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Original Article

The effects of plantar flexor static stretching and dynamic stretching using an aero-step on foot pressure during gait in healthy adults: a preliminary study

Je-myung Shim, PhD, PT[1)], Ju-hyeon Jung, MS, PT[2)*], Hwan-hee Kim, PhD, OT[3)]

[1)] *Department of Physical Therapy, College of Health and Science, Kangwon National University, Republic of Korea*
[2)] *Department of Physical Therapy, Gimhae College: 198 Saman-ro 112, Gimhae-si, Gyeongsangnam-do 621-706, Republic of Korea*
[3)] *Department of Occupational Therapy, Semyung University, Republic of Korea*

Abstract. [Purpose] The aim of this study was to examine whether plantar flexor static stretching and dynamic stretching using an Aero-Step results in changes in foot pressure during gait in healthy adults. [Subjects] Eighteen normal adults were randomly allocated to either a dynamic stretching using an Aero-Step group (DSUAS) group (n = 8) or a static stretching (SS) group (n = 10). [Methods] The DSUAS and SS participants took part in an exercise program for 15 minutes. Outcome measures were foot plantar pressure, which was measured during the subject's gait stance phase; the asymmetric ratio of foot pressure for both feet; and the visual analogue scale (VAS) measured during the interventions. [Results] There were significant differences in the asymmetric ratio of foot pressure for both feet and VAS between the two groups after intervention. However, there were no significant differences in foot plantar pressure during the gait stance phase within both groups. [Conclusion] DSUSAS is an effective stretching method, as pain during it is lower than that with SS, which can minimize the asymmetric ratio of foot pressure for both feet during gait due to asymmetric postural alignment.
Key words: Static stretching, Dynamic stretching using Aero-Step, Foot pressure

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INTRODUCTION

Most people warm up before exercising. However, the proper amount of warm-up exercise required has been a subject of debate. An active warm-up is known to improve an athlete's performance ability. Stretching is one component of warming up that improves muscle flexibility, prevents muscle damage, and improves physical performance[1–3)]. Problems mainly occur in the lower limbs, and pain and limitations in joint working force mostly occurs in the ankle joints.

Practitioners report that loss of ankle dorsiflexion range of motion (ADFROM) causes hind foot pronation as compensation, followed by altered patellofemoral tracking and finally; anterior knee joint pain[4, 5)]. In addition, limitations in gastrocnemius extensibility cause limitations in ankle dorsiflexion during stance phase of gait, as well as compensatory movements[6, 7)]. Therefore, it is important to maintain ADFROM, as a loss of it causes stress and pain to concentrations in the knee, hips, and lower back[4, 8)].

Traditionally, therapists have been evaluated a patient's soft tissue flexibility to apply the proper intervention before treatment. In addition, they have used static stretching (SS) to maintain and extend the lengths of connective tissues[4)]. In fact, SS causes pain during its application in the clinic. Moreover, SS prevents contracture of the joints, increases mobility, and improves muscle flexibility. However, recent research studies insist it is hard to reduce damage occurrence[9)]. On the other hand, dynamic stretching allows for movement of the extremities to the end range of the joint in a neutral position. It also allows for the maximum stretch of muscles at the end range of joints and causes the limb to return to the original position. This dynamic action is repeated with a slow and naturally controlled motion for a specific duration of time[1)].

There are two opinions in the existing studies. One is positive and states that SS helps reduce the injury ratio and helps in recovery? The other is negative and states that SS has little influence on injury prevention and negatively influences body performance after stretching[1, 10–12)]. This means dynamic stretching can be recommended, as it can be a substitute for a warm-up after stretching. Moreover, dy-

*Corresponding author. Ju-hyeon Jung (E-mail: hyuni610@naver.com)

namic stretching can have a more positive influence on body performance compared with SS when applied immediately after stretching. Therefore, stretching is necessary for damage prevention. However, there are different strengths and weaknesses depending on the stretching methods, as well as various opinions on supplementing them.

Therefore, this study aimed to apply a new method of dynamic stretching on an unstable plane to improve foot proprioception, as well as to induce a potential change in the neuromuscular recruitment pattern around the lower extremity[13]. In addition, the weakness of SS, including pain and decreased motor performance ability, were avoided in the new method to confirm the effect on foot pressure and gait and determine an efficient stretching method.

SUBJECTS AND METHODS

This study utilized 18 adult subjects (11 males and 7 females) who could walk normally without any abnormalities in the musculoskeletal system or neurology that could affect gait. The study was approved by the Kangwon National University Institutional Review Board. Before the experiment began, the subjects were informed in detail about the purpose and methods of the experiment, and they agreed voluntarily to participate in the experiment. A homogeneity analysis of the two groups showed no significant difference. The average age, height, and weight of the dynamic stretching using Aero-Step (DSUAS) group (n=8) and the SS group (n=10) were 29.50 ± 2.36 years, 169.8 ± 6.14 cm, and 63.60 ± 11.29 kg; and 30.28 ± 2.81 years, 171.00 ± 7.571 cm, and 66.14 ± 12.96 kg, respectively.

Before the interventions, the subjects were measured for foot pressure during gait using a Gait Analyzer^{TM} (Tech Storm Inc., Boryeong, Republic of Korea). They were randomly allotted to the SS group and DSUAS group.

