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## INVESTIGATION OF THE EFFECT OF DIFFERENT TYPES OF INSOLES ON ELECTROMYOGRAPHIC MUSCLE ACTIVATION IN INDIVIDUALS WITH PES PLANUS

### PES PLANUSLU BİREYLERİN FARKLI TİPTEKİ TABANLIKLARININ ELEKTROMYOGRAFIK KAS AKTİVASYONU ÜZERİNE ETKİSİNİN İNCELENMESİ

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#### ABSTRACT

**Objective:** The aim of this study is to examine the effect of prefabricated insoles made of different materials on lower extremity muscle activity in individuals with pes planus and to investigate whether it changes towards the pattern seen in people with normal foot arch.

**Method:** Six individuals with flexible pes planus participated voluntarily in this descriptive and correlational study. The mean age of the individuals was 33.8±11.1 years, height 1.64±0.06 m, mean weight 62.3±7.3 kg, mean Body Mass Index (BMI) 23.1±2.7 kg/m<sup>2</sup>. Pes planus severity of individuals was measured with Foot Posture Index (FPI) and Clarke angle using podoscope device and footprint method. Activation of the muscles was measured with a surface electromyography (sEMG) device for maximum isometric contraction (MIC) and during walking without insoles, soft (silicone), semi-rigid (polyform) and rigid (steel) insoles at one-day intervals.

**Results:** No significant difference in %MIC values was observed among the insoles, soft (silicone), semi-rigid (polyform) and rigid (steel) insoles within the same phase of gait ( $p>.05$ ). A significant difference was found between the heel strike (0-10%) phase of gait and the swing (60-100%) phases of gait in terms of %MIC value in the electromyography (EMG) measurement taken from the tibialis anterior muscle with a rigid (steel) insole ( $p<.05$ ). In the EMG measurement taken from the peroneus longus muscle with a semirigid (polyform) insole, a significant difference was found between the mid-stance (10%-40%) phase of the gait and the swing (60-100%) phases in terms of %MIC value ( $p<.05$ ).

**Conclusion:** While rigid (steel) insoles reduce tibialis anterior muscle activation in heel strike phase compared to swing phase, semirigid (polyform) insoles increase peroneus longus muscle activation in mid-stance phase of gait compared to swing phase.

**Key Words:** Pes planus, Flat feet, Insole, Muscle activity

#### ÖZ

**Amaç:** Bu çalışmanın amacı pes planuslu bireylerde değişik materyallerden üretilmiş prefabrikasyon tabanlıkların alt ekstremite kas aktivitesi üzerine etkisini incelemek ve normal ayak arkı olan kişilerde görülen paterne doğru değiştirip değiştirmedikini araştırmaktır.

**Yöntem:** Tanımlayıcı ve korelasyonel olarak yapılan bu çalışmaya esnek pes planusa sahip 6 birey gönüllü olarak dahil oldu. Bireylerin yaş ortalamaları 33.8±11.1 yıl, boy ortalamaları 1.64±0.06 m, kilo ortalamaları 62.3±7.3 kg, vücut kitle indeksi (VKİ) ortalamaları 23.1±2.7 kg/m<sup>2</sup> olarak bulundu. Bireylerin pes planus şiddeti podoskop cihazı ve ayak izi yöntemiyle Clark açısı hesaplanarak ve Ayak Postür İndeksi (API) ile ölçüldü. Kas aktivasyonu yüzeyel elektromiyografi (yEMG) cihazı ile maksimum izometrik kontraksiyon (MİK) ve yürüyüş sırasında tabanlıksız, soft (silikon), semirijit (poliform) ve rijit (çelik) tabanlıklar ile birer gün aralıkla ölçüldü.

**Bulgular:** Tabanlıksız, soft (silikon), semirijit (poliform) ve rijit (çelik) tabanlıklar arasında yürüyüşün aynı fazında %MİK değerlerinde farklılık gözlemlenmedi ( $p>.05$ ). Tibialis anterior kasından rijit (çelik) tabanlıkla alınan elektromiyografi (EMG) ölçümünde, %MİK değeri açısından yürüyüşün topuk vuruşu (0-%10) fazı ile sallanma (%60-%100) fazları arasında anlamlı bir fark saptandı ( $p<.05$ ). Peroneus longus kasından semirijit (poliform) tabanlıkla alınan EMG ölçümünde %MİK değeri açısından yürüyüşün orta duruş (%10-%40) fazı ile sallanma (%60-100) fazları arasında anlamlı bir fark saptandı ( $p<.05$ ).

**Sonuç:** Rijit (çelik) tabanlık topuk vuruşu fazında sallanma fazına kıyasla tibialis anterior kas aktivasyonunu düşürürken, semirijit (polyform) tabanlık yürüyüşün orta duruş fazında sallanma fazına kıyasla peroneus longus kas aktivasyonunu arttırmaktadır.

