EFFECT OF ARCH PAD ON ANKLE JOINT PRONATION DURING GAIT WITH DIFFERENT TREADMILL SPEEDS

Heung Youl Kim[1.2] and Shinji Sakurai[3]

School of Sport and Health Sciences, Tokai Gakuen University, Miyoshi, Japan[1]
National Center for Geriatrics and Gerontology, Obu, Japan[2]
School of Health and Sport Sciences, Chukyo University, Toyota, Japan[3]

The purpose of this study was to evaluate the effect of an arch pad on changes of three-dimensional (3D) ankle joint kinematics while walking and running at three different treadmill speeds (5km/h, 7km/h, and 10km/h). Six healthy male subjects were tested. Walking (5km/h) and running (7km/h,10km/h) motions with two shoe conditions (with and without medical arch pad) on a treadmill were analyzed by a motion capture system (Vicon-MX, 10 cameras, 250Hz). The effects of medial arch pad on foot eversion motion were found to be effective with all treadmill speeds. Additionally, the interaction between shoe conditions and gait speeds on eversion angle was significant($p<0.05$). Consequently, it will be important to choose an arch pad of an appropriate size and material in order for individuals to reduce pain and to prevent running injuries.

KEY WORDS: arch pad, three-dimensional ankle joint angle, treadmill speed.

INTRODUCTION: Pronation of the subtalar joint is a combination of movements; calcaneal eversion, forefoot abduction, and dorsiflexion. Those movements have an important role in shock absorption and adapting to irregularities in various surfaces while walking and running (Busseuil, Freychat, Guedj, & Lacour, 1998; Sammarco & Hockenbury, 2001). Without subtalar pronation, the external forces would have to be directly absorbed by the supporting structures to reduce potential problems associated with excessive stress. Additionally, excessive pronation of the subtalar joint in a foot, contacting the ground, is still most frequently associated with various running injuries on lower limb joints (James, Bates, & Osterning, 1978; Clement, Taunton, & Smart, 1984).
Shoe inserts or orthotics have often been proposed as one of the most important corrective strategies to prevent injury to the soft and hard structures of the body due to excessive foot and leg movements. This idea was supported by previous researchers in the foot and ankle behavior study, and then some studies found the effect of the positioning of the medial arch pads. Many researchers have suggested that excessive pronation may lead to injuries in diverse locations in the lower limbs (Hintermann & Nigg, 1998; Cheung, Ng, & Chen, 2006). Furthermore, Nigg(1986a) showed that the pronation angle becomes larger with increases in running speed. However, the effect of arch pads on the different gait speeds has yet to be investigated. Therefore, the purpose of this study was to evaluate the effect of an arch pad on changes in three-dimensional (3D) ankle joint kinematics while walking and running at three different treadmill speeds (5km/h, 7km/h, and 10km/h).

METHODS: Six healthy male students (age: 19.3 ±0.5 year, height: 170.7 ±4.0 cm, body mass: 62.7 ±8.1 kg) with no injury history in lower extremities were adopted as subjects. The subjects walked (5km/h) or ran (7km/h, 10km/h) on a treadmill with their own shoes with and without arch pads. All subjects were heel strikers. Sixteen 12-mm-diameter reflective markers were positioned on the subject's pelvis and right lower limbs (4 on the pelvis, 5 on the thigh, 3 on the lower leg, and 4 on the shoe). The positions of the reflective markers are shown in Figure 1. All of the markers were placed on the subjects by the same examiner. The arch-pad utilized in this study (Figure 2a) was molded from Sorbo®(DSIS®Arch Pad, Sanshin Enterprises Co., Ltd, Tokyo, Japan). The arch pads were custom-made for each subject (Figure 2b), and were located directly under the area between the sustentaculum talus and navicular (Figure 3). An appropriate size of arch pad, fitted the arch of each subject, and was chosen from two possible sizes and inserted into the recess beneath of the medial arch.

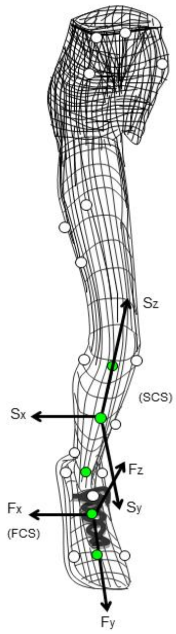

Figure 1: Frontal view of the marker locations on the lower limb.

Figure 2: (A) Arch-pads (DSIS®Arch Pad, Sanshin Enterprises Co., Ltd, Tokyo, Japan). (B) Profile of the insole.

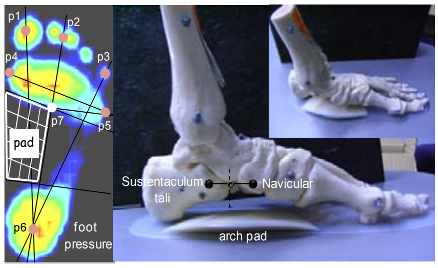

Figure 3: Location of the arch pad.

