

How Far an Arch Support Foot Orthosis Can Affect Lower Limb Joint Angular Accelerations during Normal Gait?

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ABSTRACT

The purpose of this study was to determine how far an arch support foot orthosis can affect lower limb joint angular accelerations during normal gait. In this study, sixteen male healthy volunteers were selected as participants. Subjects performed 12 walking trials at a self-selected walking speed while 3-dimensional kinematic data were collected for two conditions: shod with no orthoses, and shod with orthoses. Our results showed that the use of foot orthoses decreased the peak ankle angular acceleration during dorsiflexion ($p=0.034$). No significant difference was found in the values of knee angular accelerations between the two walking conditions ($p>0.05$). Furthermore, the subjects experienced a reduction in hip angular acceleration during extension in response to the application of foot orthoses ($p=0.027$). It seems that the use of arch support foot orthoses is effective to improve lower limb kinematics during walking and it can prevent overuse injuries in the lower extremity.

Keywords: foot orthosis, angular acceleration, walking.

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Introduction

Foot orthoses are specially made shoe inserts that help support the feet and improve foot function (1-3). Individuals who have chronic foot problems which interfere with the health and functioning of their feet may be prescribed foot orthoses by their medical specialists (4,5). It is reported that 91% of the Australian Podiatrists prescribed either custom-made or prefabricated orthotics for patients with flat feet (6,7). Also, it is demonstrated that foot orthoses are effective in treatment of a wide range of diseases such as pes cavus, pes planus, rheumatoid arthritis and plantar fasciitis (8,9). However, the biomechanical mechanism underlying the therapeutic effect of foot orthoses is still unclear.

Biomechanical analysis of human movement with 3-D motion capture cameras is a well-established technique which is a useful tool for understanding the fundamental behavior and response of the human body to medical intervention (10-15). Joint angular acceleration is a biomechanical variable which describes the relative angular acceleration of one segment relative to another segment. Understanding lower limb joint angular acceleration in healthy populations may allow podiatrists and medical specialists to obtain a comparably high level of knowledge to determine how well each individual joint movement profile is aligned with normal kinematics. It is reported that joint angular acceleration is associated with changes in walking among different population (7). Moreover, a new study showed that foot orthoses can alter joint angular velocity which is highly associated with joint angular acceleration during human walking (7). The purpose of this study was to determine how far an arch support foot orthosis can affect lower limb joint angular accelerations during normal gait. It was hypothesis that foot orthoses alters ankle joint kinematic but not knee and hip kinematic.

Material and Methods

Subjects

In this study, sixteen male healthy students were selected as participants. Subject was included if he was between 18 to 35 years old, had normal vision, normal hearing, and body mass index (BMI) of between 20-25, without any previous history of bone fractures, surgery, orthopedic disease, or neurologic problems. Subjects were all right footed determined by kicking the ball. All subjects had normal foot shape. Subjects with normal feet were included if the navicular drop was less than 10mm (7) and a foot posture index less than 10 (7). Participants were excluded if they had a limb length discrepancy greater than 5mm (7), any neurological disorder, any surgery in the lower extremities, or mental disorders. Subjects in all groups did not have any regular exercise. All subjects gave their informed consent to participate in the study.

Apparatus

Kinematics data were collected at 100 Hz using a six-camera VICON motion capture system (Vicon system, Oxford Metrics, Oxford, UK) and Sixteen reflective spherical markers (15 mm in diameters) were used to identify the body segments including the bilateral thighs, legs, and feet, as well as the pelvis. Marker locations which were determined according to the plug-in-gait model provided in Nexus software and illustrated in Figure 1.



Figure 1. Marker locations based on plug-in-gait model

Task and procedure

Before the experiments, subjects were allowed to walk freely or do warm up exercises inside the laboratory for five minutes to become familiar with the experimental environment. The starting point for walking was selected based on the practice trials so that the subject could have taken at least eight steps before entering the calibrated space. Furthermore, subjects performed five practice trials prior to the actual walking tests. A trial was excluded in case if the foot was placed on the edge of the force plate. For each experiment condition, six walking trials were recorded.

Application of orthoses

All subjects wore the same model of standard shoes (New Balance 759, USA) with no intrinsic correction, but in different sizes during experimental day. Custom-made arch support foot orthoses fabricated from microcellular rubber with a shore density of 50A/55A and with an arch angle of 20° were used in this study (Figure 2). The intention was not to alter the patient's normal function, but the main goal was to evaluate the psychological effects of using an orthotic device.



Figure 2. Custom-made arch support foot orthosis

Statistical analysis

The normality of the data distribution was confirmed by Shapiro-Wilk test. Paired sample t-test was used to measure between-condition differences. All analyzes were performed at the significant level of 0.05 using SPSS 24 software.