**Anahtar Kelimeler:** Pes planus, Düztaban, Tabanlık, Kas aktivasyonu

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## INTRODUCTION

Pes planus is defined as the loss of the medial longitudinal arch (MLA) height of the foot during weight bearing or abnormally low arch height [1]. Whether it is a congenital or acquired condition, it has features such as talus medial rotation, decreased medial arch height, and forefoot supination and abduction [2]. Although the exact cause of pes planus has not been determined, genetic factors, acquired factors, paralysis, pronated foot or obesity can cause pes planus [3]. Its true prevalence is uncertain due to the lack of precise clinical or radiographic criteria to define pes planus. However, in the adult population, studies by different investigators have reported a prevalence of approximately 5 to 14% [4,5] and it presents as an incidental finding or a symptomatic condition with variable clinical consequences ranging from mild limitations to pain leading to severe disability [6].

The medial longitudinal arch of the foot is associated with shock absorption and force transmission during standing and walking [7]. Due to pes planus, the load on the foot cannot be distributed properly and this alters the muscle activity of the intrinsic and extrinsic muscles [8]. Studies have reported that lower extremity muscle activity due to pes planus is higher or lower than that of the normal foot during gait or standing on one leg [9,10].

Conditions caused by pes planus are usually treated using some form of orthotic device. Today, there are many types in terms of measurement, design, material used and the type of production, including custom made or prefabricated. Such devices are designed to provide stability and realign the arch of the foot and have had significant success in alleviating patients' symptoms [11-13]. However, there is no consensus on the material of the insoles to be used in the treatment of pes planus.

The aim of this study was to investigate the effect of prefabricated insoles made of different materials on lower extremity muscle activation in individuals with pes planus. Our hypothesis is that the material factor to be used will change muscle activation in individuals with pes planus. When the existing literature is examined, it is seen that the effect of insoles made of different materials on muscle activity in individuals with pes planus remains unclear. Therefore, we think that analysing the EMG data during walking by dividing the data into gait phases will clarify which muscle pattern is affected by the material factor of the insoles when evaluating the effectiveness of insoles made of different materials (soft, semirigid and rigid) on muscle activation. In addition, comparing the data obtained from our study with the information in the literature regarding the muscle pattern during the phases of gait in individuals with normal foot arch will contribute to the evaluation of the effectiveness of the material factor selection in the correction of the muscle pattern and will fill the gap in the literature on this subject.

## METHOD

### Study Design

We conducted a descriptive and correlational study to examine the effect of insoles made of different materials on lower extremity muscle activity in individuals with pes planus.

### Participants

The inclusion criteria of the individuals were willingness to participate in the study, Foot Posture Index (FPI) used in the evaluation of pes planus to be +6 and above [14,15] and Clarke angle calculated by the footprint method to be below 41° [15,16]; Exclusion criteria were as follows: cardiovascular and inflammatory diseases, neurologic deficits, systemic diseases affecting the foot, pregnancy, history of spine and lower extremity surgery, leg discrepancy of more than 5mm, rigid pes planus, use of insoles in the last 12 months.

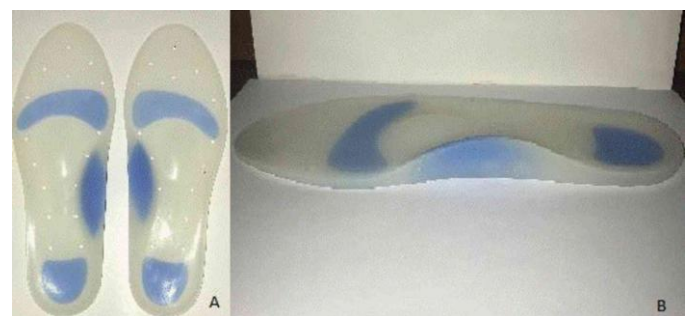
Individuals were interviewed face to face for foot posture analysis. Those who agreed to participate in the study were informed about the study and signed a written consent form.

The study was conducted at Bolu Abant İzzet Baysal University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation. The sample of the study was selected through random sampling. The number of individuals with pes planus to be included in the study was determined by performing power analysis with G\*Power 3.1 software over the insoles variables used in repeated measurements in individuals with pes planus in accordance with the purpose of the study. In this study, the effect size  $\alpha=0.05$  was taken and when power analysis was performed at 80% power and 80% confidence interval, the number of samples required for the study was determined to be 6 individuals [17]. However, since only individuals with pes planus would participate in the study, the study was started with 20 individuals, taking into account situations such as those who did not have pes planus, who could not participate in any measurement in repeated measurements or who wanted to leave at any stage of the study. One of the participants was found to have used insoles in the last 12 months and was excluded from the study. According to foot posture evaluation, 8 people were found to have pes planus. 2 people who did not want to continue the study voluntarily left the study. The evaluation form was filled out with the remaining 6 people and the study was completed with 6 female individuals, with a mean age of  $33.8 \pm 11.1$  years, mean height of  $1.64 \pm 0.06$  m, mean weight of  $62.3 \pm 7.3$  kg, mean body mass index (BMI) of  $23.1 \pm 2.7$  kg/m<sup>2</sup>.

