JPOST Journal of Prosthetics Orthotics and Science Technology
Volume 4, Number 2 Year 2025
ISSN (online): 2962-8016
DOI: 10.36082/jpost.v4i2.2289

Measurement of the Varus Thrust of a Single-Leg Standing Position Using Strain Sensors: Determining the Effectiveness of Knee Orthosis

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Abstract

Background: Osteoarthritis of the knee is based on degenerative changes in the articular cartilage, resulting in varus thrust. Therefore, the treatment involves orthosis therapy to reduce the mechanical stress.
Aims: The varus thrust of a young healthy subject is measured. Then, the relationship between orthosis and varus thrust is clarified. The purpose of this study was to assist in orthosis therapy for patients with knee osteoarthritis.
Methods: The subjects were 15 young healthy subjects. The varus thrust during single-leg standing with and without orthosis was measured by strain sensors. Comparisons between groups were analyzed using the Wilcoxon rank-sum test. The statistical software fair was JSTAT for Windows, and the significance level was set at 5%.
Results: Significant differences in strain sensor elongation were found between the groups with and without the orthosis.
Conclusion: It was confirmed that the knee orthosis suppressed the varus thrust. The future challenge is to measure patients with knee osteoarthritis.

Keywords: Knee osteoarthritis; Varus thrust; Knee orthosis

Article History

Received date: 30-04-2025
Revised date: 27-11-2025
Accepted date: 04-12-2025

Journal Prosthetics Orthotics and Science Technology (JPOST)
e-ISSN 2962-8016
Organized by Department of Prosthetics and Orthotics
Published by Poltekkes Kemenkes Jakarta I
email: jpost@poltekkesjakarta1.ac.id

Introduction

Osteoarthritis of the knee is a disease based on degenerative changes in articular cartilage that results in joint dysfunction such as pain and limited joint range of motion (Saito et al. 2006). Osteoarthritis is one of the major factors that reduce the quality of life of the elderly and affects a large number of people worldwide (Watanabe et al. 2018). In Japan, the prevalence of knee osteoarthritis in people aged 40 years or older is 42.0% in men and 61.5% in women (Yoshimura et al. 2009). The majority of patients with knee osteoarthritis in Japan have medial-type knee osteoarthritis, and the O-leg deformity progresses as the disease progresses. The disease is caused by an abnormality of the medial tibiofemoral joint component. The movement of the knee, in which the knee bulges outward and turns inward during the stance phase of walking, and the varus rotation disappears and returns to normal during the swing phase, is a characteristic finding in patients with osteoarthritis of the knee and is defined as varus thrust (Chang et al. 2004). This varus thrust is one of the risk factors for disease progression. Therefore, measurement of the varus knee thrust may contribute to future research on the risk factors for knee osteoarthritis.

Physical therapy for knee osteoarthritis requires the acquisition of postural movement strategies that reduce abnormal mechanical stress on the knee during physical activities performed under gravity, such as standing and walking (Yoshinaga et al. 2004). Genu varum progresses further when the Mikulicz line runs more medially than the center of the knee joint, triggered by factors such as cartilage loss or meniscus injury. Orthosis therapy is used to reduce mechanical stress. The goal of orthosis therapy is to compensate for joint instability and abnormal motion from outside the joint to prevent further damage to the joint. Therefore, it is expected to be effective in correcting lower limb alignment, improving knee joint stability, controlling abnormal motion, relieving pain and other symptoms, and preventing progression (Motoda et al. 2008).

Furthermore, a new adjustable knee brace exists that analyzes the forces acting on the knee joint. However, it does not address the effects on the user(Xin Zhou et al. 2024).In this study, we conducted a basic study to examine the effect of orthosis on the varus knee thrust in young healthy subjects. We will conduct this study to collect basic data as a control group for comparison with a group of patients with osteoarthritis of the knee. The purpose of this study was to measure the varus thrust of young healthy subjects in the single-leg standing position and to clarify the relationship between orthosis and varus thrust. The purpose of this study was to clarify the relationship between orthosis and varus thrust and to provide some assistance in orthosis therapy for osteoarthritis of the knee.

Methods

The subjects were 15 young healthy subjects (13 males and 2 females). The knee joints were free of deformity of two transverse digits or less. Subjects were 23.5 ± 2.0 years of age, 172.0 ± 7.8 cm in height, 66.6 ± 13.7 kg in weight, and 22.5 ± 3.4 BMI (mean ± standard deviation). The purpose and methods of the study were explained to the subjects, and their written consent to participate in the

study was obtained. This study was conducted in compliance with the Declaration of Helsinki and was approved by the Ethics Committee of Sakura Juji Fukuoka Hospital (approval number: 2025033101).

A strain sensor (C-STRETCH: Bando Chemical Co., Ltd.) was used to measure the varus thrust during one-leg standing. The sensor is small and lightweight, with dimensions of 48 mm (length), 24 mm (width), 14 mm (height), and 16 g (weight). Therefore, it can be used for measurement without affecting the one-leg standing posture. The sampling grade was set at 1000 Hz. The acquired data were displayed on the transmitter's LCD screen in real time as the length of the sensor elongation and were captured on a personal computer via a wireless connection. The strain sensor outputs the change in elongation as an electrical signal. The output data are automatically converted to displacement (mm) on the measurement device side (Bando Chemical Co. 2025). This strain sensor is sufficiently accurate for use in estimating the knee flexion angle and the knee eversion angle (Kirinoe et al. 2020; Takekawa et al. 2023). A correlation between elongation and the joint angle on the sagittal and anterior forehead planes was observed. The strain sensor was placed on the right side in the standing position. The sensor was attached to the lateral femoral epicondyle and fibular head (Figure 1). The strain sensor was tensioned in the starting position. The subject was then asked to stand on one leg with the knee joint in extension for 5 seconds. The movement on the frontal plane was measured. The value employed was the maximum extension of the strain sensor. This was defined as the varus thrust. This process was measured randomly without and with a knee brace (Ex-Aid Knee-Light Sport 2: Nihon Sigmax Co., Ltd.), respectively (Figure 2).

