

## Research Article

# Design and Evaluation of a New Type of Knee Orthosis for Improving the Performance of Subjects with Knee Osteoarthritis

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**Abstract** | Knee joint osteoarthritis (OA) is a disease which influences the performance of the joint during walking. Various types of knee orthosis have been designed to improve the performance of the subjects, however, such cases are often associated with post-operational complications. The aim of this study is to design an orthosis which is easy to use, economical and effective. A new knee orthosis was designed to improve the performance of OA patients during standing and walking. Two subjects with knee osteoarthritis recruited in this research study. The gait performance of the subjects and their stability to stand was evaluated by the use of motion analysis system and a force plate (Kistler). The mediolateral excursion of the knee joint decreased while walking with the knee orthosis in contrast to normal walking. Moreover, the mediolateral moment applied on the knee joint decreased significantly. This new design of the orthosis improves the performance of the subjects during walking. It carried same performance as that of the knee cage, and additionally is more cosmesis, ease in use and is economical.

**Editor** | Mohammad Taghi Karimi, Department of Orthotics and Prosthetics, Faculty of Rehabilitation, Isfahan University of Medical Sciences, Isfahan, Iran.

**Received** | October 15, 2015; **Revised** | December 22, 2015; **Accepted** | December 25, 2015; **Published** | February 23, 2016

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**Citation** | Mirbod, S. M. (2016). Design and evaluation of a new type of knee orthosis for improving the performance of subjects with knee osteoarthritis. *Health Rehabil.* 1(1): 24-28.

**Keywords** | Knee orthosis, Gait, Stability, Osteoarthritis

## Introduction

Knee osteoarthritis (OA) is a disease which influences joint articular surfaces. As a result the smooth motion of the joint is disturbed and the patients suffer from pain associated with the knee motion (Wilson, 1989; Goldberg et al., 1997). There are various types of treatments used to decrease pain during walking, to align the mechanical axis of the joint and to decrease the mediolateral instability of the joint, which include using various kinds of knee brace, lateral wedge insole and subtalar strap (Birmingham et al., 2001; Childs et al., 2004; Divine and Hewett, 2005; Fang et al., 2006; Goldberg et al., 1997; Grace et al., 1988; Harrington, 1983; Kakihana

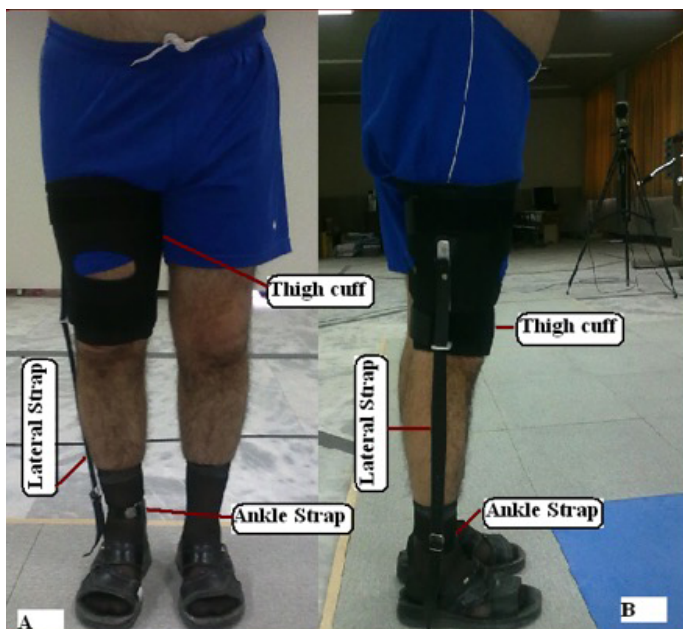
et al., 2005; Keating et al., 1993; Kerrigan et al., 2002; Kristin et al., 2007; Kuroyanagi et al., 2002; Matsuno et al., 1997; Pollo, 1998; Richards et al., 2005; Toda et al., 2004; Toda and Segal, 2002). Although, knee brace has some benefits for the patients with knee OA, such as reducing the knee joint varus moment, improving the configuration of the loads applied on the joint and decreasing the pain associated with the joint while walking (Birmingham et al., 2001; Divine and Hewett, 2005; Grace et al., 1988; Matsuno et al., 1997), the patients experience some problems which include tendency of the brace to migrate distally and overstretching of joint ligaments which may increase the instability of the joint during a long period of usage (Goldberg et al., 1997). Moreover, changing the

alignment of the orthosis is a big issue which needs to be resolved. Therefore, the aim of this research was to design a new type of orthosis which is easy to be used and is as efficient as the knee brace, which overcome the aforementioned problems. Moreover, it was aimed that the new orthosis improves the performance of the subjects with a reasonable cost.