### Insoles

In the study, 3 prefabricated insoles were used: soft (silicone), semirigid (polyform) and rigid (steel). Among the insoles available for all shoe sizes, those that matched the participants' own shoe size were selected.

Each type of insoles had medial and transverse arch supports. Soft insoles were made of 100% silicone (Figure 1). Semirigid insoles consisted of polyform arch support on 1mm thermoplastic material (Figure 2). The rigid insoles had a steel medial arch support and were covered with leather (Figure 3). To ensure standardization, all insoles of different materials had equal medial arch height.



**Figure 1.** Top (A) and side views (B) of the soft (silicone) insole.



**Figure 2.** Top (A) and side views (B) of semirigid (polyform) insole



**Figure 3.** Top (A) and side views (B) of Rigid (steel) insole.

### Outcome Measures

Foot posture was determined using the footprint method and Foot Posture Index (Foot Posture Index-6). We used podoscope in the footprint method. When we did not have the opportunity to use the podoscope device because it was shared with other researchers in the faculty, we used the trace of the powdered foot on black cardboard, which is similar to the podoscope measurement method and is a suitable method for evaluating foot arches [18]. In the footprint method, the Clarke angle was determined from the photograph taken of the individuals participating in the study while they were on the podoscope (Quirumed, Inc, Spain) or from the trace of the powdered foot on black cardboard while standing still. Angle Meter application (IOS) was used to determine the angle.

A different day was planned for the experimental study in which electromyography (EMG) would be measured. Muscle activation measurements of the individuals were completed with a Delsys Trigno Wireless System superficial EMG device (sample rate 2000 Hertz, transmittance band 20-450 Hertz and average noise cancellation rate >80 decibels (dB), (Delsys, Inc, USA).

Measurements were performed during maximum isometric contraction (MIC) and muscle function (gait). Before the sensors and electrodes were placed on the individual's leg, the area was shaved and thoroughly cleaned with alcohol cotton wool until slight redness was observed. The sensors were fixed to the leg with rigid tape. Silver/silver chloride (Ag/AgCl) bipolar sEMG electrodes (3.7cm x 3.3cm) were used with a distance of 2 cm between each other. The electrodes were placed parallel to the direction of muscle fiber extension, controlled by palpation and in accordance with SENIAM protocols. Measurements were performed on the dominant legs of the individuals. The signals received during the measurements were checked on the screen of the computer used and when artifacts occurred, the measurement was stopped to check the electrodes and sensors. Before starting the measurements, explanations were given to the individuals about the movements they were asked to perform during MIC. For MIC measurements, individuals were positioned as in SENIAM protocols and maximum resistance was applied for 5 s. Each measurement was repeated 3 times and the mean value of 3 measurements was taken. A one-minute rest period was given for each muscle group to prevent muscle fatigue.

EMG muscle activation of the individuals participating in the study was measured 4 times in total during walking, without insoles and with 3 different insoles: soft (silicone), semirigid (polyform) and rigid (steel) insoles. The design and material of the insoles were the same for each participant and insoles were selected in randomized order.

The gait analysis was started without insoles and the study was completed in 3 days with a one-day break between measurements taken with insoles. A metronome was used to standardize the gait speed and was set to 109 steps per minute [19]. A trial walk was performed for the individuals to get used to the rhythm. Afterwards, they were asked to take 5 steps starting with the dominant foot. All measurements were made with a comfortable, fixed sneaker belonging to the individual.

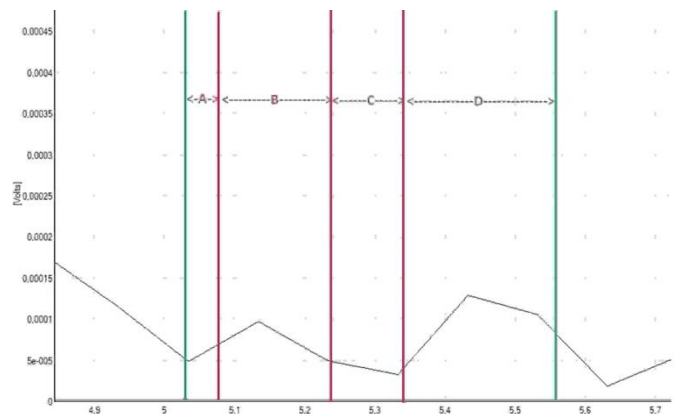
### EMG Data Analysis

The recorded EMG signals were analyzed with the Delsys Analysis System 4.5.0 application.

