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Effect of the Pes Planus on Vertical Jump Height and Lower Extremity Muscle Activation in Gymnasts*

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* *Bu çalışma, 640747 numaralı "Cimnastikçilerde pes planus varlığının kas aktivasyonu ve dinamik denge üzerine etkisinin incelenmesi" başlıklı yüksek lisans tezinden üretilmiştir.*

Abstract

The aim of this study was to examine the effect of the pes planus vertical jump height and muscle activation in gymnasts. Forty-four gymnasts (mean age, 12.47±4.34 years) were included in the study. Pes planus was evaluated using a podoscope. Muscle activation was measured with a surface electromyography device during maximum voluntary isometric contraction (MVIC) and vertical jump test. Vertical jump height was evaluated using a contact mat. There was no significant difference in MVIC values of gastrocnemius medialis (GM), soleus (S), peroneus longus (PL), tibialis anterior (TA) muscles of gymnasts with and without pes planus (GM p=0.526; S p=0.157; PL p=0.696; TA p=0.223). In athletes with pes planus, GM muscle in rising phase of vertical jump; in the landing phase, the activation of the GM and S muscles was found to be lower (GMrising phase p=0.004; GMlanding phase p=0.014; Slanding phase p=0.017). In conclusion, it was found that the pes planus had no effect on vertical jump and MVIC values. It was observed that the activation of GM and S muscles was low during vertical jump in gymnasts with pes planus.

Key words: Gymnasts, Pes Planus, Vertical Jump, Muscle Activation

Özet

Bu çalışmanın amacı, cimnastikçilerde pes planusun dikey sıçrama yüksekliği ve kas aktivasyonuna etkisini incelemekti. Çalışmaya 44 cimnastikçi (ortalama yaş, 12.47±4.34 yıl) dahil edildi. Pes planus, bir podoskop kullanılarak değerlendirildi. Kas aktivasyonu, maksimum istemli izometrik kontraksiyon (MIIK) ve dikey sıçrama testi sırasında yüzeyel elektromiyografi cihazı ile ölçüldü. Dikey sıçrama yüksekliği, kontakt mat kullanılarak squat sıçrama yöntemiyle değerlendirildi. Pes planuslu olan ve olmayan cimnastikçilerin gastrocnemius medialis (GM), soleus (S), peroneus longus (PL), tibialis anterior (TA) kaslarının MIIK değerlerinde anlamlı fark bulunmadı (GM p=0.526; S p=0.157; PL p=0.696; TA p=0.223). Pes planuslu cimnastikçilerde, dikey sıçramanın yükselme fazında GM kası; iniş fazında GM ve S kaslarının aktivasyonlarının daha düşük olduğu bulundu (GMyükselme fazı p=0.004; GMiniş fazı p=0.014; Siniş fazı p=0.017). Sonuç olarak, pes planusun dikey sıçrama ve MIIK değerlerine etkisinin olmadığı bulundu. Pes planuslu cimnastikçilerde dikey sıçrama sırasında GM ve S kaslarının aktivasyonunun düşük olduğu gözlendi.

Anahtar Kelimeler: Cimnastik, Pes Planus, Dikey Sıçrama, Kas Aktivasyonu

INTRODUCTION

Gymnastics is an aesthetic olympic branch where systematic and rhythmic movements are performed at high levels in harmony with the body (18). The International Gymnastics Federation has defined 6 disciplines artistic, rhythmic, trampoline, aerobic and acrobatic gymnastics. Trampoline gymnastics include a series or routine of several saltos, twists, and jumps on trampoline. Artistic gymnastics has some different events and requirements between men and women. The six men's events include the floor exercise, pommel horse, still rings, vault, parallel bars, and high bar. Women's artistic events include vault, uneven parallel bars, balance beam, and floor exercise (4,7).

Gymnastics requires a combination of physical fitness components such as speed, agility, strength, balance and flexibility (10). The lower limb muscle function is affected by foot type (13). Deformation of foot arch is important for force transfer and shock absorption, especially in sports including jump or sprint. There is also a specific relationship between arch structure and sports injury (6).

Pes planus is generally defined as a postural disorder caused by lowering or absence of the medial longitudinal arch height of the foot (19). The loads on the foot are not distribute evenly in pes planus. The muscles and other structures compensate unevenly load distribution. Pes planus presents in two forms, defined as rigid or flexible (15,16). The World Health Organisation describes rigid pes planus as a rigid, congenital or spastic deformity of the foot and flexible pes planus as an acquired joint disorder resulting in a valgus foot deformity (28). Pes planus cause several complications such as foot pain, knee pain, low back pain and increase the risk of sport injury. It has been reported that the pes planus was responsible for 60-90% of overuse injuries of the lower extremity. (21, 26).