Results

There was significant difference between the peak ankle angular acceleration when subjects wore foot orthoses as compared with shod condition. As the Figure 3 shows, the use of orthoses decreased the peak ankle angular acceleration during dorsiflexion ($p= 0.034$).

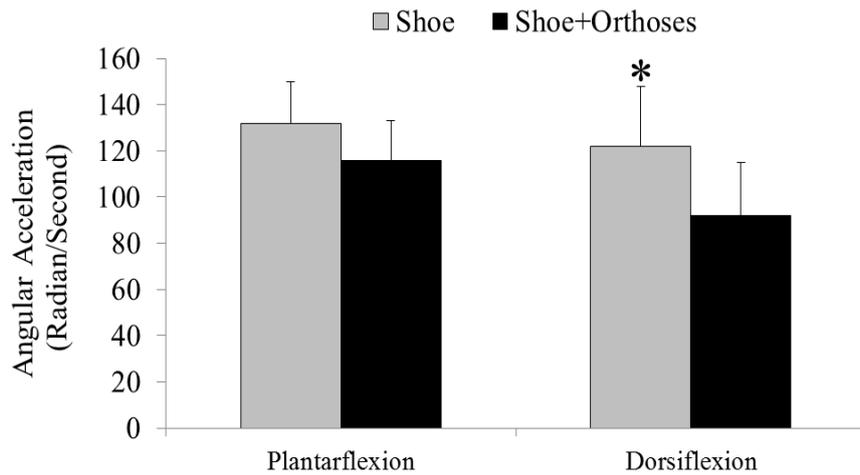


Figure 3. Maximum ankle angular acceleration for the both walking conditions.

Figure 4 illustrates the peak knee angular acceleration for the both walking conditions. No significant difference was found in the values between the walking conditions ($p>0.05$).

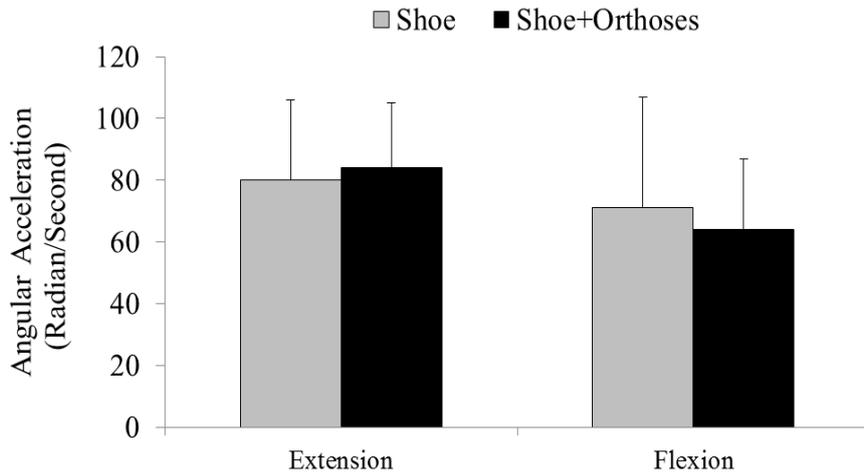


Figure 4. Maximum knee angular acceleration for the both walking conditions.

Figure 5 depicted the peak hip angular acceleration for the both walking conditions. The subjects experienced a reduction in hip angular acceleration during extension in response to the application of foot orthoses ($p=0.027$).

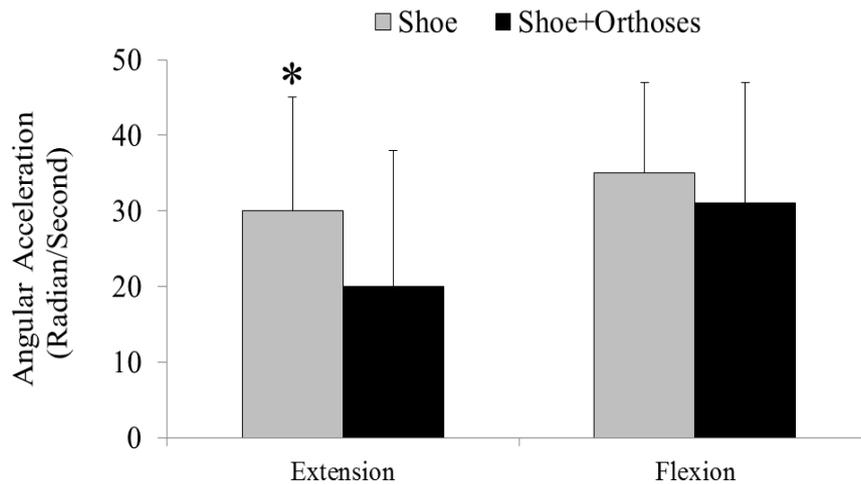


Figure 5. Maximum hip angular acceleration for the both walking conditions.