For the analysis of the individual who was asked to isometrically contract the relevant muscle for 5 seconds, the signals released during the middle 3 seconds were taken into consideration and the value was recorded in microvolts ( $\mu V$ ). The mean values obtained in the analysis of the MIC repeated 3 times for each muscle was used in the calculation of %MIC. The raw signals were cleaned of motion artifact with a 20-500 bandpass filter and the root mean square values (RMS) were calculated at 0.1 s intervals.

After 20-500 bandpass filtering of the raw data, RMS values were calculated at 0.1-second intervals and recorded in microvolts ( $\mu V$ ) [20,21]. The stride used for the analysis was divided into phases of the gait by dividing it into parts based on duration. Accordingly, heel strike between 0 and 10%, mid-stance between 10%-40%, push-off phase between 40-60% and swing phase between 60-100% were divided into 4 parts (Figure 4) [3]. The following equation was used to normalize the muscle activation value:

$$\%MIC \text{ (during muscle activity)} = (RMS (\mu V) / MIC (\mu V)) * 100 [22].$$



**Figure 4.** EMG data obtained from the tibialis anterior muscle divided into walking phases: A: Heel strike B: Mid-stance C: Push-off D: Swing

### Ethical Approval

Approval for the study was obtained on 16.03.2021 and with the number 2021/73 from Bolu Abant Izzet Baysal University Clinical Research Ethics Committee.

### Statistical Analysis

The conformity of the data to normal distribution was evaluated by Histogram, Q-Q graphs and Shapiro-Wilk test. Friedman's analysis was used in the evaluation of repeated measurements of insoles material variables. Dunn's test was used for multiple comparisons. The relationship between quantitative data was evaluated by Spearman correlation analysis. Data analysis was performed in R 4.2.2 (www.r-project.org) program and Turcosa Cloud (Turcosa Ltd Co) statistical software. Significance value was accepted as  $p < .05$ .

### RESULTS

In the evaluation of the severity of pes planus, the frequency and mean Clarke angle and FPI values specific to the dominant and nondominant foot were calculated. Accordingly, the dominant foot Clarke angle was found to be  $24.5 \pm 4.9$  degrees and the nondominant Clarke angle  $17.8 \pm 8$  degrees. Dominant foot FPI score was  $11 \pm 0.6$  and nondominant FPI was  $8.8 \pm 1.4$ . The mean %MIC values of tibialis anterior, peroneus longus, gastrocnemius medialis and soleus muscles in different phases of gait were compared in repeated EMG measurements without insoles and with 3 different insoles.

While there was no statistically significant difference between the gait phases in the EMG measurements obtained from the tibialis anterior muscle without insoles, with soft (silicone) and semirigid (polyform) insoles ( $p > .05$ ), there was a significant difference between the 0-10% and 60-100% phases of gait in terms of %MIC value in the EMG measurement obtained with rigid (steel) insoles ( $p < .05$ ) (Table 1).

In the EMG measurements obtained from the peroneus longus muscle without insoles, with soft (silicone) and rigid (steel) insoles, there was no statistically significant difference between the gait phases in terms of %MIC value ( $p > .05$ ), while in the EMG measurement obtained with

semirigid (polyform) insoles, a significant difference was found between the 10-40% and 60-100% phases of gait in terms of %MIC value ( $p = .042$ ). There was no significant difference between the %MIC values of no insoles, soft (silicone), semirigid (polyform) and rigid (steel) insoles in the same phase of gait ( $p > .05$ ) (Table 2).

In the EMG measurements obtained from the gastrocnemius medialis and soleus muscle without insoles, with soft (silicone), semirigid (polyform) and rigid (steel) insoles, there was no statistically significant difference in %MIC values between gait phases ( $p > .05$ ).

**Table 1.** Comparison of tibialis anterior muscle function with and without insoles and between percentile phases of gait and within each phase

| Variables            | Percentage Phases of Walking |                               |                              |                              | P            |
|----------------------|------------------------------|-------------------------------|------------------------------|------------------------------|--------------|
|                      | 0-10%                        | 10%-40%                       | 40%-60%                      | 60%-100%                     |              |
| No insole            | 35.0(12.4-73.5)              | 43.0(16.7-77.3)               | 37.9(19.7-78.3)              | 30.5(22.7-53.2)              | 0.978        |
| Soft (silicone)      | 37.2(15.0-58.0)              | 40.5(31.7-60.0)               | 26.0(15.0-35.9)              | 37.3(28.0-60.7)              | 0.457        |
| Semirigid (polyform) | 26.5(14.3-69.1)              | 33.5(15.1-73.9)               | 41.8(21.3-64.8)              | 39.7(31.0-53.0)              | 0.706        |
| Rigid (steel)        | 3.5(0.0-26.9) <sup>a</sup>   | 30.5(18.2-52.1) <sup>ab</sup> | 15.5(8.6-30.0) <sup>ab</sup> | 30.5(27.6-78.1) <sup>b</sup> | <b>0.002</b> |
| <b>p*</b>            | 0.229                        | 0.985                         | 0.133                        | 0.204                        |              |

Data are expressed as median (1st quartile-3rd quartile), p: Comparison results for each muscle according to walking phases, p\*: Comparison results for each walking phase according to insole types. Same letters in the same row indicate similarity of difference between phases, different letters indicate difference. Friedman analysis was used.