Jumping is a movement that an individual has made against his or her own body weight. Jumping performance depends on features such as muscle strength, explosive speed, flexibility, body anthropometry and motor coordination (9,17). Jumping is an important motor skill in all gymnastics disciplines and has a decisive role in performance (17). Jumping ability in gymnasts may be affected by lower extremity malalignment such as pes planus (6). Therefore, the aim of the present study was to determine the effect of the pes planus on vertical jump height and muscle activation in gymnasts.

MATERIALS AND METHODS

This is a cross-sectional study. Participants were divided into two groups, athletes with and without pes planus. Forty-four gymnasts aged 8-22 (mean age; 12.47±4.34 years) were included in the study. Gymnasts, who have been training regularly for 2 years (22 artistic and 22 trampoline gymnasts) were participated voluntarily in the study. Gymnasts with acute injuries and a history of lower extremity surgery in the last 6 months were excluded from the study (24). Athletes, their families and coaches were informed about the study. This study was approved by the University Ethical Committee. Sample size analysis was calculated based on a statistical power (1-beta) of 80% and an alpha of 0.05. A sample size of 32 was required for this study (24).

The pes planus was diagnose by photographing the footprint with podoscope (19). The Clarke angle was obtained by calculating the angle between the line connecting the medial edges of the first metatarsal head and the heel and the second line connecting the first metatarsal head (24). Participants were divided into 2 groups according to the Clark angle (<30 with pes planus, ≥30 without pes planus). The dominant leg was determined by as the leg used to kick a ball. Vertical jump height was assessed by the squat jump test using a contact mat (Swift Performance Equipment, Lismore, NSW, Australia). Each participants were asked to stand barefoot for 4 seconds on the mat with their hands touching their hips. Each gymnasts jumped with both feet from a squat position for maximum height and recorded best score of three jump efforts at 30-second intervals (17). The Jack's test is a dorsiflexion test of the thumb. I. MTF joint extension angle is measured by pulling the thumb to passive and active extension (12). The navicular drop test is the difference between the navicular heights measured when the foot is weighted and not (20).

Muscle activation was measured using sEMG (Delsys, USA). Measurements were taken from the dominant extremities of the athletes during vertical jump. For maximum voluntary isometric contraction (MVIC) measurements, the athletes were positioned according to the SENIAM protocol (25). According to SENIAM, the electrodes were placed on the bulge of the muscle for the measurement of gastrocnemius medialis (GM) muscle activation. For soleus (S) muscle activation, electrodes were placed 2/3 of the line between the medial condyle of the femur and the medial malleolus. For tibialis anterior (TA) muscle activation, electrodes were placed on 1/3 of the line between the tip of the tibia and the medial malleolus. To measure peroneus longus (PL) muscle activation, electrodes were placed 1/4 of the line between the head of the fibula and the lateral malleolus. For MVIC measurements, maximum resistance was given to all muscles for 5 seconds and the movement was repeated three times and the highest value was recorded. While measuring the muscle functions of the athletes, the sEMG data during squat jump were analyzed by dividing them into 3 parts as rising phase, staying in the air phase and landing phase. First, the lowest points and peaks of the graph were determined. Delsys Analysis System 4.5.0 application was used in the analysis of the recorded signals. An unprocessed image was recorded from the muscles from which the sEMG signal was received. The sample rate of the signals was then reduced to 1000 Hertz, and then motion artifact was removed with a 20-400 Hertz band-pass filter. The root-square values of the mean squared values of the filtered signals at 0.1 second intervals were calculated. Then, these values were converted into microvolts (μV) and recorded. Analyzes were made by taking into account the signals that the athlete, who was asked to contract the related muscle for 5 seconds isometrically, revealed during the middle 3 seconds for analysis. In order to perform normalization, the MVIC values showing the workload of the muscle were also calculated as %MVIC and recorded as follows.

%MVIC= [Measured value during function (μV) / MVIC measured value (μV)] x 100

Statistical analysis

Statistical analysis was carried out using SPSS (IBM SPSS Statistics for Windows, Version 20.0. IBM Corp., Armonk, N.Y., USA). Data were analysed for the normality of sample distribution with Shapiro-Wilk Test. Independent Sample t-Test and Mann Whitney U Test were used to analyze the differences between the two groups. The relationships between the variables were examined with the Spearman Correlation Coefficient. The significance level was taken as 0.05.

RESULTS

Of the gymnasts participating in the study, 12 were males and 32 were females. According to Clark's angle, pes planus were diagnosed for 7 females and 21 males. Demographic data of gymnasts are given in Table I.

