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Effects of Combined Wedge on Angle and Moment of Ankle and Knee Joint During Gait in Patients With Genu Varus

The purpose of this study was to investigate the effects of combined wedge on the range of motion in ankle and knee joint, ankle eversion moment and knee adduction moment, and center of pressure excursion of foot for genu varus among adult men during gait. This study was carried out with 10 adult men for genu varus in a motion analysis laboratory in J university. The subjects of the experiment were measured above 5cm width between the knees on contact of both medial malleolus of ankle while standing. The width of their knees in neutral position was measured without the inversion or eversion of the subtalar joint by the investigator. The subjects of the experiment were ten who were conducted randomly for standard insole, insole with 10° lateral on rear foot wedge, insole at 10°lateral on rear foot and 5° medial on fore foot wedge. Before and after intervention, changes on the range of motion in ankle and knee joint, ankle eversion moment and knee adduction moment, and center of pressure excursion were measured. In order to compare analyses among groups; repeated one-way ANOVA and Scheffé post hoc test were used. As a result, combined wedge group was significantly decreased compared to control wedge group in terms of knee varus angle in mid-stance($p<.05$). Combined wedge group was significantly decreased compared to lateral wedge group in terms of ankle eversion moment in whole stance($p<.05$). Combined wedge group was significantly decreased compared to lateral wedge group in terms of knee adduction moment in whole stance($p<.05$). Combined wedge group was significantly decreased compared to lateral wedge in terms of center of pressure excursion in whole stance($p<.05$). The results of this study suggest that combined wedge for genu varus decreased ankle eversion moment and knee adduction moment upon center of pressure excursion. We hypothesize that combined wedge may also be effective in the protection excessive ankle pronation.

Key words: *Ankle eversion moment, Combined wedge, Genu varus, Knee adduction moment, Lateral wedge*

Hae Sun Yang, Houng Sik Choi

Hanseo University, Seosan, Korea

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Address for correspondence
Houng Sik Choi, PT, Ph.D
Department of Physical Therapy, Hanseo University, 46, Haemi-myeon, Seosan, Korea
TEL: +82 41-660-1381
E-mail: mailto:hschoi@hanseo.ac.kr

INTRODUCTION

Genu varus is one of the acceleration diseases affecting knee joint osteoarthritis(OA), which is associated with pain, functional limitation, and appearance. The potential consequences of genu varus and internal rotational laxity and stiffness of the tibiofemoral joint on knee joint biomechanics have recently been examined(1). Several authors have confirmed the presence of overall frontal plane joint laxity in patients with knee OA(2). As the large medial compartment load contributes to the progressive erosion of the medial compartment's articular cartilage, the medial soft tissue structures may become involved as well. As the cartilage is worn away, the subchondral bone surfaces draw nearer to each other, reducing the distance between the medial compartment's ligament insertions. Joint laxity could lead to instability that has been reported(3). There are various treatments to align the axis of the leg and have investigated reduction in the knee adduction moment and to improve the quality of life for genu varus(4). Wedges are safe and less costly if they decrease knee adduction moment and appearance. Lateral wedges were originally proposed to manage the medial compartment of knee(5) and to manage GRF relative to the ankle for genu varus during gait. Even though lateral wedge has been effective for knee adduction moment and GRF during gait, some patients have complained of pain in the ankle and other joints. They have complained of discomfort and even stopped wearing them due to pain in the ankle and other joints(6). In a recent study, 47% of individuals had problems with their rare foot lateral wedge insole through discomfort(7). A reason for increased discomfort and pain in the ankle may be the consequence of increased ankle eversion moments that are acting on ankle joint due to typical lateral wedge insoles. Further, the GRF produces plantar pressure during pre-swing. GRF is to lead the excessive pronation of the forefoot in pre-swing, which has been associated with an increased risk of lower limb(8). There was a fair evidence in a statically assessed limb with a genu varus alignment where there was more pressure under the plantar aspect of foot(9).

Variation of wedge type could be influenced to foot position and biomechanic effects for limitations of lateral wedge. Research has shown that an effect on plantar pressure by prevent pronation changes during gait(10). This is likely to be due to the increased support of forefoot, which makes this insole effective at decreasing stress during gait(11). Also, the knee adduction moment with medial support wedge on fore foot was investigated and 4.2-5.1% was marginally smaller than the reduction investigated by others(12). Further, knee adduction moment with medial support wedge on fore foot was investigated to be 8.7% are smaller than the reduction investigated in others.

It was shown that 5°medial wedge on fore foot significantly decreased the knee varus torque during gait(12). It would reduce the knee adduction moment by the alignment of the axis of the foot. These researches were helpful in investigating for the factors for the biomechanical effects of the ankle and knee. Therefore, this study investigated that the effects of kinetic and kinematic with combined wedge for genu varus during gait. In this study, combined wedge would be hypothesized to reduce significantly the effects of the center of pressure, angle of the ankle and knee, and ankle and knee adduction moment for genu varus during gait.

