al, 1997; Kohatsu and Schurman, 1990). The predominance of medial compartment OA results from the high medial compartment forces during static and dynamic weight-bearing activities such as gait (Morrison, 1970; Prodromos et al, 1985; Schipplein and Andriacchi, 1991). In the healthy knee, between 71% and 91% of total joint load is transmitted through the medial tibiofemoral compartment compared to 100% in the OA knee (Morrison, 1970; Prodromos et al, 1985; Schipplein and Andriacchi, 1991). During walking, the normal forces acting on the knee produce a varus torque throughout stance phase, which tend to adduct the knee into varus (Andriacchi, 1994; Noyes et al, 1992). Several studies have showed that these varus torques and increased medial compartment joint loads are believed to responsible for the progression of knee OA (Goh et al, 1993; Schipplein and Andriacchi, 1991; Wang et al, 1990). The mechanical alignment shifting toward varus increases the moment arm of the ground reaction force about the knee joint center and results in a higher knee varus torque (Kettelkamp et al, 1976; Maly et al, 2002).

Medial compartment knee OA is dealt with by various conservative treatments to reduce knee varus torque and joint loads. Several studies have shown the clinical benefit of valgus knee bracing (Hewett et al, 1998; Matsuno et al, 1997; Pollo et al, 2002). Pollo et al (2002) showed that valgus knee bracing significantly reduced the varus torque and the medial compartment load and Komistek et al (1994) showed that valgus knee bracing significantly increased the joint space in medial compartment knee OA patients during heel strike.

Sasaki and Yasuda (1987) first showed the effects of lateral wedged insoles to treat medial compartment knee OA. Although they did not directly measure knee varus torque, they showed that the angulated lateral board did not alter the femorotibial angle through static analysis, but did increase the valgus position of the subtalar joint.

Several studies clinically evaluated the use of various wedged insoles to treat OA of the knee. Sasaki and Yasuda (1987) also showed that patients with early stage medial knee compartment OA had less knee pain when using a lateral wedged insole but on those with advanced stage medial knee compartment OA the insoles were ineffective. Keating et al (1993) showed that 61% of knees with medial knee compartment OA had improved pain scores with a lateral wedged insole. Ogata et al (1997) showed that the medial wedged insole was effective in decreasing the medial thrust and reducing pain with lateral knee compartment OA patients and a lateral wedged insole was effective in decreasing the lateral thrust during walking with medial knee compartment OA patients, as measured by a unidirectional accelerometer attached to the tibial tubercle of the knee. Wolfe and Brueckmann (1991) showed that lateral wedged insoles diminished medial compartment loads in OA patients with genu varum by changing the angle of force through the joint and use of medial wedged in-
sole for OA patients with genu valgus was effective to reduce knee pain. In his first dynamic biomechanical study of wedged insoles, Crenshaw et al (2000) showed that lateral wedged insole significantly decreased the knee varus torque by almost 7% in 17 healthy subjects. Kerrigan et al (2002) showed that lateral wedged insoles significantly decreased the knee varus torque by almost 6% in patients with medial knee compartment OA. Although many studies have verified the clinical effectiveness of wedged insoles in the reduction of knee varus torque using only lateral wedged insole, no studies have been published that attempt to quantify knee varus torque using various angles of wedged insoles during gait. The purpose of the present study was to quantify the effect of the angle of medial and lateral wedged insoles on knee varus torque during walking in healthy subjects.

**Methods**

**Subjects**

Fifteen healthy subjects with no history of lower limb surgery or disease were recruited for this study (Table 1).

**Instrumentation**

The wedged insoles used in this study were custom-fabricated by a local orthotics company. The orthotists were instructed to manufacture them to be laterally and medially inclined at an angle of 10° and 15° along the half length of the insole from the hind foot through the forefoot. The object used to construct the removable medial-lateral heel wedged insoles was a cork (Figure 1). The insoles were supplied in several sizes to accommodate the differences in shoe size among the subjects. Wedged insoles were strapped to an ankle sprain supporter designed to fit around the ankle (Figure 2). Kinematic and kinetic analyses were performed using a four-camera high resolution Motion Analysis system Elite (operating at 50 Hz) and an AMTI force platform (operating at 50 Hz). Kinetic data were collected on only one side for each subject, which was determined randomly before testing.

