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Effects of semi-rigid arch-support orthotics: an investigation with potential ergonomic implications

Dan Kelaher*, Gary A. Mirka, Karin Q. Dudziak

The Ergonomics Laboratory, Department of Industrial Engineering, North Carolina State University, Box 7906, Raleigh, NC 27695-7906, USA

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Abstract

For many years, arch-support orthotics have been prescribed for individuals with discomfort and/or abnormal skeletal alignments in the structures of the lower extremity. Recently there has been an increased interest in promoting semi-rigid orthotics as an ergonomic aid for asymptomatic workers who must stand all day at their workplace. A laboratory study was performed to assess the biomechanical impact of prefabricated semi-rigid orthotics on asymptomatic individuals. Ten subjects wore semi-rigid arch-support orthotics (experimental condition) for two months and flexible polyurethane/Sorbothane ® shoe inserts (control condition) for two months. Throughout this 18-week testing period, the subjects returned to the lab to perform a battery of assessment tests at regularly scheduled intervals. These tests examined subject strength, standing posture, stability, fatigue effects, and body part discomfort. The results of this study showed no significant changes in the strength, posture, or stability as a function of insert type. The subjects reported a reduction in low-back discomfort along with an increase in foot discomfort during a fatiguing exertion task while wearing the semi-rigid orthotics as compared to the control condition.

Keywords: Orthotics; Posture; Stability; Fatigue; Discomfort

1. Introduction

Complaints of low-back pain, varicose veins, leg and foot pain are common among people who stand while they work (Brand et al., 1988; Stuart-Buttle, 1994). Providing a foot rail or 'anti-fatigue' mats are often the option chosen for reducing these symptoms. The foot rail allows the operator to alternate lifting the left and right foot which will improve circulation by reducing some of the static muscle contractions that can occur in the back and legs. The 'anti-fatigue' mats have been hypothesized to help reduce static loading in the legs and back by encouraging more alternating muscle activity which increases venous return of the blood in the lower legs (Kim et al., 1994). However, both anti-fatigue mats and foot rails can only be effective where installed and restrict access for material handling devices such as carts or pallet jacks. One option is to use cushion inserts inside the shoe (Redfern and Chaffin, 1995), providing some of the benefits of the mats while not having the 'anti-mobility' drawback. The two principle benefits from both the inserts and the mats are a reduction in the impulse loading to the musculoskeletal system (a cushioning effect) and an increase in the circulation in the lower extremities due to an increase in the contraction/relaxation of the muscles of the legs (a circulation effect).

Another potential intervention that should be considered for alleviating discomfort during standing work is the use of arch-support orthotics. The biomechanical rationale behind the use of arch-support orthotics is conceptually different than the benefits of the cushion/mat approach. The theory is that the orthotic will provide biomechanical support to the foundation of the body (the feet) which will improve lower-extremity and whole-body alignment/biomechanics. With a flattened arch, the talus is displaced medially and the calcaneus rotates outward (eversion), causing poor transmission of the weight of the body through to the medial longitudinal arch (Franco, 1987). This can eventually lead to many different problems in the knees, hips, and low back (Franco, 1987). This process of pronation, although an integral part of the midstance phase in the normal gait cycle, should not be present in quiet stance. Further, differences in the degree of pronation between

* Corresponding author. Tel.: 919-515-7210; fax: 919-515-5281.
E-mail address: dpkelahe@eos.ncsu.edu (D. Kelaher).

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the right and left foot can generate a functional leg length discrepancy which may cause lateral pelvic tilt, causing lateral shear forces in the intervertebral discs (Danbert, 1988). Excessive pronation of the foot is a condition that has often been successfully remedied with arch support orthotics by supporting the medial longitudinal arch of the foot in a position such that the weight of the body is evenly transferred through the talocalcaneonavicular joint of the foot, to the medial longitudinal arch, and finally to the calcaneus and metatarsal bones.