Statistical analysis was performed by comparing the results of the Wilcoxon rank-sum test between the groups with and without orthosis. The varus thrust was measured once. The analysis included 5 seconds of standing on one leg. Statistical software JSTAT for Windows was used, and the significance level was set at 5%.



Figure 1*. Strain sensor attachment position*
The sensor was attached to the lateral femoral epicondyle and fibular head

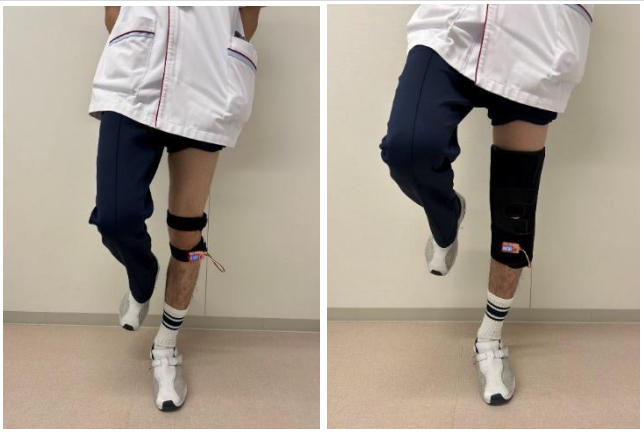


Figure 2. *Measurement scenes with and without orthosis devices*

Results

Shows the individual results of the strain sensor (Table1). The strain sensor extension was 1.38±0.74 mm without suspenders and 0.46±0.52 mm with suspenders. There was a significant difference in strain sensor elongation between the orthosis and non-orthosis groups ($p<0.05$). In other words, wearing the orthosis suppressed the varus thrust (Table 2).

Table 1. Varus thrust(Individual)

No.	gender	without orthotics	with orthotics
ID 1	male	0.73	0.87
ID 2	female	2.69	0.37
ID 3	male	1.58	0.89
ID 4	male	1.55	0.01
ID 5	male	2.45	2.05
ID 6	male	0.37	0.16
ID 7	female	0.74	0.4
ID 8	male	2.05	0.02
ID 9	male	0.67	0.55
ID 10	male	1.61	0.01
ID 11	male	2.32	0.3
ID 12	male	1.27	0.37
ID 13	male	1.38	0.53
ID 14	male	0.64	0.33
ID 15	male	0.68	0.11

unit: mm

Table 2. Varus thrust

	varus thrust
without orthotics	1.38±0.74*
with orthotics	0.46±0.52*
	unit: mm
	*: p<0.05

Discussion

This study measured the varus thrust of young healthy subjects in the single-leg standing posture. The results were compared with and without orthosis. The results showed that the orthosis suppressed the varus thrust during one-leg standing, and the difference was significant.

Wearing the orthosis suppressed the varus thrust in the one-leg standing position. In a study using a three-dimensional analyzer to measure the amount of lateral knee deviation, the lateral deviation of the knee joint during walking was measured based on body surface markers attached to the outside of the knee joint. The results showed that the amount of lateral knee joint deviation was 13.6 ± 5.5 mm in young healthy subjects, 17.8 ± 6.7 mm in elderly healthy subjects, and 22.1 ± 7.7 mm in patients with end-stage knee osteoarthritis (Bando Chemical Co. 2025). In other words, varus thrust occurs even in healthy young subjects. The purpose of orthosis is to reproduce the physiological motion of joints by compensating for the instability and abnormal motion caused by abnormal joint components outside the joint. The purpose is to prevent further abnormalities in the joint components. Specific roles include correcting and preventing deformity, controlling abnormal joint motion, assisting joint motion, and providing load-bearing support (Motoda et al. 2008). Knee braces are used in a wide range of applications, including knee braces, knee braces, knee braces, and knee joint fixation devices. Knee orthosis increase the immobilization of the knee joint and control abnormal motion. They also correct lower limb alignment, thereby reducing the load on the joint surfaces. As a result, pain reduction and prevention of the progression of knee osteoarthritis can be expected (Deie et al. 2017). Therefore, it is conceivable that the wearing of knee braces had an effect on the suppression of varus thrust.

A limitation of this study is that it cannot be limited to patients with knee osteoarthritis because the subjects were young healthy subjects. Future work is needed to clarify the results with a view to measure knee osteoarthritis patients in clinical practice.

Conclusion and Recommendation

This study analyzed the varus thrust during single-leg standing in young healthy subjects with and without orthosis. The results showed that wearing an orthosis device suppressed the varus thrust. The results suggest that wearing an orthosis device is one factor that improves the one-leg standing posture. However, this study was conducted on young healthy subjects. The results cannot refer to knee osteoarthritis. In addition, measurements other than those of the knee joint were not taken. Furthermore, it fails to account for differences in gender and weight. Therefore, the interpretation of

the results is limited. In the future, we will conduct similar measurements on patients with knee osteoarthritis in clinical practice. Furthermore, improvement is needed because the device may be moving along with the motion. Additionally, we plan to divide participants into an orthosis-wearing group and a non-wearing group, and consider conducting X-ray examinations with orthosis wearers, non-wearers, and healthy young adults as the control group. The challenge is to clarify the results from multiple perspectives.

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