METHODS

Subjects

Ten subjects with genu varus and 22-26 years old were recruited from laboratories in J University. Genu varus was evaluated the width between the knees. Grade 1 is below 2.5cm. Grade 2 is 2.5cm~5cm. Grade 3 is 5~7cm. Grade 4 is above 7cm. Korea recommend surgery above grade 3. The selected subjects had width between the knees 2.5cm~5cm, and did not have any neuromusclular disorders and history of ankle, knee or hip pain.

Methods

Subjects were worn comfortable fitted pants to fix a reflective marker on the body. Subjects were measured for height, weight, ankle diameter, knee diameter, width between knees, and before gait analysis. Limb segments were identified by 25mm, retro reflective markers placed over the bilateral iliac crests, greater trochanters, lateral femoral condyles, lateral malleolus, and the heads of the 5th metatarsals to indicate the ends of the segments and to identify appropriate joint centers. Rigid thermoplastic shells, each with four markers firmly affixed, were attached to the posterolateral aspect of the thigh and shank and covered with an elastic wrap to minimize movement between the shell and the bone. An additional shell with a triad of markers was placed on the posterior pelvis, while two additional markers were placed on the posterior heel counter of the subject's shoe to track the foot's coordinate system along with the marker placed over the 5th metatarsal head. Subjects performed practice walking trials across an 8-meter walkway until a consistent velocity was achieved as measured by two photoelectric cells placed 286.5 cm apart. The motions of the lower extremity segments were tracked with Motion Analysis System*. The subjects walked

*Eva RT 5.0.3, Motion Analysis Corporation, Califonia, USA
**AMTI 4500, Motion Analysis Corporation, Califonia, USA

across a 6-component force plate**, placed flush with the floor in the middle of the volume to collect ground reaction force data. Ground reaction force data were collected at 1920 Hz and were synchronized with Motion Analysis System for simultaneous collection. Marker trajectory data were filtered with a 6Hz low pass filter, and force plate data were filtered using a low pass filter with a cutoff frequency of 40Hz. Subjects underwent gait analysis with Motion Analysis System for measurement of center of pressure, angle of ankle and knee joint, knee adduction moment, and ankle eversion angle. All subjects were examined on 3 s in random order.(1) control (standard insole)(2) insole with 10° lateral wedge on rear foot with no additional support(typical lateral wedge)(3) combined wedge (insole with 10° lateral on rear foot and 5° medial on fore foot wedge in the standard shoes). The insoles were wedged along the lateral edge of the entire length of the foot. Wedges were made of high density ethyl vinyl acetate and were worn bilaterally inside the participant's standard shoes.

Table 1. Characteristics of subjects

	Mean±SD
Age(yrs)	22±0.7
Height(cm)	175±4.3
Weight(kg)	69.5±8.6

RESULTS

Discrete kinetic and kinematic variables were identified and averaged for each subject's walking trials. The timings for events were as follows: early stance(0-33% of stance phase), mid-stance (34-67% of stance phase) and late stance(68-100% of stance phase)(13). Ankle eversion angle was not statistically significant between control and lateral wedge in whole stance($p>.05$). The ankle eversion angle for combined wedge was decreased compared to lateral wedge and control in whole stance. The coronal plane kinematics of knee varus angle was statistically significant among groups in mid-stance($p<.05$). Knee varus angle

Table 2. Comparison of knee varus angle,ankle eversion moment,knee adduction moment,cop excursion

	Among Groups	Sum of Square	Mean Square	p
Knee varus angle	(early stance)	4.89	2.45	0.08
Ankle eversion moment		965.12	482.56	0.00*
Knee adduction moment		779.37	389.68	0.00*
COP excursion		11732.44	5866.22	0.00*
Knee varus angle	(mid stance)	3.26	1.63	0.00*
Ankle eversion moment		879.11	439.56	0.00*
Knee adduction moment		680.32	340.16	0.03*
COP excursion		24771.81	12385.9	0.00*
Knee varus angle	(late stance)	5.24	2.62	0.09
Ankle eversion moment		987.11	493.55	0.00*
Knee adduction moment		732.73	366.36	0.04*
COP excursion		24179.66	12089.82	0.00*

*$p< .05$

for combined wedge was statistically significant compared to control wedge in mid-stance($p<.05$). Ankle eversion moments were statistically significant among groups in whole stance($p<.05$). Knee adduction moments were statistically significant among groups in whole stance($p<.05$). The center of pressure excursion was statistically significant among groups in whole stance ($p<.05$).

