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Does foot posture differ according to gender and lower extremity muscle strength in pre-adolescent swimmers?

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Abstract: Abnormal foot adaptations may affect muscle strength and may be associated with injury in athletes. The aim of this study is to investigate whether foot posture differs according to gender and lower limb muscle strength in pre-adolescent swimmers. Pre-adolescent swimmers who were trained at least 8 hours in a week between the ages of 8-12 and who did not have a history of ankle disability and pain were included. The Foot Posture Index (FPI) was used to determine foot posture. The lower limb muscle strength was measured using hand dynamometer. According to FPI total scores, swimmers were divided into two groups as normal footed (n = 36) and pronated (n = 24). Twenty-nine female and 31 male swimmers (mean age F: 11.06±1.53; M: 11.05±1.68 years) participated in the study. Twenty-four subjects had prone foot posture (10 females, 14 males), while 36 subjects had normal foot postures (19 females, 17 males). There was no statistically significant difference between lower extremity muscle strengths (knee flexion-extension, ankle dorsi, and plantar flexion) between swimmers with normal foot posture and swimmers with the prone foot posture (p=0.608, p=0.613, p=0.592, p=0.895). In addition, FPI scores were similar by gender (p= 0.299). This study revealed that pre-adolescent swimmers with different foot postures had similar lower extremity muscle strength and that foot posture did not differ by gender.

Keywords: Foot posture; ankle; muscle strength, gender.

1. Introduction

In recent years, research on sports biomechanics for the prevention of sports injuries have drawn attention (Andersen & Williams, 1988; Emery & Pasanen, 2019). Training programs applied to prevent injuries may vary specific to sports. Swimming is a sports branch that is done in water and the load is less than other land sports because of body weight. Although the load is low, swimming is a type of sport in which repetitive movements occur in the lower extremities in addition to the upper extremity.

In recent years, research on the static and dynamic loading of the foot in different sports has increased (Fellin, Rose, Royer, & Davis, 2010; Kluitenberg, Bredeweg, Zijlstra, Zijlstra, & Buist, 2012; Van Hooren et al., 2020). The foot, which provides the connection between the body and the

ground, has an important role in the general development of the musculoskeletal system. Basic structural changes occur in the foot posture to accommodate mobility. This stage of functional mobility is necessary for the physiological development of the foot (Bosch, Gerß, & Rosenbaum, 2010). Foot posture development may differ due to the loads that occur according to the activities performed.

Various clinical measurement methods like arch index, valgus index, navicular drop, and foot posture index (FPI) are available to determine the foot posture (Cavanagh & Rodgers, 1987; Pierrynowski, Smith, & Mlynarczyk, 1996; Song, Hillstrom, Secord, & Levitt, 1996). FPI, evaluates the multidimensional structure of the foot posture in all three planes (Redmond, Crane, & Menz, 2008). Since its measurement does not require the use of special equipment, it is widely used for clinicians and researchers working in this field to detect pathologies that may occur in the foot posture (Redmond, Crosbie, & Ouvrier, 2006). FPI has been used to evaluate the foot postures of athletes in different sports such as runners, futsal players, athletes, volleyball players, and professional dancers (Burns, Keenan, & Redmond, 2005; Cain, Nicholson, Adams, & Burns, 2007; Cimelli & Curran, 2012; De Groot et al., 2012; Teyhen et al., 2011). However, studies examining foot posture in swimmers are limited (Lopezosa-Reca, Gijon-Nogueron, Garcia-Paya, & Ortega-Avila, 2018). Lopezosa et al. (Lopezosa-Reca et al., 2018), examined whether the foot posture of football players and swimmers differed according to the sports performed and found that the foot posture could differ between sports branches. Therefore, it may be important to determine the foot posture, which may differ depending on the sport.

The deterioration of the normal posture of the foot due to the type of sport, the intensity of the loading and the type may affect the lower extremity muscle strength (Hahn & Foldspang, 1997). In swimming, internal rotation, plantar flexion and inversion mainly occur in the ankle regardless of the swimming style. It has been stated that this movement pattern can facilitate the pronation of the foot by affecting the foot muscle strength (Aspenes & Karlsen, 2012). Because this repetitive movement pattern occurs intensely in swimming, it may be important to identify a possible foot posture change. Because this repetitive pattern of movement in the lower extremity occurs intensely in swimming, it may be important to examine foot posture and muscle strength. However, when the literature is examined, it is noteworthy that there are few studies examining foot posture in swimmers. In particular, there is no study examining whether the foot posture differs according to gender and lower limb muscle strength in pre-adolescent swimmers. Therefore, the aim of this study is to determine whether foot posture differs according to gender and lower limb muscle strength in pre-adolescent swimmers.

2. Materials and Methods

Subjects — Twenty-nine female and 31 male swimmers were evaluated in this cross-sectional study in which the effect of foot posture on lower extremity muscle strength in pre-adolescent swimmers was examined. Before the assessments, an informative meeting was held for the coaches, swimmers, and their parents. The swimmers, who were directed to work by the team coaches of the ANKA sports swimming club, filled out a form containing demographic information (age, height, weight, swimming experience, etc.) before the evaluation. Informed consent was obtained from all swimmers and their

parents prior to data collection. Evaluations were made in Beytepe Olympic Swimming Pool. The study was approved by the Hacettepe University Non-Interventional Clinical Research Ethics Committee with the decision number GO20 /858. The procedures were followed in accord with the Helsinki Declaration of 2008.

