Available online at ***www.ijmrhs.com***

ISSN No: 2319-5886

International Journal of Medical Research and Health Sciences, 2025, 14 (4): 1-7

The Effects of Knee Valgus Orthosis on Knee Joint Contact Forces in Subjects with Knee Osteoarthritis

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Received: 15-May-2024, Manuscript No. IJMRHS-24-135213; **Editor assigned:** 18-May-2024, PreQC No. IJMRHS-24-135213 (PQ); **Reviewed:** 03-June-2024, QC No. IJMRHS-24-135213; **Revised:** 14-May-2025, Manuscript No. IJMRHS-24-135213 (R); **Published:** 21-May-2025

ABSTRACT

Background: *An increase in knee joint loading increases the symptoms of knee joint Osteoarthritis (OA). One of the conservative treatments used for the subjects with knee OA is knee valgus orthosis which is used to decrease the load on knee joints.*

Objective: *The aim of this study was to determine the effects of a new design of knee orthosis on joint contact force and muscle force in the subjects with knee OA.*

Methods: *Ten subjects with knee OA were recruited in this study. A motion analysis system with 7 high speed cameras and a Kistler force plate were used to record the motion of the subjects in walking and the forces applied on the leg. OpenSIM software was used to determine the knee joint contact force during walking with and without the orthosis.*

Results: *The knee orthosis decreased the peaks of vertical component of knee joint contact forces (p<0.05). Moreover, it did not influence on walking speed. The use of the orthosis decreased extension moment of the knee joint and the peaks of the forces produced by muscles surrounding the knee joint.*

Conclusion: *The use of this orthosis decreased the knee joint contact forces. This suggests that the orthosis could be used to alleviate the symptoms of knee OA. Clinicians are to be aware of the findings of this study as the use of the orthosis could be incorporated into the management of subjects with knee OA.*

Keywords: Knee, Orthosis, Osteoarthritis

INTRODUCTION

Knee Osteoarthritis (OA) prevalence is increasing worldwide. It has been estimated that 85% of all people over age 60 may be affected with this condition. Pain, activity limitation, reduced range of joint movement, joint instability (which may increase the risk of falling) are associated with knee OA. The loads applied to the knee joint are believed to play a significant role in the onset of knee OA [1].

It has been observed that knee adduction moment is the primary determinant of the loads applied on the medial side of knee joint which is two times higher than that on the lateral side. Various treatment approaches have been used to decrease the symptoms associated with knee OA and to improve the performance of these subjects during standing and walking. These approaches include surgery (wedge osteotomy and arthroplasty) and conservative treatment (physical therapy exercise and use of valgus brace). Moreover, the subjects with knee OA adopt some strategies to decrease the loads applied on knee joint [2].

Knee braces such as generation II brace, medial unloading Monarch brace and Vista CA brace have being used to improve the alignment of knee joint and to decrease the loads on knee joints. It has been shown that use of knee orthoses reduces adduction moment of knee joint (which is the main indicator of the loads applied on knee) and reduces knee pain while walking. Another valgus orthosis was designed by Karimi et al., with modular structure with ability to change the alignment of the components relative to each other's based on patients' need [3].

In previous studies the efficiency of orthoses to decrease the loads of knee joint was determined based on the magnitude of adduction moments which is claimed to be an important proxy of knee loads. However, to date, the knee joint contact force during walking with knee brace in subject with OA has not been examined. A preliminary study was done by the authors of this paper on 5 subjects with knee OA and only a few parameters were investigated. The results of that study, which was aimed mostly to introduce the new orthosis, confirmed that the loads applied on knee joint decreased follow the use of the orthosis. However, there was no study which evaluated the joint contact force, muscles force on larger number of subjects with knee OA. Therefore, the aim of this study was to investigate the effect of this orthosis on the magnitude of knee joint contact force and muscle forces in the subjects with knee OA. The main hypothesis associated with this study was that use of knee orthosis will significantly decrease knee joint contact and muscular forces in the subjects with knee OA [4].