For SS, this study used a Slant Board (Rivers Edge Products, USA), which can be adjusted to different angles, set at 30°. The subjects stretched for 15 min continuously. The subjects were asked to maintain their pelvis in a neutral position. This study allowed leaning against a wall when fatigued by long the SS of standing. If a subject claimed to be experiencing pain in the lower limbs or any discomfort, the intervention was stopped immediately.

For DSUAS, an Aero-Step XL (Togu, Prien-Bachham, Germany) was used to provide an unstable base during performance of the exercise program. The Aero-Step was 51 cm in length, 37 cm in width, and 8 cm in height. It is composed of soft rubber and two compartments filled with air. The exercise program included the following exercises. For 15 min, three movements were performed for 5 min each[13].

Foot plantar pressure was measured during the subject's gait stance phase. The foot area is divided into 10 areas, including F1 (fourth and fifth toes), F2 (third and second toes), F3 (first toe), F4 (outer forefoot), F5 (middle forefoot), F6 (inner forefoot), R3 (outer middle foot), R4 (inner middle foot), R1 (outer heel), and R2 (inner heel). The collected pressure information was analyzed using the Gait Analyzer application software (ver. 3.1)[14]. After the interventions, the asymmetric ratio of both foot pressures (ARFP) was calculated by putting the foot pressure values of both feet in the following formula: ARFP = | 1 − (lesser foot pressure (right or left) / greater foot pressure)|. A large absolute value indicates good asymmetry, and vice versa[15].

This study measured the level of pain using the Visual Analogue Scale (VAS) during the interventions.

The collected data were analyzed using PASW for Windows (ver. 18.0). To compare the changes generated by the two interventions (dynamic stretching and SS), this study used the Wilcoxon signed-rank test. The Mann-Whitney U test was used to compare the two interventions at the significance level of (α) = 0.05.

Table 1. Between-group comparisons of VAS scores and ARFPs

	DSUAS	Static stretching	z [a]
VAS	0.62±0.91	6.00±1.15	0.00*
ARFP	0.10±0.04	0.16±0.03	−2.43*

[a]Between-group comparison. Mean ± SD. VAS: visual analogue scale; ARFP: asymmetric ratio of both foot pressure; DSUAS: dynamic stretching using Aero-Step. *p<0.05

RESULTS

The foot pressures of the subjects were measured, and then the results were compared. Both DSUAS and SS showed no significant difference in each region (p>0.05).

Comparison of the VAS scores showed that there was a significant difference between the DSUAS and SS groups. In addition, there was a significant difference in ARFP between the groups after the interventions (p<0.05) (Table 1).

DISCUSSION

Acute stretching generates an analgesic effect that improves injured athletes' performances by minimizing muscular inhibition caused by pain[3]. The previous studies, which analyzed the effect of stretching using neurophysiological and mechanical factors, indicates that stretching techniques allow for neural inhibition through muscle stretching. In other words, stretching reduces reflex activity and muscle resistance, which causes increased joint range of motion[16]. Likewise, the effectiveness, efficiency, and neurophysiological foundations of stretching have been proven through various preceding studies. Moreover, many earlier studies dealt with SS[17]; however, recent studies focus more on dynamic stretching[18].

In this study, there was no significant difference in foot pressure between the two stretching groups. This result is consistent with the previous study that reported reduced performance and disconnected force power immediately after stretching[3]. Due to the design of this study, significant changes in foot pressure could not be observed, though acute changes were confirmed after the interventions.

One interesting thing, however, is the decreased mean value of the R4 (inner middle foot) region. An increase in the R4 region is a typical found in individuals with flatfoot. The reason for the decreased mean value of the R4 region is

improvement of the contraction and tightness of the gastrocnemius-soleus muscle by the two types of stretching, which increased ankle dorsiflexion. This result suggests that, the gastrocnemius-soleus muscle could easily transit to a supple and rigid position and maintain the sole's concavity during the stance phase and push-off phase of gait[19]. Meanwhile, the DSUAS group showed a greater decrease in the mean foot pressure in the R4 region compared with the SS group. This is because DSUAS requires more muscle contraction and induced central programming of muscle contraction/coordination, as well as warm-up activity[3]. On the other hand, SS is simply application of passive stretching of the muscles. Therefore, it could not generate the organic transition of the gastrocnemius-soleus muscle between contraction and release during gait. Therefore, it did not cause as great a reduction in the R4 region as DSUAS.

Meanwhile, this study showed a meaningful change in the ARFPs. The DSUAS group stretched their muscles on an unstable support plane, which generated increased stimulation of the proprioceptors and mechanoreceptors of the plantar skin and ankle joints[13]. As a result, muscle activation occurred from the ankle to the knee and from the knee to the hip; and improved the postural alignment during gait.

One more interesting thing in this study was that the two groups showed significant differences in pain while stretching. This result suggests that the pain that occurs during an intervention changes muscle recruitment, and disturbs maintenance of the ideal (symmetric) posture. A previous study reported that the analgesic effect caused by stretching influenced not only pain fibers but also other nerves (proprioceptive nerve)[3].

Therefore, the DSUAS applied in this study can stretch the gastrocnemius-soleus muscle properly, decreasing pressure on the R4 (inner middle foot) region and preventing flatfoot. In addition, it is considered an effective stretching method, as less pain is experienced during it than SS, which can minimize the ARFP during gait due to asymmetric postural alignment. However, this study was a preliminary study conducted with a small number of healthy subjects. Therefore, future studies should deal with how to relieve symptoms and improve foot pressure symmetry during the gait of flatfoot patients.

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