The values of the Clark, navicular drop, I. metatarsophalangeal (MTF) joint extension angles of the participants in the group with and without pes planus are given in Table II.

There was no significant difference between the GM MVIC, S MVIC, TA MVIC and PL MVIC values of the group with and without pes planus (GMMVIC p=0.526; SMVIC p=0.157; TAMVIC p=0.223; PLMVIC p=0.696). (Table III).

A significant difference was observed between the GM rising activation, GM descent activation and S descent activation values between athletes with and without pes planus GMrising phase p=0.004; GMlanding phase p=0.014; Slanding phase p=0.017). (Table IV).

A weak positive correlation was observed between the clark dominant angle values of the participants and the PLMVIC values of the muscles (p=0.048; r=0.3). However, no significant correlation was found between the clark dominant angle values of the participants and the GMMVIC, SMVIC and TAMVIC values (GMMVIC p=0.086; SMVIC p=0.132; TAMVIC p=0.068). (Table V).

The relationship between muscle activation values and clark dominant angle values of athletes with and without pes planus is given in Table VI.

DISCUSSION

This study was carried out to determine the effect of the pes planus on vertical jump height and muscle activation in gymnasts. Our results showed that 63.6% of the gymnasts had flexible pes planus in this study. There was no significant difference between the the gymnasts with and without pes planus for the vertical jump height, but the vertical jump height were approximately 8% higher in the gymnasts without pes planus. Similar to our result, Alexandrovic et al. (1) found that there was no significant difference between the vertical jump height of adolescent individuals with different degrees of pes planus. Mihajlovic et al. (19) evaluated athletes with different degrees of pes planus and they no found a significant relationship between vertical jump height and degree of pes planus. Hu (11) suggested that there was no relationship between the medial arch height of the foot and the vertical jump height in healthy young males. David et al. (8) evaluated the presence of pes planus with the navicular drop test in 105 healthy adults and concluded that there was no difference between the vertical jump heights of individuals with and without pes planus. In our study, the pes planus had not any effect on vertical jump height. This can be explained by the fact that the athletes have flexible pes planus and have not completed their growth and development. Also, gymnastics training consisted of regular ballet and plyometric exercises. Many factors such as anthropometric, physiological and biomechanical characteristics play a role in the jumping action (2). The vertical jump is an explosive activity that requires neuromuscular coordination involving muscles of the ankle, knee, hip joints and trunk (3). To our knowledge, changes in muscle activation can be observed in individuals with pes planus as a result of muscle fatigue following prolonged activity.

In the present study, there was no significant difference between athletes with and without pes planus for muscle activation. To our knowledge, there is no study that divides the vertical jump into phases to examine the activation of the selected muscles during the vertical jump. It was observed that the activation values of GM rising phase, GM landing phase and S landing phase during vertical jump were different from each other in the gymnasts with and without pes planus. In gymnasts without pes planus, it was observed that the GM activation was higher in the rising phase and the activation of the GM and soleus muscles was higher in the landing phase. It was found that the GM and S muscle activations of the group without pes planus were higher than the group with pes planus in the rising and landing phases of the vertical jump; in the landing phase of the vertical jump, the S muscle activation of the group without pes planus was higher than the group with pes planus, and these muscles showed a statistically significant difference between the two groups. The activations of the muscles during the vertical jump may be different (5, 23). It can be explained that the these muscles show greater activation during vertical jump. Other possible explanation for this result is that gymnasts is exposed to loads of similar intensity and duration in the trainings. Moreover, the physical activity, muscle fatigue, and motivation can affect muscle activation (27). Chang et al. (5) compared the muscle activations of young people with and without pes planus during vertical jump and reported that the activations of TA and vastus lateralis muscles of the pes planus group were significantly higher, but the abductor hallucis, gastrocnemius and biceps femoris muscles activation values were significantly lower. Niu et al. (22) observed the muscle activations during landing from different heights in young people and reported that although the S muscle showed earlier activation as the height increased, the TA muscle activated later. Um et al. (27) compared with unilateral and bilateral pes planus and without pes planus. The authors reported that the activation of the rectus femoris, TA, GM and biceps femoris muscles in bilateral pes planus was higher than the other groups, but there was no difference between the groups. Kim and Lee (14) studied the muscle activations in young individuals with and without pes planus on a treadmill at different slopes using EMG. They reported that the TA, vastus medialis, vastus lateralis, PL, GM, gastrocnemius lateralis muscle activations were lower in the group with pes planus than in the group without pes planus.