MATERIALS AND METHODS

Ten subjects with knee OA were recruited in this study. Table 1 shows the characteristics of the subjects participated in this study. The severity of knee OA was determined according to the American College of Rheumatology criteria for diagnosis of OA which include medial knee pain and radiographic osteophytes in the medial side of knee joint. More especially the severity of OA was determined by Kellgren and Lawrence grade (K-L). The subjects with musculoskeletal disorders that influenced their ability to stand and walk were excluded from the study. Shiraz University of medical sciences, ethics Committee approved this study. The participants were asked to sign the consent forms before data collection [5].

Table 1 The characteristics of the subjects participated in this study

	Mass (kg)	**Height (m)**	**Age (year)**
Mean ± SD	53.37 ± 3.02	1.57 ± 0.065	72.45 ± 3.70

A Kistler force plate was used to measure the force applied on the leg during walking with and without orthosis. A motion analysis system (Qualysis with 7 high speed cameras) was used to record the motions of the body. The following parameters were examined in the study: Force applied on leg during walking, knee joint contact forces, spatiotemporal gait parameters, muscles forces and the ranges of motion of knee, hip and ankle joints.

Procedure

Twenty two reflective markers with 14 mm diameters were attached to the following anatomical landmarks: Lateral and medial sides of knee and ankle joints, first and fifth metatarsal heads, heels in right and left sides, sternum, top of head, sacrum and left and right anterior superior iliac spine, posterior superior iliac spine, acromioclavicular joints greater trochanter in both sides and C7. In addition, 4 marker clusters were attached to the anterolateral surfaces of thighs and shanks in right and left sides. The subjects walked with and without the orthosis and 5 successful trials were collected. The data were recorded with frequency of 100 Hz and were filtered with Butterworth low pass filter with cut off frequency of 10 Hz. The full description of the orthosis can be found in the previous publication of the authors 19 (Figure 1). As can be seen from Figure 1, the new knee orthosis consists of shank and thigh shells with an adjustable polycentric knee joint. The knee joint of the orthosis can be adjusted in frontal plane to change the alignment of knee joint in mediolateral direction. Moreover, there are two pads inside the upper lateral and lower medial parts of shank shell (the forces of the pads can be changed by especial screws) [6].

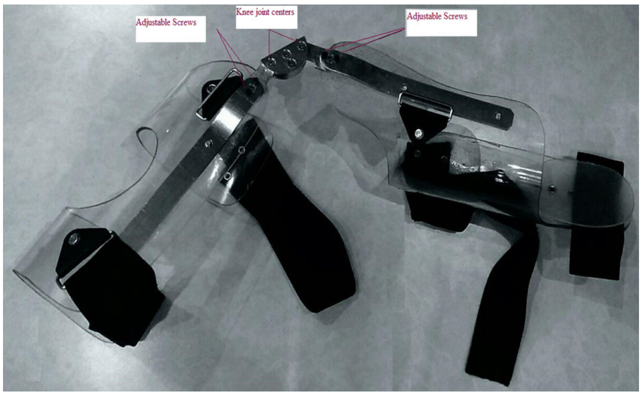

Figure 1 The knee orthosis used in this study

All markers were labeled and exported as 3D to Mokka software. Mokka software was used to convert 3D format into Trc format. OpenSim software was used to determine the kinematic and moments of knee joints, and the force applied on the knee joint. Figure 2 shows the flow chart of the procedure used in this study. It should be emphasized that the scaling procedure in OpenSim was done with error less than 3 cm for all subjects. The error of the model for inverse kinematic was less than 2 cm [7].

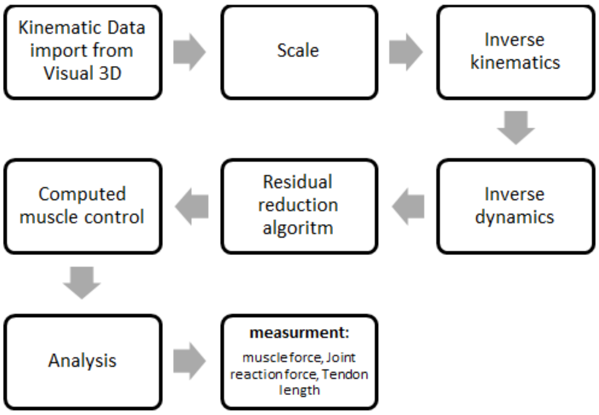

Figure 2 The procedures of OpenSIM software used to determine joint contact force

Test of normality was carried out using the Shapiro Wilk tests to examine the distribution of the data for each parameter. Since Shapiro Wilk test revealed that the parameters had a normal distribution (p>0.05), paired T-test was used to compare the two sets of data (with and without walking). Significant value was set at p<0.05.