Discussion

The purpose of this study was to investigate how far an arch support foot orthosis can affect lower limb joint angular accelerations during normal gait. It was hypothesized that foot orthoses alter ankle joint kinematics but not knee and hip kinematics.

Our results showed that the use of foot orthoses decreased the peak ankle angular acceleration during dorsiflexion. One previous study indicated that when the ankle accelerated into plantarflexion during pre-swing, the foot orthoses delivered restorative dorsiflexion moment (1). In line with the present results, Jafarnejadgero et al (2018) have demonstrated that the application of foot orthoses affects ankle kinematics during walking (7). Also, it has previously demonstrated that foot orthoses could decrease ankle internal moment during gait (1). Therefore, it is plausible that the decreased ankle acceleration may be due to the fact that foot orthoses could reduce ankle muscle moment during walking. Crabtree et al. (2009) observed more variable ankle moment at high angular velocity due to slipping and bowing which could have substantial and unexpected effects during dynamic activities of daily living (16). They also reported an increase in plantarflexion moment in all foot orthoses conditions in early stance of gait cycle.

The results of the present study showed that foot orthoses did not change knee angular acceleration during gait. The maximum knee angular acceleration occurs in the short push-off phase of gait (17). The previous studies reported that the application of foot orthoses can alter kinetic (17-19) and kinematic (20-23) of the knee joint during gait. Unlike the previous literature our results did not confirm that. However, we only examined joint angular acceleration and our intervention may affect the other biomechanical variables that were not examined in the present work. This study provides the first reference database of the effect of use of foot orthoses on lower limb joint angular accelerations during gait.

In consistent with a study conducted by Jafarnejadgero et al (2018), our results demonstrated that wearing foot orthoses alters hip dynamics during gait. Jafarnejadgero et al (2018) argued that wearing foot orthoses could change between asymmetry during gait (7). Allard et al. (1996) reported a significantly greater peak muscle power generation in the dominant limb of subjects possibly as the result of gait adjustments attributed to different limb functions during gait (24). However, the decreased hip extension angular acceleration moment asymmetry measured in the current study may have clinical applications. This study is the first to identify that foot orthoses affect lower limb joint angular accelerations during normal gait. The authors encourage further research to be done to determine whether the individuals with different pathologies show the same biomechanical response to foot orthoses.

A number of limitations of the current study should be acknowledged. All participants were male volunteers, and hence care must be exercised in extrapolating and generalizing these results to females. Furthermore, the skin marker based approach has its limitations. For example, the kinematic calculations are substantially dependent on marker placement and may also be affected by soft-tissue movement artifact (25). Nevertheless, to minimize errors associated with marker replacement, a same expert person attached

them during both walking conditions. Another limitation of this study is related to the absence of longitudinal impacts of these medical interventions. All of these are unresolved questions for future investigations.

Conclusion

During walking, wearing foot orthoses decreases ankle and hip angular accelerations. Therefore, the use of arch support foot orthoses is effective to improve lower limb kinematics during walking and it can prevent overuse injuries in the lower extremity. Further investigations are warranted to explore the long-term effects of foot orthoses therapy on other gait characteristics such as joint kinetics and lower limb muscular activity and to examine the effects of sex and maturation.

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چکیده فارسی

تا چه میزان پوشیدن کفی حمایت کننده قوس پا در هنگام راه رفتن می تواند بر شتاب زاویه ای مفاصل اندام تحتانی اثر گذار باشد؟

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هدف از مطالعه حاضر تعیین مقدار اثرگذاری پوشیدن کفی حمایت کننده قوس داخلی طولی پا بر میزان شتاب زاویه ای مفاصل اندام تحتانی در هنگام راه رفتن می باشد. در این مطالعه تعداد ۱۶ داوطلب مرد شرکت داشتند. درحالیکه اطلاعات کینماتیک ۳ بعدی حرکات ثبت می شد، آزمودنی ها تعداد ۱۲ آزمایش راه رفتن را با سرعت دلخواه در دو شرایط پوشیدن کفی و عدم استفاده از آن انجام می دادند. نتایج نشان داد که استفاده از کفی موجب کاهش بیشه ی شتاب زاویه ای مفصل مچ پا حین حرکت دورسی فلکشن می گردد ($p=0/034$). استفاده از کفی نتوانست موجب تغییر مقادیر شتاب زاویه ای مفصل زانو گردد ($p>0/05$). همچنین، استفاده از کفی منجر شد تا میزان شتاب زاویه ای مفصل ران هنگام اکستنشن کاهش یابد ($p=0/027$). بنظر می رسد که استفاده از کفی حمایت کننده قوس پا یک روش موثر در بهبود کینماتیک حرکت اندام تحتانی باشد و بتواند از آسیب های مرتبط با کار اضافی در اندام تحتانی جلوگیری کند.

واژه های کلیدی: کفی حمایت کننده قوس پا، شتاب زاویه ای، راه رفتن