Our study have several limitations. It can be difficult for young athletes to understand and learn the measurement method. To our knowledge, the learning process should be take longer in order to perform the desired movements correctly. The age range of gymnasts in this study was wide. The age-related musculoskeletal development level is different, therefore a difference is expected between the activation values of the selected muscles. It is important to measure muscle strength with highly reliable devices in order to reveal whether the height that gymnasts can reach during vertical jump is due to muscle strength or instant activation of the muscle during vertical jump. Also, vertical jump is an explosive activity. Therefore, future studies with camera integration will provide more reliable results to see more clearly the transition time to different phases of jumping. Athletes from two different gymnastic disciplines, which require different skills of their lower extremities, participated in our study. Future studies can be investigated the effect of pes planus with a larger sample and the participation of athletes belonging to only one gymnastics branch.

The results of this study showed that the pes planus had no effect on vertical jump and MVIC parameters. It was observed that the activation of GM and S muscles was low during vertical jump in gymnasts with pes planus. More consistent and objective information can be obtained with different methods to evaluate pes planus in future studies. The effect of the pes planus on performance can be investigated in other sports branches that include jumping activity. In studies based on muscle activation, measuring muscle strength with high-reliability devices will increase the power of the study. Therefore we suggest exercise interventions for improving lower limb muscle strength related to foot deformities.

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Conflicts of Interest

None to declare.

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Table 1. Demographic data of athletes with and without pes planus

	Gruplar	n	$\bar{X}$ ±ss / Median (Min-Max)	t/Z	p
Age (Years) **	With pes planus	28	12.28±4.30	-0.383	0.704
	Without pes planus	16	12.81±4.53		
Height (m) **	With pes planus	28	1.45± 0.182	-0.245	0.807
	Without pes planus	16	1.46±0.169		
Weight (kg) **	With pes planus	28	39.96±16.77	-0.019	0.985
	Without pes planus	16	40.06±16.69		
Body Mass Index (kg/m^2) *	With pes planus	28	18.205(13.19-26.03)	-0.329	0.742
	Without pes planus	16	16.59(13.43-26.03)		

*n: Number of individuals, $\bar{X}$: Arithmetic mean, ss: Standard deviation, p<0,05; t: t value of Independent Sample t-Test, Z: Z value of Mann Whitney U Test, * The results of the independent sample t-test are given with the arithmetic mean and standard deviation values. ** Results of Mann Whitney U test are given with median (minimum-maximum) values.*

Table 2. Examination of Clark, Navicular Drop, I. MTF Extension values of the athletes

Gruplar		n	$\bar{X}$±ss / Median (Min-Max)	t/Z	p
Clark dominant angle (º) **	With pes planus	28	26.95(8.8-29.9)	-5.466	**<0.001**
	Without pes planus	16	31.7(30.5-36.5)		
Clark nondominant angle (º) *	With pes planus	28	24.63±6.62	-3.783	**<0.001**
	Without pes planus	16	30.33±3.35		
Naviküler drop dominant value (cm) **	With pes planus	28	1.13 ± 0.48	-3.737	**<0.001**
	Without pes planus	16	0.61 ± 0.27		
Naviküler drop nondominant value (cm) **	With pes planus	28	1.07 ±0.43	-2.286	**0.022**
	Without pes planus	16	0.73 ± 0.26		
I.MTF Extension active dominant limb angle*	With pes planus Without pes planus	28 16	32.14±5.48 35.56±6.16	-1.903	0.064
I.MTF Extension passive dominant limb angle*	With pes planus Without pes planus	28 16	40.64±5.04 43.81±5.58	-1.927	0.061

*n: Number of individuals, $\bar{X}$: Arithmetic mean, ss: Standard deviation, p<0,05; t: t value of Independent Sample t-Test, Z: Z value of Mann Whitney U Test, * The results of the independent sample t-test are given with the arithmetic mean and standard deviation values. ** Results of Mann Whitney U test are given with median (minimum-maximum) values.*

Table 3. Examination of vertical jump heights and MVIC values of the muscles of the athletes with and without pes planus

	Groups	n	$\bar{X}$±ss / Median(Min-Max)	t/Z	p
Vertical jump height (cm)	With pes planus	28	26.9(16.7-28.2)	-0.817	0.414
	Without pes planus	16	29.35(17.7-50.9)		
GM_{MVIC} (µV) *	With pes planus	28	577.141(204.77-1892,86)	-0.634	0.526
	Without pes planus	16	507.80(378.35-910,04)		
S_{MVIC} (µV) **	With pes planus	28	271±98,16	1.441	0.157
	Without pes planus	16	263±112,11		
TA_{MVIC} (µV) *	With pes planus	28	427.09(213.07-911.72)	-1.220	0.223
	Without pes planus	16	483.54(321.33-849.15)		
PL_{MVIC} (µV) *	With pes planus	28	263.29(120.35-849.22)	-0.390	0.696
	Without pes planus	16	253.69(185.87-575.36)		