RESULTS

The mean values of walking speed with and without orthosis were 48.94 ± 9.2 and 47.68 ± 8.51 (m/min), respectively (p=0.36). There was no difference between stride length and cadence of the OA subjects while walking with and without the knee orthosis (p>0.05). Table 2 shows the mean values of spatiotemporal gait parameters during walking with and without orthosis [8].

Table 2 Mean and SD of spatiotemporal gait parameters

Parameters	Without orthosis	With orthosis	P-value
Velocity (m/min)	47.68 ± 8.51	48.94 ± 9.20	0.36

Cadence (steps/min)	102.78 ± 32.08	107.89 ± 32.40	0.15
Stride length (m)	0.94 ± 0.28	0.96 ± 0.23	0.26

The magnitude of ground reaction force components in the two conditions are shown in Table 3. As it can be seen from the table, there was no significant difference between the forces applied on the leg in two conditions (p-value>0.05) [9].

Table 3 Mean of ground reaction force comments while walking with and without orthosis

Parameters	**Without orthosis**	**With orthosis**	**p-value**
GRF vertical (1^{th} peak) (N/BW)	0.98 ± 0.12	1.007 ± 0.09	0.19
GRF vertical (2^{th} peak) (N/BW)	1.03 ± 0.12	1.00 ± 0.14	0.17
GRF anteroposterior (1^{th} peak) (N/BW)	0.10 ± 0.04	0.11 ± 0.04	0.11
GRF anteroposterior (2^{th} peak) (N/BW)	0.13 ± 0.05	0.12 ± 0.04	0.41
GRF mediolateral (N/BW)	0.04 ± 0.02	0.03 ± 0.02	0.21
Note: GRF: Ground Reaction Force; N: Newton; BW: Body Weight			

The moments applied on the leg were the other parameters evaluated in this study. The mean values of extension moment during walking with and without orthosis were 0.015 ± 0.01 and 0.019 ± 0.02 Nm/BW, respectively. Although the mean values of extension moment during walking with the orthosis decreased, the difference was not statistically significant. There was no difference between the range of motion of knee joint in sagittal plane during walking with and without orthosis (Table 4) [10].

Table 4 Mean of range of motion and sagittal plane moments of knee joint

Parameters	**Without orthosis**	**With orthosis**	**p-value**
Extension moment (N.m/Kg)	0.019 ± 0.02	0.015 ± 0.01	0.026^{*}
Flexion moment (N.m/Kg)	0.02 ± 0.020	0.018 ± 0.01	0.4
Knee ROM (degree)	56.9 ± 14.20	55.06 ± 7.50	0.28
Note: N: Newton; m: meter; ROM: Range of Motion			

The first peaks of knee joint contact force in vertical direction were 2.97 ± 0.39 N/BW and 2.54 ± 0.38 N/BW, during walking with and without the orthosis, respectively (p=0.03). Table 5 shows the summary of the mean values of joint contact force components [11].

Table 5 Mean of knee joint contact force components while walking with and without the orthosis

Parameters	**Without orthosis**	**With orthosis**	**p-value**
JCF anteroposterior (N/BW)	0.88 ± 0.24	1.01 ± 0.5	0.18
JCF vertical (1^{th} peak) (N/BW)	2.97 ± 0.39	2.54 ± 0.38	0.03^{*}

JCF vertical (2th peak) (N/BW)	3.20 ± 0.68	2.61 ± 0.46	0.01*
JCF mediolateral (N/BW)	0.24 ± 0.08	0.22 ± 0.37	0.25
Note: JCF: Joint Contact Force			

The peaks of muscles forces surrounded knee joint were also evaluated in this study. As can be seen from Table 6, the forces produced by knee muscles decreased follow the use of orthosis; however, for most of the muscles the differences were not significant (p-value>0.05) [12].