**Procedure**

On arrival to the gait laboratory, the purpose and methods of the study were explained to the subject. A signed informed consent was obtained after all questions had been answered to the subject's satisfaction. Retro-reflective markers were attached to the subject's lower extremities according to the S.A.F.Lo (Servizio di Analisi della

<table>
<thead>
<tr>
<th>Table 1. General characteristics of subjects</th>
<th>(N=15)</th>
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<tbody>
<tr>
<td><strong>Mean±SD</strong></td>
<td><strong>Range</strong></td>
</tr>
<tr>
<td>Age (yrs)</td>
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</tr>
<tr>
<td>Height (cm)</td>
<td>174.0±4.8</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>73.7±8.8</td>
</tr>
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</table>

1) B.T.S. Milan, Italy
2) Advanced Medical Technology Inc, Newton, U.S.A
Funzionalit Locomotoria) marker system. Markers were placed bilaterally over the posterosuperior iliac spine, below the sacrum, the lateral knee epicondyle, the lateral malleous, and on the forefoot over the head of the fifth metatarsal (Figure 3). Subjects were allowed to become used to the testing procedure by walking at a self-selected speed up and down an 8-m walkway for several minutes. After the subject was comfortable with the procedure, a trial exercise was completed and from this, cadence was collected. The subject was then instructed to walk at this pace and start from a specified position for the remainder of the test in order, to control velocity. Velocity was kept constant in this study because forces at the knee are related directly to velocity. Each subject was tested in the gait laboratory in five conditions. (1) the control condition (no insole) (2) lateral 10 degree wedged insole conditions (L 10°) (3) lateral 15° wedged insole condition (L 15°) (4) medial 10° wedged insole condition (M 10°) (5) medial 15° wedged insole condition (M 15°). Test order was selected randomly. Five trials of each condition were collected for each subject for averaging and additional statistical analysis.

Data analysis

Knee varus toqrues were collected using the Elite program. Knee varus torque was normalized to gait cycle (0%: initial contact; 100%: ipsilateral initial contact) and stance phase (0%: initial contact; 100%: ipsilateral toe off) using MatLab 5.3 (MathWorks Inc.). The averaged peak knee varus torque during the stance phase of the gait cycle according to the different insole angles (10 or 15 degrees) were compared using one-way ANOVA with repeated measures. To assess statistically significant differences in each of the five conditions, a Bonferroni adjustment was
made for the multiple (6) variables analyzed. Statistical significance was defined at p<.0083 (.05/6). SPSS Version 10.0 for Windows was used to analyze the averaged peak knee varus torque.

**Results**

The means and standard deviation for the average peak knee varus torque for both early and late stance are listed in Table 2 and 4. The results showed that in the early stance phase, the average peak knee varus torque increased significantly for both the medial 10 and 15 degree wedged insole conditions and decreased significantly for both the lateral 10 and 15 degree wedged insole conditions as compared with no insole (p<.05). However, there were no significant differences between the 10 and 15 degree wedged insole conditions with either the medial or lateral wedged insole (p>.05) (Table 3 and Figure 4). In the late stance phase, the average peak knee varus torque increased significantly for the medial 10 and 15 degree wedged insole conditions (p<.05), but not for the lateral 10 and 15 degree wedged insole conditions as compared with no insole (p>.05) (Table 5 and Figure 5). The general pattern of varus knee torque was similar in all five conditions. The varus knee torque curves of the 10 and 15 degree medial wedged insole and the 10 and 15 degree lateral wedged insole versus no insole are shown in figures 6 and 7.

**Table 2.** Means and standard deviation of averaged peak knee varus torque in five conditions in early stance (Nm/kg)

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Mean±SD</th>
<th>Range</th>
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<tr>
<td>M 15°</td>
<td>.52±.09</td>
<td>.40~.66</td>
</tr>
<tr>
<td>M 10°</td>
<td>.51±.09</td>
<td>.39~.65</td>
</tr>
<tr>
<td>No insole</td>
<td>.45±.09</td>
<td>.34~.62</td>
</tr>
<tr>
<td>L 10°</td>
<td>.43±.09</td>
<td>.31~.58</td>
</tr>
<tr>
<td>L 15°</td>
<td>.43±.10</td>
<td>.31~.60</td>
</tr>
</tbody>
</table>

M: Medial wedged insole
L: Lateral wedged insole

**Table 3.** Summary table of repeated measures analysis of variance: averaged peak knee varus torque in five conditions in early stance

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>F</th>
<th>p</th>
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<td>.00</td>
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<td>.02</td>
<td>.00</td>
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<tr>
<td>Total</td>
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Figure 4. The percentage increase in averaged peak knee varus torque using the five conditions in early stance phase

Table 4. Means and standard deviation of averaged peak knee varus torque in five conditions in late stance (Nm/kg)

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Mean±SD</th>
<th>Range</th>
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<tbody>
<tr>
<td>M 15°</td>
<td>.47±.11</td>
<td>.37~.69</td>
</tr>
<tr>
<td>M 10°</td>
<td>.46±.11</td>
<td>.35~.72</td>
</tr>
<tr>
<td>No insole</td>
<td>.44±.10</td>
<td>.33~.69</td>
</tr>
<tr>
<td>L 10°</td>
<td>.43±.11</td>
<td>.31~.67</td>
</tr>
<tr>
<td>L 15°</td>
<td>.43±.14</td>
<td>.31~.74</td>
</tr>
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</table>