The majority of the previous research performed on the effects of arch-support orthotics has emphasized the impact that these products have on lower-extremity biomechanics during gait. Orthotics have been found to affect lower-leg biomechanics, by minimizing both foot pronation during running (Bates et al., 1979) and maximum internal tibial rotation during normal walking (Cornwall and McPoil, 1995). Other reports have discussed the effects that these devices have on individuals who have structural deficiencies in the feet or legs, such as flat feet, genu varus ('bowlegged'), and genu valgus ('knock-knees') (Bordelon, 1989; Gross et al., 1991).

In addition to the lower extremity research, several studies have investigated the effects of orthotics on a more global scale. A study by Behler et al. (1994) tested the standing stability of elderly subjects. They asked a group of women (aged 65 and over) who had experienced at least two but not more than six falls in the previous year to wear a pair of neutral foot orthotics and measured the excursion of the center of pressure while standing. Their results showed a decrease in the excursion of the center of pressure while wearing the orthotics and hypothesized that neutral posture foot orthotics may increase whole-body stability. The effects of orthotics on whole-body energy demand have also been considered. Otman et al. (1988) found that arch-support orthotics decreased heart rate, blood pressure and oxygen consumption for subjects with flat feet while walking. In contrast, Burkett et al. (1985) found an increase in oxygen demand for trained runners wearing orthotics while running.

While there is considerable evidence that arch support orthotics are an effective treatment for people with structural abnormalities of the lower extremities (herein referred to as the symptomatic group), there has been a recent effort to present these devices as prophylactic devices for the asymptomatic individuals who stand during the workday. What is not clear is that the positive response to the orthotics from this symptomatic group can be extrapolated to an asymptomatic population. Any device that can reduce discomfort, increase strength, improve posture, increase resistance to fatigue and improve stability has obvious ergonomic and productivity advantages. The goal of this research project was to evaluate the effects of semi-rigid arch-support orthotics on these various industrially relevant biomechanical measures in asymptomatic individuals.

2. Methodology

2.1. Subjects

Twelve subjects (five males and seven females) were recruited to participate in this study. Ten subjects (all but two females) participated in the 18-week comparison study while the remaining two females participated in the six-month study. Basic anthropometric data for the ten 18-week subjects is shown in Table 1. The subject pool was screened to eliminate all subjects with a history of foot and/or leg problems or anyone who had worn arch support orthotics previously.

2.2. Treatment Conditions

The independent variable in each of the biomechanical assessments was shoe insert type: a semi-rigid orthotic insert or a flexible polyurethane/Sorbothane® insert. The semi-rigid orthotics were prefabricated and made from EVA plastic. They spanned approximately two-thirds of the length of the foot, supporting from the heel to the base of the first metatarsal head. The thickness of the orthotic was approximately 2 mm underneath the calcaneus and ranged from 10 to 15 mm (depending on orthotic length) in the center of the arch. The polyurethane/Sorbothane® inserts (termed 'flexible inserts' for the rest of this paper) were evaluated as a placebo treatment. These inserts were polyurethane along the entire length of the shoe with sections of Sorbothane® under the calcaneal and metatarsal areas. They were approximately 6 mm thick under the calcaneus when uncompressed and 3 mm when compressed by a 62 kg male. For the purposes of this experiment, the important difference between the flexible insert and the orthotic insert, was that under load, the flexible insert provided no arch support (due to the compressibility of the polyurethane material) while the orthotic insert provided significant support to the arch (due to the relative incompressibility of the EVA plastic material).

2.3. Experimental procedure

The subjects wore each type of insert for a period of 2 months with a two week break separating the two experimental periods. Half of the subjects began with the flexible inserts and the other half of the subjects began with the semi-rigid orthotics. After two months, the subjects removed the inserts that they were wearing and wore no inserts for a period of two weeks. They then returned to the lab and were fitted for the other insert type. During these experimental 2-month periods, the