Table 6 Mean of peaks of knee muscles forces while walking with and without knee orthosis

Parameters	**Without orthosis**	**With orthosis**	**p-value**
Lateral head of gastrocnemius	0.33 ± 0.12	0.28 ± 0.90	0.19
Medial head of gastrocnemius	0.97 ± 0.30	0.75 ± 0.28	0.06
Vastus lateralis	0.39 ± 0.21	0.41 ± 0.11	0.38
Vastus intermediate	0.24 ± 0.13	0.25 ± 0.06	0.38
Vastus medialis	0.18 ±0.09	0.19 ± 0.05	0.4
Rectus femoris	0.55 ± 0.17	0.59 ± 0.25	0.26
Gracilis	0.02 ± 0.01	0.015 ± 0.008	0.04
Biceps (Long head)	0.35 ± 0.12	0.28 ± 0.1	0.08
Biceps (Short head)	0.4 ± 0.22	0.33 ± 0.19	0.22
Semitendinosus	0.12 ± 0.04	0.09 ± 0.04	0.1
Semimembranosus	0.56 ± 0.02	0.48 ± 0.02	0.13

DISCUSSION

The number of the subjects with knee OA is increasing specially in those with symptoms in medial side. The patients with knee OA often use various knee orthoses to stabilize their joint, reduce pain and to improve their performance during walking. The effects of knee braces have been evaluated based on adduction moment. However, reducing the peak of knee adduction moment may not correspondent to decrease in the peak of knee contact force. Therefore, the aim of this study was to evaluate the effect of a newly designed knee valgus orthosis on knee joint contact force in patients with knee OA [13].

The results of the current study showed that the spatiotemporal gait parameters and the mean values of the force applied on the leg did not differ significantly while the subjects walking with and without orthosis. These findings, therefore, implies the use of orthosis did not restrict the abilities of the subjects. Lack of symptomatic relief, brace discomfort, poor fit and skin irritation are some issues associated with other knee orthoses. As the orthosis did not influence walking speed, therefore, it possible that subjects did not experienced the aforementioned problems [14].

OpenSim software was used to measure the joint contact force in this group of the subjects. The mean values of the first and second peaks of knee joint contact force decreased significantly by using the knee orthosis. It should be noted that the joint contact force is a combination of external forces (ground reaction force, muscular force surrounding the knee joint and supportive ligaments). As the force transmitted through leg did not decrease with the use of the orthosis, this suggests that reduction in knee joint contact force may be mostly due to change in performance of the muscles surrounding the knee joint [15].

The results of the present study agree with the findings of the study of Tran, et al. which was done on one OA female subject. There are some theories regarding the load distributions on the knee joint in OA subjects. Based on Condylar-lift-off theory, the main problem in the subjects with OA in medial compartment is lateral joint opening which can be delayed by increasing the compressive forces at the knee. Therefore, these subjects would need to increase contraction of quadriceps to increase the compressive force to stabilize the knee joint. The results of this study also confirmed that the use of knee orthosis stabilized the knee joint and reduced the knee space in lateral side. As a result, the subjects with knee OA may require less compressive force to stabilize the knee joint. It means that mean values of knee flexion and extension moments decreased simultaneously [16].

The extension and flexion moments of the knee and the forces produced by muscles surrounding the knee joint were the other parameters examined in the present study. The moments of knee decreased following the use of the orthosis. This suggests that subjects did not use more compressive force to stabilize the knee joint. Reduction in force of the muscles surrounding knee joint is good evidence regarding the stability provided by knee orthosis. It means that the subjects did not require stabilizing the knee joint dynamically [17-19].

Although the results of this study confirmed the positive effect of knee orthosis on decreasing joint contact force, there are some limitations to the study. The main limitation of this study was lack of follow up duration as the immediate effect of orthosis was evaluated. Considering that knee OA is a chronic condition, future studies would be required to determine the effects of the orthosis on these parameters during walking. In addition, the subjects included in the study were with less variation in OA severity. It is hoped that futures studies will include larger sample of subjects with knee OA of various severities [20].

CONCLUSION

The result of this study confirmed that the peak of vertical components of joint contact force decreased following the use of the knee orthosis. This may be due to decrease in moments and muscular forces required to stabilize the knee joint. This suggests that the orthosis could be used to alleviate the symptoms of knee OA. Clinicians are to be aware of the findings of this study as the use of the orthosis could be incorporated into the management of patients with knee OA.

CONFLICT OF INTEREST

None.

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