**Table 2.** Comparison of peroneus longus muscle function between insole and without insole variables and between percentile phases of gait and within each phase.

| Variables            | Percentage Phases of Walking   |                                |                                |                              | p            |
|----------------------|--------------------------------|--------------------------------|--------------------------------|------------------------------|--------------|
|                      | 0-10%                          | 10%-40%                        | 40%-60%                        | 60%-100%                     |              |
| No insole            | 50.6(22.1-61.7)                | 68.0(34.8-95.2)                | 71.4(23.6-99.4)                | 53.8(26.4-96.5)              | 0.597        |
| Soft (silicone)      | 50.4(4.5-71.3)                 | 56.7(30.4-112.0)               | 30.4(15.4-56.3)                | 41.2(25.5-101.1)             | 0.241        |
| Semirigid (polyform) | 76.1(38.9-146.7) <sup>ab</sup> | 100.3(48.5-112.2) <sup>a</sup> | 40.7(21.0-117.0) <sup>ab</sup> | 56.0(16.5-82.4) <sup>b</sup> | <b>0.042</b> |
| Rigid (steel)        | 14.3(0.0-56.0)                 | 43.2(33.7-103.8)               | 62.5(24.9-108.1)               | 55.0(28.7-114.9)             | 0.597        |
| <b>p*</b>            | 0.149                          | 0.241                          | 0.221                          | 0.284                        | 0.149        |

Data are expressed as median (1st quartile-3rd quartile), p: Comparison results for each muscle according to walking phase, p\*: Comparison results for each walking phase according to insole types. Same letters in the same row indicate similarity of difference between phases, different letters indicate difference. Friedman analysis was used.

## DISCUSSION

In our study, the effect of prefabricated insoles of different materials on electromyographic muscle activation was investigated in individuals with pes planus. As a result of repeated measurements in which the effect of insoles of different materials on EMG in 4 phases of gait was examined, no significant difference was found between the %MIC values of insoles without insoles, soft (silicone), semirigid (polyform) and rigid (steel) insoles in the same phase of gait. There was no statistically significant difference in the %MIC values between the gait phases in the EMG measurements obtained from the gastrocnemius medialis and soleus muscles without insoles, with soft (silicone), semirigid (polyform) and rigid (steel) insoles. In the EMG muscle activation measurements obtained from the tibialis anterior muscle without insoles, with soft (silicone) and semirigid (polyform) insoles, there was no statistically significant difference between the gait phases in terms of %MIC value, while in the EMG measurement obtained with rigid (steel) insoles, it was observed that the tibialis anterior muscle function decreased in the heel strike (0-10%) phase of gait compared to the swing (60%-100%) phase. In the EMG measurements obtained from the peroneus longus muscle without insoles, with soft (silicone) and rigid (steel) insoles, there was no statistically significant difference between the gait phases in terms of %MIC value, while in the EMG measurement obtained with semirigid (polyform) insoles, it was found that peroneus longus muscle function increased in the mid-stance (10%-40%) phase of gait compared to the swinging (60%-100%) phase. When we compared the data we

obtained with the literature information about the muscle pattern of the normal arch of the foot in these 4 phases of gait, polyform insoles increased peroneus longus muscle activation in the mid-stance phase compared to the swing phase as with the normal muscle pattern. Steel insoles reduced tibialis anterior muscle activation in the heel strike phase compared to the swing phase, and they distract muscle activation from the normal foot pattern during gait [3].

Pes planus may develop due to loss of strength and stability or overuse of the known extrinsic dynamic supporters of the MLA such as triceps surae, peroneus longus, tibialis posterior and anterior muscles [23,24]. EMG provides powerful information about neuromuscular function, provided appropriate signal processing is performed. Some studies have shown a decrease in strength and EMG amplitude in the muscles responsible for maintaining neutral foot posture [7,24]. Based on studies showing that the use of insoles can change the EMG amplitude in the stabilizer muscles of the foot, the use of the electromyographic evaluation method to evaluate muscle activation in our study seems to be appropriate for the purpose of the study [25-33]. Foot orthoses are widely used in the treatment of flexible pes planus. The evidence supporting this intervention was presented in 2 systematic reviews published in 2014 and 2021 [34,35], but the level of evidence on EMG muscle activation is unclear.