## Material

### Orthosis

A new type of the knee orthosis has been designed which consists of some straps and a soft knee orthosis. The strap which encircles the ankle joint is attached to the soft knee orthosis via another long strap as is shown in Figure 1. The force applied on the knee joint can be changed by tightening the lateral strap.



**Figure 1:** The new design of the knee orthosis developed for patients with knee OA, one trial of subject 1

### Subjects

Two patients with knee OA without any other reported musculoskeletal disorders participated in this study. The mean values of their mass, height and age were 72 Kg, 1.72 meter and 52 year, respectively. The subjects were evaluated as having a medial compartment knee OA according to the American College of Rheumatology criteria for a diagnosis of Knee OA, medial knee pain and radiographic osteophyte at the medial joint space (Hochberg et al., 1995). The severity of knee OA was defined by use of the Kellgren and Lawrence grade (K-L grade) based on X-ray of the knee as was described in atlas of standard radiology (Kellgren and Lawrence, 1957). The subjects were

asked to walk with and without orthosis. Before running the tests, an Ethical approval was obtained from Ethics Committee of Isfahan University of Medical Sciences. The subjects were asked to sign a constant form before data collection. The following parameters were evaluated in this research study:

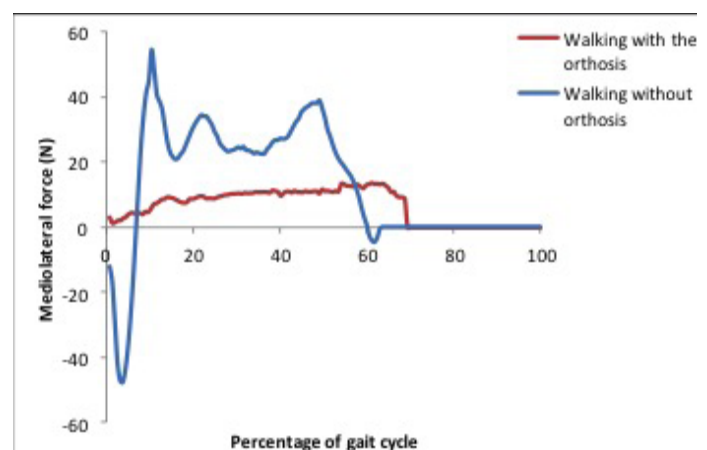
- Spatiotemporal gait parameters
- The mediolateral and vertical forces applied on the foot
- The mediolateral excursion of the knee joint
- The anteroposterior and mediolateral stability of the subjects while standing with and without knee orthosis

### Procedure

The markers (14mm sphere) were attached to the body according to preferred method of marker fixation which has been developed in Bioengineering Unit of Strathclyde University (Malizos, 2006; Agustsson, 2002). The subjects were asked to walk along the gait lab to collect 5 successful trials. The stability of the subjects was evaluated when the subject was standing on a force plate for a period of a minute. The collected data were filtered with a cut off frequency of 10 Hz. The gait trials were divided into gait cycle using heel strike data. The difference between the mean values of the parameters was evaluated by use of two sample t test with a significant point as 0.05.

## Results

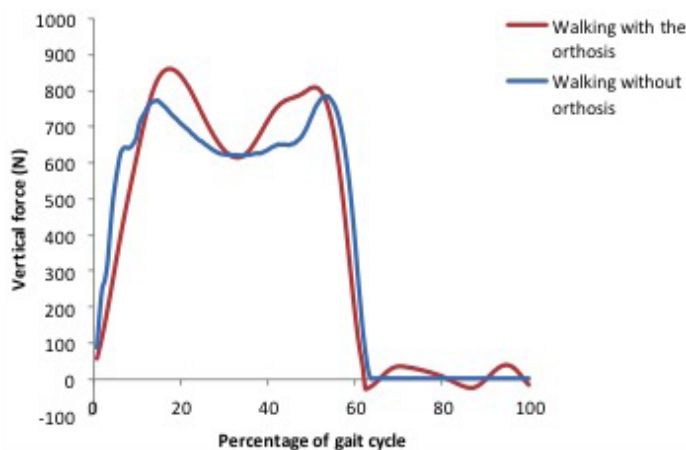
The gait parameters during walking with and without orthosis are shown in Table 1. Figures 2, 3 and 4 show the pattern of the mediolateral force, the vertical force and the adductor moment applied on the knee joint while walking with and without orthosis.