M: Medial wedged insole
L: Lateral wedged insole

Table 5. Summary table of repeated measures analysis of variance: averaged peak knee varus torque in four conditions in late stance

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>F</th>
<th>p</th>
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<td>.06</td>
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<td>Condition</td>
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<td>Error</td>
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<tr>
<td>Total</td>
<td>74</td>
<td>1.01</td>
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*Statistically significant difference at p<.05/6=.01

**Figure 5.** The percentage increase in averaged peak knee varus torque using the five conditions in late stance phase

**Figure 6.** Knee varus torque during walking plotted over an averaged gait cycle

**Figure 7.** Knee varus torque during walking plotted over an averaged gait cycle. Effect of 10° lateral wedged insole and 15° lateral wedged insole versus no insole
Discussion

Various orthotic wedges or posts have been applied broadly in the treatment of a variety of foot disorders such as varus deformity of the hindfoot alone or with varus or valgus deformity of the forefoot, and abnormal pronation as well as low back pain and knee OA (Bird et al, 2003; Kerrigan et al, 2002; Kogler et al, 1994). When used to treat these deformities and disorders, the function of the wedges is primarily to correct skeletal alignment in order to normalize standing posture and walking (Kogler et al, 1994). Although many previous studies have reported the clinical effectiveness of wedged insoles and reduction of knee varus torque using only lateral wedged insole with medial knee compartment OA patients, our study is the first to determine the effect of the angle of lateral as well as medial wedged insoles on knee varus torque and to offer guidelines for the prescription of wedged insoles for the degree of incline.

Using five conditions: no insoles, L 10°, L 15°, M 10°, M 15°, in early stance phase, the average peak knee varus torque increased significantly 11.9% and 14.5% in the M 10° and M 15° conditions. However average knee varus torque decreased 5.1% with no insole and 5.8% in the L 10° and L 15° conditions. The average knee varus torque increased 6.4% in the late stance phase, and 7.3% in the M 10° and M 15° conditions. In comparison, peak knee varus torque was decreased 2.4% with no insole and 5% in the L 10° and L 15° conditions. Not using the full length of the insole from hindfoot to toe, the averages of the knee varus torque differed more in the early stance phase than in the late stance phase under all conditions. The medial wedged insole, which increased the knee varus torque, was more effective both dynamically and clinically. These findings would appear to support previous suggestions that it is easier to compensate for knee valgus rather than varus deformity (Harrington 1983).

Another method for reducing knee varus torque is to change the walking patterns, which affect foot inversion moment while walking (Hurwitz et al, 2002; Lin, 2001; Simpson and Jiang, 1994). Hurwitz et al (2002) concluded that increased peak knee varus torque can result from a toe-in gait, while a toe-out gait decreases the peak knee varus torque in OA patients. Although orthotic devices such as wedged insole and knee valgus braces have been used to reduce knee varus torque, alteration of the walking pattern also may be useful to decrease knee varus torque in some individuals with OA. Further studies, comparing knee varus torque with various degrees of inclined wedged insoles in foot progression angles, are needed in knee OA patients.

Osteoarthritis is a disease in which the articular cartilage degenerates, which in the knee leads to a collapse of the affected compartment and an increase in knee coronal plane angulation. This increase in coronal angulation in turn leads to change in coronal moment, which increases the load on the affected compartment (Kettelkamp et al, 1976; Maly et al, 2002). Therefore, the use of wedged insoles can reduce abnormally high forces, which can provide relief of pain and subsequently improvement of function (Keating, 1993; Sasaki and Yasuda, 1987).

Yasuda and Sasski (1987) suggested the wedged insole serves as a stimulant to patients with osteoarthritic knees because it causes an everted orientation of the foot relative to the floor and thus alters normal standing and walking. They hypothesized that the patients
adapt by changing the spatial position of their lower limbs through shifts in muscle activity and trunk posture, resulting in a decreased loading of the medial joint surface of their knees. We also agree that change of knee varus torque will be relevant to muscle activity.

Further studies are needed to examine the effects of various degrees of inclined wedged insoles on muscle activity in subjects with knee OA.

Results from this present study indicate that biomechanical wedged insoles appear to influence the forces on the medial and lateral compartment of the knee in the healthy subjects participating in this study. Therefore, conservative therapy, such as use of an insole, will be useful for knee OA patients.

Further studies, including randomized controlled trials that study the long-term effect of various degree of inclined wedged insoles, are needed in knee OA patients.

**Conclusion**

Knee osteoarthritis causes a loss of joint space in the compartment, effecting the knee varus torque and potentiating progressive joint space loss and angulation, creating a vicious cycle. Thus, Rehabilitation modalities aimed at interrupting this cycle by controlling knee varus torque may be most effective. In this study, we provide guidelines for the prescription of various wedged insoles, such as the degree of incline. Further studies are needed to examine long-term effects of various degrees of inclined wedged insoles on subjects with knee OA.

**References**