Our study has similar and different characteristics with other studies in terms of factors such as the stiffness of the material used in the insoles, EMG measurement during walking on flat ground, the target



population being individuals with pes planus, the muscles in which EMG activation was evaluated and the parameter evaluated in EMG analysis. For this reason, we consider it appropriate to evaluate each factor in itself.

Wulandari et al. [25] investigated the effect of shoes with insoles of different stiffness on EMG activation during walking in healthy subjects and compared 4 conditions: flexible, semi-flexible and rigid insoles with bare feet. The results showed that there were significant differences between the four walking conditions for several statistical parameters such as peak, peak time, peak duration, and onset of peak amplitude for the gastrocnemius medialis, tibialis anterior and vastus medialis muscles. In our study, there was no difference in %MIC between EMG activations of tibialis anterior, gastrocnemius medialis, peroneus longus and soleus muscle without and with insoles. Compared to Wulandari et al. [25], one reason for the difference in our analysis result may be that the population we studied was individuals with pes planus. Another reason may be that the reference value is the EMG %MIC value that we evaluated without insoles with the person's own shoes, not bare feet.

There are also studies examining the effect of insoles stiffness on EMG muscle activation in the population with pes planus. Huang et al. [29] compared the effect of different insoles on the EMG fatigue parameter in the rectus femoris muscle during downhill and uphill walking in pes planus and stated that the stiffness of the sole will increase not only the physical sensory input but also the fatigue of the lower extremity muscles. Our study differs from the study of Huang et al. [29] in terms of walking on flat ground, the muscles measured by EMG and the parameter (%MIC) examined in EMG.

Another factor that may affect the effectiveness of orthoses on EMG is whether they are prefabricated or customized. In our study, the effect of prefabricated insoles on EMG muscle activation was examined. Ahmad et al. [30] compared the EMG RMS and fatigue parameters of the tibialis anterior and peroneus longus muscles during gait by comparing the commercially available prefabricated insoles with custom-made insoles and reported that the custom-made insoles gave better results in terms of the parameters examined. In another study, in 10 rheumatoid arthritis patients with posterior tenosynovitis and pes planus, the effect of barefoot, shoe and customized insoles variables on muscle activation during the sole contact and midstance-push phase of gait was compared and it was found that the timing of peak amplitude of the soleus and gastrocnemius medialis muscle changed and the peak amplitude of the tibialis anterior muscle increased [31].

Murley et al. [33] compared EMG activation during different phases of gait between individuals with pes planus and individuals with normal arch of the foot without insoles, with prefabricated and customized insoles and found an increase in tibialis anterior muscle peak amplitude (19%) and a decrease in peroneus longus muscle activity (13%) in the group with pes planus during the contact phase of gait. During mid-stance-push, the group with pes planus exhibited increased activity in the tibialis posterior (26%) and decreased activity in the peroneus longus (14%) compared to those with normal feet. During the contact phase of gait, tibialis posterior EMG amplitude was shown to be significantly reduced with the prefabricated orthosis (19%) and the custom orthosis (12%) compared to the shoe-only condition. In contrast, during the mid stance-push phase, the peroneus longus EMG amplitude was significantly increased with the prefabricated orthosis (19% and 14% increase, respectively) compared to the shoe only and custom orthotic conditions ( $p < .05$ ). Our study is similar to Murley et al. [33] in terms of including individuals with pes planus and evaluating tibialis anterior and peroneus longus muscle activation by dividing into gait phases. However, compared to Murley et al. [33], there was no control group. In addition to tibialis anterior and peroneus longus muscles, gastrocnemius medialis and soleus muscles were also included in EMG measurement. Gait was divided into 4 phases and mid-stance and push-off phases were evaluated as two separate phases. Comparisons between measurements were made

between no insoles and insoles of different materials. All the insoles we used were prefabricated and it remains unclear how the degree of stiffness of individualized insoles will affect EMG muscle activation.

Another factor that may affect the research result is the duration of insoles use. Saeedi et al. [32] evaluated the effect of prefabricated modified UCBL orthosis on muscle activation of tibialis anterior, peroneus longus and gastrocnemius medialis muscles during gait after 1 month of use in 21 male individuals with asymptomatic pes planus and reported that the orthosis increased the muscle activity of peroneus longus compared to barefoot. In our study, the acute effect of insoles was evaluated. Therefore, the long-term effect of insoles on EMG in individuals with pes planus and its interpretation is unknown.

Another factor that may affect the study results is the transverse arch support height in the insoles. Since all silicone insoles with sufficient arch support in the market also have transverse arch support, the other two types of insoles were selected from those with transverse arch support. However, the transverse arch support height could not be standardized among different types of insoles used in the study due to their unavailability in the market. Therefore, it is not known how the transverse support height of the insoles used in individuals with pes planus affects muscle activation during walking.