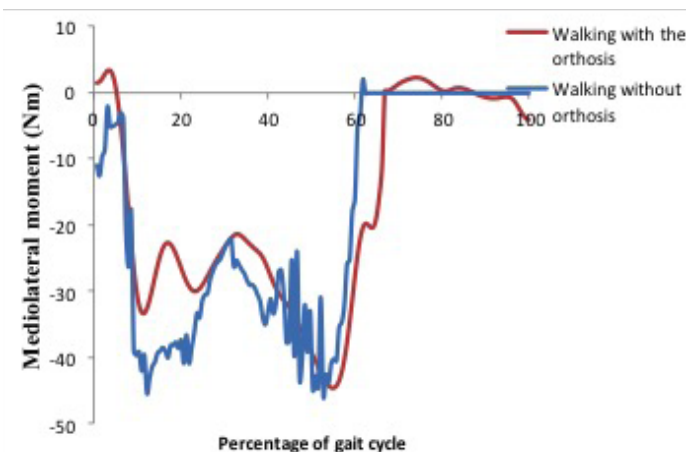
**Figure 2:** The mediolateral force applied on the foot while walking with and without orthoses (knee cage and the new design of knee orthosis)

**Table 1:** The gait parameters of the subjects while walking with and without orthoses (the comparison was done between normal walking and walking with each orthosis)

Parameters	Subject 1		Subject 2	
	Normal walking	Walking with the new orthosis	Normal walking	Walking with the new orthosis
Walking speed (m/min)	93.9 ±9.8 P-value=0.366	92.2 ±4.2	71.1±14.5 P-value = 0	113.82±10.07
Stride length (m)	1.34 ±0.04 P-value= 0.005	1.12 ±0.08	1.32±0.09 P-value=0.06	1.38±0.062
Cadence (steps/min)	81.43 ±7.2 P-value=0.036	90.9 ±7.3	86.2±7.2 P-value=0	115.4±6.26
Knee flexion (degree)	62.11 ±0.9 P- value = 0.06	59.6 ±1.7	55.2±6.2 P-value= 0.56	56.8±1.2
Knee adduction (degree)	11.26 ±1.3 P- value = 0.05	9.3 ±1.5	9.9±1.07 P-value= 0	5.6±0.556
Knee moment (N.m)	51.9 ±8.5 P-value = 0.027	38.6 ±5.6	38.6±2.5 P-value=0.04	34.2±1.5
Vertical force (N)	797 ± 11.6 P- value = 0.23	820 ±33.8	678.8±45 P-value=0.5	672.3±21.1
Mediolateral force (N)	37.4 ±11.1 P-value = 0.77	35.9 ±0.8	38.9±6.8 P-value= 0.07	43.5±13



**Figure 3:** The vertical force applied on the foot while walking with and without orthoses



**Figure 4:** The abduction/adduction moment of the knee joint while walking with and without orthoses

## Discussion

Based on the results of the research done, the mediolateral moment applied on the knee joint increases in patients suffering from knee OA (Morrison, 1970; Ogata et al., 1977; Sharma et al., 1998; Childs et al., 2004). Therefore it is important and practical to decrease the moment applied on the knee joint by use of some orthotic interventions. As can be seen from the results of this research, the mean

values of the mediolateral moment applied on the knee joint decreased significantly while walking with the new design of the orthosis in contrast to walking normally. It is shown that there is no significant difference between the force applied on the knee joint while walking with and without orthosis. Therefore the main reason regarding decreasing the mediolateral moment is changing the point of application of the mediolateral force.

The spatiotemporal gait parameters of the subjects improved while walking with the new design of orthosis. It represents that wearing the new orthosis not only decreases the performance of the subjects but also improve it. As can be seen from Table 1, the excursion of the knee joint did not decrease while walking with the new orthosis. Therefore the orthosis did not influence the knee joint ROM.



The same as results of other research study, the results of this study also showed that the difference between the stability of the subjects in standing with the knee orthoses is the same as that in normal standing. The main problem of the subjects with the knee OA is related to single limb support not double limbs support. Therefore, it is recommended that the stability of the subjects and the influence of the new orthosis on this parameter are evaluated during single limb support. One of the main parameter which represents the stability of the subject while walking is the excursion of the knee joint in the mediolateral plane. The higher the mediolateral excursion of the knee joint, is associated with the higher knee joint instability. As can be seen from Table 1, the excursion of the knee joint decreased significantly following use of the knee orthoses. As the stability of the knee joint improved, the subjects do not need to move their trunk sideway to enhance stability.

The knee joint range of motion did not differ in normal walking and walking with the new design of the orthosis in contrast to walking with the knee cage. Moreover the new design has some advantages compared with the knee cage which include:

- The weight of the new orthosis is less than the knee cage orthosis
- The performance of the new orthosis is the same as that of the knee cage
- The new orthosis is more economically efficient than the knee cage
- The new orthosis dose not restrict the knee joint motion in Sagittal plane
- The amount of protrusion of the orthosis under cloth is less than that of knee cage orthosis

## Conclusion

The new design of the knee orthosis has some advantages in contrast to available design of the knee cages. It is recommended evaluating the performance of the new orthosis on more patients with knee OA. Moreover, it is recommended to evaluate the other parameters such as oxygen consumption while walking and also the quality of life follow use of the new design of knee orthosis.

## Conflict of interest

None

## Acknowledgment

I would like to acknowledge from the subjects participated in this study.

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