Ten consecutive steps at each speed were recorded and analyzed with a motion capture system (Vicon-MX, 10 cameras, 250Hz). Three-dimensional ankle joint motions were expressed in terms of Cardan angles as recommended previously (Cole, Nigg, Ronsky & Yeadon, 1993). Additionally, all motions was described as foot motion relative to the lower leg segment. As a result, rotation in the sagittal plane (y-z plane) was defined as dorsi-plantar flexion, in the coronal plane (x-z plane) as inversion-eversion, and in the transverse plane (x-y plane) as internal-external rotations (Figure 4). The statistical analysis used was two-way repeated measures ANOVA with shoe conditions (with and without arch pad) and treadmill speeds (5km, 7km,10km).

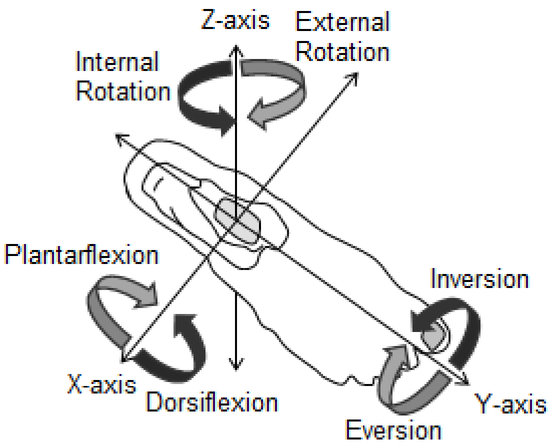

Figure 4: The x-y-z coordinate system was used to describe motions of the ankle joint. The x-axis was oriented lateral-medial, the y-axis posterior-anterior, and z-axis distal-proximal. Ankle motion was described as foot motion related to the lower leg segment.

RESULTS: Maximal dorsiflexion angles become larger with increases in speed, but the difference in time series curves of the joint angle in the sagittal plane (y-z plane) on shoe conditions was not observed (Figure 5; A1, B1). Similarly, such a trend was common in the transverse plane(x-y plane) (Figure5; A3, B3). On the other hand, a remarkable change in time series curves on shoe conditions was seen in the coronal plane(x-z plane) (Figure 5; A2, B2).

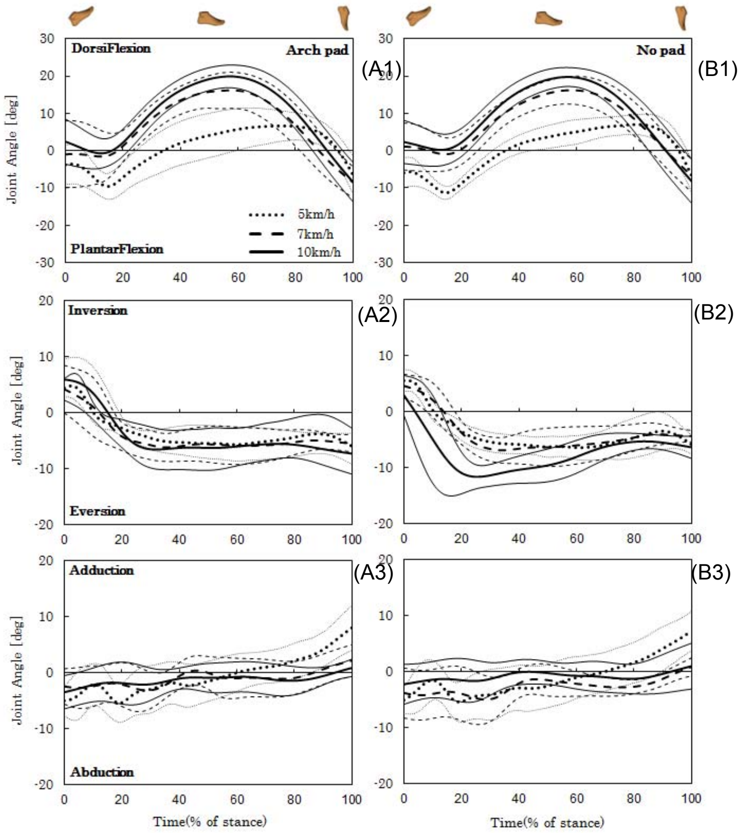

Figure 5: Mean and standard deviations of time series curves between shoes with and without arch pads in terms of 3D ankle joint angles (dorsiflexion: top panel, eversion: center panel, and abduction: bottom panel) at three different treadmill speeds (5km/h, 7km/h, and 10km/h).

As for peak values in dorsiflexion and abduction, there were few differences between the two conditions (with and without arch pads) though the angle values differed with gait speed. The peak eversion angle without arch pads tended to be bigger at higher running speed as reported in the previous studies. In comparison, the peak eversion angle with arch pads remained small even at higher running speed (Figure 6b). The interaction was significant between shoe conditions and gait speeds ($p<0.05$).