### Limitations

The small sample size due to the pandemic, using the same height of arch supports for each participant and the lack of simultaneous video recording during EMG measurements are the limitations of our study. Using synchronous camera recording systems during EMG measurements in different phases of gait in individuals with pes planus may provide clearer information in dividing the gait four phases (heel strike, mid-stance, push-off and swing) and analyzing each phase.

### CONCLUSION

In our study, a large-scale comparison of lower extremity muscle activation measured in the heel strike, mid-stance, push-off and swing phases of gait in individuals with pes planus was made between insoles and without insoles and insoles made of different materials. In the literature, there are studies examining the effect of insoles on EMG muscle activation in individuals with pes planus, but our study is the only study examining the effect of the material on muscle activation in different phases of gait. The following results were obtained in our study;

1. In individuals with pes planus, rigid (steel) insoles decreased tibialis anterior muscle activation in the heel strike (0-10%) phase of gait compared to the swing phase (60-100%). The use of steel insoles should be discouraged because they reduce tibialis anterior muscle activation in the heel strike phase compared to the swing phase, and they distract muscle activation from the normal foot pattern during gait.
2. In individuals with pes planus, semirigid (polyform) insoles caused an increase in peroneus longus muscle activation in the mid-stance phase of gait (10%-40%) compared to the swing phase (60%-100%). The use of thermoplastic insoles may be recommended for individuals with pes planus because polyform insoles provide medial arch support by increasing peroneus longus muscle activation in the mid-stance phase compared to the swing phase.