*n: Number of individuals, $\bar{X}$: Arithmetic mean, ss: Standard deviation, p<0,05, Z: Z value of Mann Whitney U Test, t: t value of Independent Sample t-Test * Mann Whitney U test results are given with median (minimum-maximum) values. **It is an independent sample t test and the results are given as arithmetic mean±standard deviation. µV:Microvolt cm: Centimeter MVIC: Maximum Voluntary Isometric Contraction*

Table 4. Examination of the activation values of the muscles of the athletes during jumping

	With pes planus Median(Min-Max)	Without pes planus Median(Min-Max)	Z	p
GM rising phase activation (μV)	66.172(43.98-150.64)	95.94(51.02-172.34)	-2.855	**0.004**
GM on air activation (μV)	30.05(2.17-123.25)	37.54(2.93-97.7)	-0.952	0.341
GM landing phase activation (μV)	51.16(20.58-314.08)	85.15(18.72-349.37)	-2.464	**0.014**
S rising phase activation (μV)	106.74(40.60-272.34)	103.2(68.43-260.77)	-0.537	0.591
S on air activation (μV)	28.15(4.42-143.07)	36.72(11.89-211.42)	-1.317	0.188
S landing phase activation (μV)	55.41(12.64-197.51)	108.08(16.45-488.51)	-2.391	**0.017**
TA rising phase activation (μV)	36.9(12.93-89.37)	32.09(13.16-56.29)	-0.927	0.354
TA on air activation (μV)	13.62(1.74-54.57)	17.97(5.96-61.84)	-0.878	0.380
TA landing phase activation (μV)	59.86(16.61-172.93)	61.44(20.79-96.92)	-0.317	0.751
PL rising phase activation (μV)	89.37(39.64-173.52)	85.37(60.64-238.19)	-0.073	0.942
PL on air activation (μV)	36.5(4.29-69.61)	41.69(11.62-109.93)	-0.634	0.526
PL landing phase activation (μV)	67.79(9.09-654.6)	72.7(35.17-358.54)	-1.000	0.317

Table 5. The relationship between the MVIC values of the athletes and the clark dominant angle values

		Clark Dominant Angle		
		With pes planus	Without pes planus	All gymnasts
GM_{MVIC} (μV)	r	-0.288	-0.239	-0.261
	p	0.137	0.374	0.086
S_{MVIC} (μV)	r	-0.251	0.144	-0.230
	p	0.198	0.594	0.132
TA_{MVIC} (μV)	r	0.179	0.11	0.278
	p	0.363	0.684	0.068
PL_{MVIC} (μV)	r	0.381	0.32	0.300
	p	**0.045***	0.228	**0.048***

Spearman Correlation Analysis, p<0,05 μV:Microvolt MVIC: Maximum Voluntary Isometric Contraction

Table 6. The relationship between muscle activation values and clark dominant angle values of athletes

		Clark Dominant Angle		
		With pes planus	Without pes planus	All gymnasts
GM rising phase activation (μV)	r	-0.043	0.165	0.370*
	p	0.829	0.542	**0.013**
GM on air aktivation (μV)	r	0.128	0.508*	0.24
	p	0.515	**0.044**	0.117
GM landing phase activation (μV)	r	0.021	0.093	-0.134
	p	0.916	0.733	0.385
S rising phase activation (μV)	r	0.156	0.236	0.135
	p	0.429	0.38	0.381
S on air activation (μV)	r	0.143	-0.063	0.145
	p	0.468	0.816	0.348
S landing phase activation (μV)	r	0.36	0.436	0.353*
	p	0.06	0.091	**0.019**
TA rising phase activation (μV)	r	0.025	0.523*	-0.028
	p	0.898	**0.038**	0.856
TA on air activation (μV)	r	-0.004	0.088	-0.011
	p	0.985	0.745	0.942
TA landing phase activation (μV)	r	0.015	0.389	-0.035
	p	0.939	0.137	0.821
PL rising phase activation (μV)	r	-0.269	0.361	-0.049
	p	0.166	0.17	0.750
PL on air activation (μV)	r	-0.002	-0.093	0.033
	p	0.99	0.733	0.834
PL landing phase activation (μV)	r	-0.21	0.29	0.025
	p	0.284	0.276	0.874

*Spearman Korelasyon Analizi , *p<0,05 düzeyinde anlamlı . μV:Mikrovolt*