DISCUSSION

This study was meant to investigate the effects of combined wedge on angle and moment of ankle and knee joint and center of pressure excursion during gait in subjects with genu varus. Wedge is used to treat pronated feet and fore foot varus/valgus deformity and to improve skeletal alignment during gait(14). Wedge influenced the biomechanical effect of the femur, tibia, and calcaneus and reduced the medial torque on knee by reducing tensile force(15). Also, wedge increased the range of motion in hip, knee, and ankle. Lateral wedge influenced the foot position by toe-out, which reduced medial torque on knee(16)(17). Even though lateral wedge has been effective and is the solution to reducing the knee adduction moment during gait, some patients have complained of pain in the ankle and other joints(18). There is GRF that is to lead the excessive pronation of the forefoot for genu varus in pre-swing which has been associated with an increased risk of lower limb(18)(19). Combined wedge was 5° medial on forefoot up to 10° lateral rear foot wedge. At first, in this study, combined wedge was evaluated whether to prevent excessive pronation to typical lateral wedge. Combined wedge displaced the center of pressure excursion laterally. The results have shown that the center of pressure excursion was statistically significant between lateral wedge and combined wedge in whole stance($p<.05$). The center of pressure excursion was statistically significant between control and combined wedge in whole stance($p<.05$). However, the center of pressure excursion was not statistically significant between control and lateral wedge in whole stance($p>.05$). The recent literature shows medial wedge reducing the cop of the ankle by everting the forefoot. Ankle eversion for combined wedge was decreased compared to lateral wedge and control. However, ankle eversion was not statistically significant among combined wedge, lateral wedge, and control in whole stance($p>.05$).

Ankle eversion angle for lateral wedge increased compared to control in early and mid-stance. Ankle eversion angle for lateral wedge decreased compared to control in late stance. However, ankle eversion angle was not statistically significant between control and lateral wedge in whole stance in agreement with previous studies($p>.05$)(20).

Knee varus angle for combined wedge was decreased compared to lateral wedge in mid-stance. However, there was no statistical significance between lateral wedge and combined wedge($p>.05$). Knee varus angle for combined wedge was statistically significant compared to control and lateral wedge in mid-stance with previous literature($p<.05$)(21-23). Knee varus angle for combined wedge was increased compared to control and lateral wedge group in late stance. There was no statistical significance among groups in late stance($p>.05$).

Ankle eversion moment in late stance was statistically significant compared to lateral wedge($p<.05$). However, there was no statistical significance between control and combined wedge($p>.05$). Ankle eversion moment in late stance was statistically significant between control and lateral wedge($p<.05$). Combined wedge decreased the stress on the medial side of ankle and forefoot(24)(25).

Knee adduction moment for combined wedge was statistically significant in early stance similar in previous literature($p<.05$). Lateral wedges immediately reduced knee adduction moment. Knee adduction moment for combined wedge was statistically significant compared to control in early stance($p<.05$). There was no statistical significance between control and lateral wedge in early stance($p>.05$). Knee adduction moment was not statistically significant among groups in mid-stance and late stance($p>.05$).

The limitation of this study was that only 20-29 year old male subjects were involved. Further, this study investigated the immediate effects of combined wedge. There was the potential for a carry-over effect from the previous point to affect the subsequent. Therefore, future studies in this field should be investigated over a longer period of time.

CONCLUSIONS

This study was to investigate the biomechanical effects of combined wedge for 20-29 year olds with genu varus during gait. This study analyzed ankle eversion angle, knee varus angle, ankle eversion moment, knee adduction moment, and center of pressure excursion among three groups during gait. Ankle eversion angle was not statistically significant among groups in whole stance($p>.05$). The ankle eversion angle was decreased between lateral wedge and combined wedge in whole stance, but there was no significant difference between the lateral wedge and combined wedge in whole stance($p>.05$). Knee varus angle was statistically significant among groups in mid-stance($p<.05$). Knee varus angle for combined wedge was statistically significant compared to control wedge in mid-stance($p<.05$). Knee varus angle for combined wedge was decreased compared to lateral wedge in mid-stance and late stance. However, the knee varus angle was not statistically different in lateral wedge and combined wedge in mid-stance and late stance($p>.05$). Ankle eversion moments were statistically significant among groups in whole stance($p<.05$). Ankle eversion moments for combined wedge were increased compared to lateral wedge in whole stance. There was statistical significance between lateral wedge and combined wedge($p<.05$). Ankle eversion moments were statistically different between lateral wedge and combined wedge in whole stance($p<.05$). Knee adduction moments were statistically significant among groups in whole stance($p<.05$). Knee adduction moments for combined wedge were statistically significant in whole stance compared to lateral wedge($p<.05$). The center of pressure excursion was statistically significant among groups in whole stance($p<.05$). Center of pressure excursion for combined wedge was statistically significant in whole stance compared to lateral wedge and control($p<.05$).

In conclusion, combined wedge was effective in decreasing knee and ankle moment by laterally displacing the center of pressure. Thus, combined wedge may be useful to be comfortable and to prevent excessive ankle pronation for genu varus.

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