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## REFERENCES

- Shibuya N, Kitterman RT, LaFontaine J, Jupiter DC. Demographic, physical, and radiographic factors associated with functional flatfoot deformity. *J Foot Ankle Surg.* 2014;53(2):168-172.
- Arangio GA, Reinert KL, Salathe EP. A biomechanical model of the effect of subtalar arthroereisis on the adult flexible flat foot. *Clin Biomech Bristol Avon.* 2004;19(8):847-852.
- Neumann DA. *Kinesiology of the musculoskeletal System.* 2nd ed. St. Louis, MO: Mosby; 2009.
- Aenumulapalli A. Prevalence of flexible flat foot in adults: A cross-sectional study. *J Clin Diagn Res.* 2017;11(6): AC17-AC20.
- Ukoha UU, Egwu OA, Okafor IJ, Ogugua PC, Igwenagu VU. Pes planus: Incidence among an adult population in anambra state, southeast nigeria. *Int J Biomed Adv Res.* March 2012;3(3):166-168.
- Lee MS, Vanore JV, Thomas JL, et al. Diagnosis and treatment of adult flatfoot. *J Foot Ankle Surg.* 2005;44(2):78-113.
- Fiolkowski P, Brunt D, Bishop M, Woo R, Horodyski M. Intrinsic pedal musculature support of the medial longitudinal arch: an electromyography study. *J Foot Ankle Surg.* 2003;42(6):327-333.
- Wang WJ, Crompton RH. Analysis of the human and ape foot during bipedal standing with implications for the evolution of the foot. *J Biomech.* 2004;37(12):1831-1836.
- Murley GS, Landorf KB, Menz HB, Bird AR. Effect of foot posture, foot orthoses and footwear on lower limb muscle activity during walking and running: A systematic review. *Gait Posture.* 2009;29(2):172-187.
- Kim MK, Lee YS. Kinematic analysis of the lower extremities of subjects with flat feet at different gait speeds. *J Phys Ther Sci.* 2013;25(5):531-533.
- Xu R, Wang Z, Ren Z, Ma T, Jia Z, Fang S, et al. Comparative study of the effects of customized 3D printed insole and prefabricated insole on plantar pressure and comfort in patients with symptomatic flatfoot. *Med Sci Monit.* 2019;25:3510-3519.
- Yurt Y, Şener G, Yakut Y. The effect of different foot orthoses on pain and health related quality of life in painful flexible flat foot: a randomized controlled trial. *Eur J Phys Rehabil Med.* 2019;55(1):95-102.
- AmirAli Jafarnezhadgero, Esmaeili A, Seyed Hamed Mousavi, Urs Granacher. Effects of foot orthoses application during walking on lower limb joint angles and moments in adults with flat Feet: A systematic review with meta-analysis. *J Biomech.* 2024;176:112345.
- Redmond AC, Crosbie J, Ouvrier RA. Development and validation of a novel rating system for scoring standing foot posture: The foot posture index. *Clin Biomech.* 2006;21(1):89-98.
- Menz HB, Munteanu SE. Validity of 3 clinical techniques for the measurement of static foot posture in older people. *J Orthop Sports Phys Ther.* 2005;35(8):479-486.
- Ghazaleh L, Saleh-Sedghpour B, Mohajerinejad N, Mansoobi E. Comparing three footprint grades to evaluate footprint indexes for flat foot diagnosis. *Physical treatments: PTJ.* 2019;30:137-146.
- Vijayakumar K, Subramanian R, Senthilkumar S, Dineshkumar D. An analysis of arches of foot: A comparison between ink foot print method and custom made podoscope device method. *J Pharm Res Int.* 2021;3:249-256.
- Peng Y, Wong DWC, Wang Y, et al. Immediate effects of medially posted insoles on lower limb joint contact forces in adult acquired flatfoot: A pilot study. *Int J Environ Res Public Health.* 2020;17(7):2226.
- Shin HS, Lee JH, Kim EJ, Kyung MG, Yoo HJ, Lee DY. Flatfoot deformity affected the kinematics of the foot and ankle in proportion to the severity of deformity. *Gait posture.* 2019;72:123-128.
- Castelein B, Cools A, Parlevliet T, Cagnie B. Modifying the shoulder joint position during shrugging and retraction exercises alters the activation of the medial scapular muscles. *Man Ther.* 2016;21:250-255.
- Raphaël Hamard, Jeroen Aeles, Kelp NY, Romain Feigean, Hug F, Taylor. Does different activation between the medial and the lateral gastrocnemius during walking translate into different fascicle behavior? *J Exp Biol.* 2021;224(12).
- Elsais WM, Preece SJ, Jones RK, Herrington L. Between-day repeatability of lower limb EMG measurement during running and walking. *J Electromyogr Kinesiol.* 2020;55:102473.
- Andreasen J, Mølgaard CM, Christensen M, et al. Exercise therapy and custom-made insoles are effective in patients with excessive pronation and chronic foot pain A randomized controlled trial. *Foot.* 2013;23(1):22-28.
- Headlee DL, Leonard JL, Hart JM, Ingersoll CD, Hertel J. Fatigue of the plantar intrinsic foot muscles increases navicular drop. *J Electromyogr Kinesiol.* 2008;18(3):420-425.
- Wulandari, A. D. Wibawa, D. P. Wulandari, I. P. Alit Pawana and S. Rahayu, "The influence of footwear with different sole on the EMG activity of lower limb muscle during walking," 2020 ISITIA, Surabaya, Indonesia, 2020, pp. 180-185.
- Casado-Hernández I, Becerro-de-Bengoa-Vallejo R, Losa-Iglesias ME, et al. Influence of different hardness custom foot insoles in the electromyography activity patterns of the thigh and hip muscles during motorcycling sport: A crossover study. *Sensors.* 2020;20(6):1551.
- Casado-Hernández I, Becerro-de-Bengoa-Vallejo R, Losa-Iglesias ME, et al. Electromyographic evaluation of the impacts of different insoles in the activity patterns of the lower limb muscles during sport motorcycling: A cross-over trial. *Sensors.* 2019;19(10):2249.
- Scott LA, Murley GS, Wickham JB. The influence of footwear on the electromyographic activity of selected lower limb muscles during walking. *J Electromyogr Kinesiol.* 2012;22(6):1010-1016.
- Huang YP, Kim K, Song CY, Chen YH, Peng HT. How arch support insoles help persons with flatfoot on uphill and downhill walking. *J Healthc Eng.* 2017;2017:9342789.
- Ahmad UH, Kudus NA, Ab Rahman MH, Syifaa' Jamaluddin N, dan Pembuatan FT. Electromyography sensing on tibialis and peroneus muscle against improvised flat feet orthotic insole. *Proceedings of Mechanical Engineering Research Day.* 2019:16-18.
- Barn R, Brandon M, Rafferty D, et al. Kinematic, kinetic and electromyographic response to customized foot orthoses in patients with tibialis posterior tenosynovitis, pes plano valgus and rheumatoid arthritis. *Rheumatol.* 2014;53(1):123-130.
- Saeedi H, Mousavi ME, Majddoleslam B, Rahgozar M, Aminian G, et al. The evaluation of modified foot orthosis on muscle activity and kinetic in a subject with flexible flat foot: single case study. *Prosthet Orthot Int.* 2014;38(2):160-166.
- Murley GS, Landorf KB, Menz HB. Do foot orthoses change lower limb muscle activity in flat-arched feet towards a pattern observed in normal-arched feet? *Clin Biomech.* 2010;25(7):728-736.
- Banwell HA, Mackintosh S, Thewlis D. Foot orthoses for adults with flexible pes planus: a systematic review. *J Foot Ankle Res.* 2014;7(1):23.
- AmirAli Jafarnezhadgero, Esmaeili A, Seyed Hamed Mousavi, Urs Granacher. Effects of foot orthoses application during walking on lower limb joint angles and moments in adults with flat Feet: A systematic review with meta-analysis. *J Biomech.* 2024;176:112345.

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