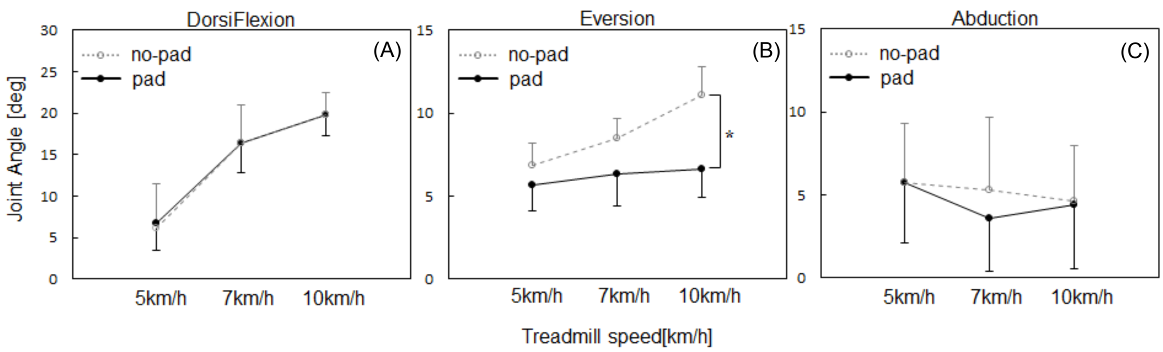

Figure 6. Comparisons between shoes with and without medial arch pad in terms of 3D ankle joint angles (dorsiflexion, eversion, and abduction) at three different treadmill speeds (5km/h, 7km/h, and 10km/h). *Significant interaction was detected.

DISCUSSION: Excessive pronation increases the risk of overuse syndromes on the lower limbs. Thus, the correct alignment of the lower limb during stance phases of the walking and running is one of the most important functions of shoes, shoe inserts, and orthotics. Therefore, it is believed that the ability to reduce maximum pronation is the most important aspect to evaluate foot control obtained from a device such as a medial arch pad. The results of this study indicate that maximum eversion was statistically and significantly decreased by inserting a medial arch pad into a running shoe. That might be an outcome on the control of rearfoot and midfoot motions due to insert a wide range of arch pad between the sustentaculum talus and navicular in a foot. On the other hand, Nigg et al (1986b) stated that the total foot eversion didn't change between medial support and no support shoe, but this study found that the eversion changed between them. Those differences may be considered to be a characteristic of running speed, material properties and a shape of arch pad, a position of insertion, a subject's foot shape, and running style. If, however, patients with ankle instability have symptoms of unstableness while walking or running, the use of a medial arch pad may be a effective method. The size and height of an arch pad should be selected carefully because a thick arch support can cause over elevation of the medial longitudinal arch. Moreover, the arch support may result in increasing the risk of inversion sprain. In another important change, this study found that the time series curves in the sagittal plane (y-z plane) motion were similar, but the coronal plane(x-z plane) and the transverse plane(x-y plane) motions were not coincident with all subjects. Subject characteristics and shoe shape might be a factor as described above, but this mechanism is not well understood.

CONCLUSION: Arch pads can reduce the excessive pronation during running, especially at higher speed. Furthermore, it is suggested that suitable arch pads should be chose by individual characteristics of runners including the running distance and speed.

REFERENCES:

Busseuil, C., Freychat, P., Guedj, E.B., & Lacour, J.R. (1998). Rearfoot-forefoot orientation and traumatic risk for runners. *Foot & Ankle International*, 19, 32–37.

Cheung, R.T.H., Ng, G.Y.F., & Chen, B.F.C. (2006). Association of footwear with patellofemoral pain syndrome in runners. *Sports Medicine*, 36, 199–205.

Clement, D.B., Taunton, J.E., & Smart, G.W. (1998). Achilles tendinitis and peritendinitis: etiology and treatment. *American Journal of Sports Medicine*, 12, 179-184.

Cole, G.K., Nigg, B.M., Ronsky, J.L & Yeadon, M.R. (1993). Application of the joint coordinate system to three dimensional joint attitude and movement representation: A standardization proposal. *Journal of Biomechanical Engineering*, 115, 344-349.

Hintermann, B., & Nigg, B.M. (1998). Pronation in runners: Implications for injuries. *Sports Medicine*, 26, 169–176.

James, S.L., Bates, B.T., & Osternig, L.R. (1978). Injuries to runners. *American Journal of Sports Medicine,* 6, 40-50.

Nigg, B.M. (1986a) Experimental techniques used in running shoe research. In Nigg, B.M (Ed), *Biomechanics of Running Shoes* (pp. 27-61). Human Kinetics Publishers, Champaign, IL.

Nigg, B.M., Bahlsen, A.H., Denoth, J., Luethi, S.M., & Stacofl, A. (1986b). Factors influencing kinetic and kinematic variables in running. In Nigg, BM (Ed), *Biomechanics of Running Shoes* (pp. 139-159). Human Kinetics Publishers. Champaign, IL.

Sammarco, G.J., & Hockenbury, R.T. (2001). Biomechanics of the foot and ankle, In Nordin, M & Frankel, V.H. (Eds.), *Basic Biomechanics of the Musculoskeletal System* (pp.223-255). Lippincott Williams & Wilkins.