Volunteer swimmers who participated in swimming training for at least 8 hours in a week were included in this study. Swimmers who had a history of lower extremity injury and felt pain during the evaluation were excluded from the study. The dominant side was chosen by determining the foot preference for activities such as hitting the ball.

Design- This study is a cross-sectional study investigating whether foot posture differs according to gender and lower limb muscle strength in pre-adolescent swimmers.

Methodology - Assessment of Foot Posture- Foot posture was evaluated using the Foot Posture Index (FPI) developed by Redmond et al. (Redmond et al., 2006). FPI, which has acceptable validity and good reliability in clinical measurement, evaluates the multi-part structure of foot posture in all three planes and does not require the use of special equipment (Cornwall, McPoil, Lebec, Vicenzino, & Wilson, 2008; Keenan, Redmond, Horton, Conaghan, & Tennant, 2007). The FPI was scored by 12 years experienced physiotherapist (G.İ.K.). FPI is a 6-item clinical assessment tool used to evaluate foot posture. The six criteria used in the evaluation are talar head palpation, supramalleolar and inframalleolar curvature, calcaneal frontal plane position, prominence in the region of the talonavicular joint, congruence of the medial longitudinal arch, and abduction/adduction of the forefoot on the rearfoot. Each FPI component is scored from −2 to +2, −2 represents signs of supination, and +2 indicates positive signs for pronation. The total score ranges from −12 to +12. Total scores between 0 and +5 refer to normal/neutral foot posture. ≥ +6 values were accepted as pronated foot, values below 0 were accepted as the supinated foot (Taha & Feldman, 2015).

Foot posture measurement was made before the morning swimming training session. FPI was evaluated using the standard method similar to previous studies (Martínez-Nova et al., 2014; Redmond et al., 2006). For assessment, swimmers were asked to stand for approximately 2 minutes in a comfortable position with bare feet, stepping on the double limb. Each leg was scored and recorded according to the stated description. According to FPI total scores, swimmers were divided into two groups as normal footed (n = 36) and pronated (n = 24).

Assessment of Muscle Strength — MicroFet 2 hand-held dynamometer (Model-01165, Lafayette Instrument Company, Lafayette IN, USA) was used to measure lower limb muscle strength. It is valid and reliable for isometric muscle strength measurement in swimmers (Coinceicao et al., 2018). Advantages of this device; It is easy to use, does not take time to measure, and is low cost. The muscle strength measurement protocol was performed by two five-year experienced physiotherapists (A.Ö. & F.Ö.).

Each swimmer included in the study was informed about muscle strength measurement before starting the assessment. To ensure the correct movement, swimmers were asked to perform maximum contraction against the rater's hand before testing (Thorborg, Petersen, Magnusson, & Hölmich, 2010). The measurements were made according to the "break test" technique. In this protocol, the evaluator pushes the dynamometer until motion is free in the joint so that it can overcome maximum muscle strength (Van der Ploeg & Oosterhuis, 1991).

For the measurement of knee extension strength, the individuals were seated with the knees flexed at 90°, feet free, arms crossed on the chest. During the knee extension muscle strength measurement, after the individuals completed the maximum knee extension, the leg applied with a hand was stabilized. The hand holding the dynamometer was placed vertically to the leg, 1-2 cm above the level of the malleoli. After the knee extension movement was completed, the individuals were asked to continue the isometric contraction for 5 seconds by applying the maximum force in the opposite direction to the resistance of the evaluator (Figure 1a).

Swimmers were positioned in the prone position for knee flexion, ankle plantar, and dorsiflexion muscle strength measurements. For the measurement of knee flexion muscle strength, after the extremity on the measured side was placed in a 90° flexion position, the hand holding the dynamometer was placed vertically to the posterior side of the distal surface of the tibia (same level as the knee extension). The swimmers were asked to continue the isometric contraction for 5 seconds by applying the maximum force in the opposite direction to the resistance of the evaluator (Figure 1b).

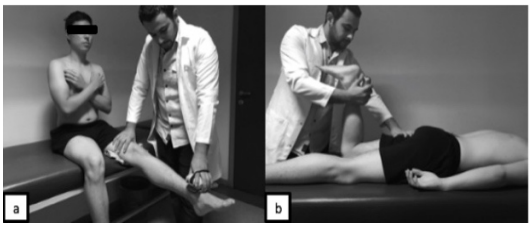

Figure 1. Knee extension and flexion muscle strength measurement **a)** Knee extension muscle strength **b)** Knee flexion muscle strength

To measure the ankle plantar and dorsiflexion muscle strength, swimmers were placed with their feet hanging from the edge of the table from the ankle. Then, ankle dorsiflexion and plantarflexion have tested by positioning the ankle in the neutral position and placing the dynamometer over the dorsal and the plantar surface of the midfoot, respectively, just proximal to the metatarsal phalangeal joints. The same measurement protocol was applied for the measurement of ankle dorsi and plantar flexion muscle strength (Figure 2a-b).

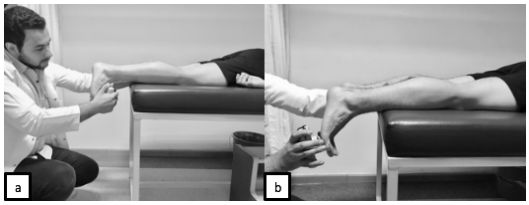

Figure 2. Ankle plantar flexion and dorsiflexion muscle strength measurement **a)** Dorsiflexion muscle strength **b)** Plantar flexion muscle strength

For all measurements, the average of 3 consecutive maximum contraction measurements made at 30-second intervals was taken. Measurements were made bilaterally as the dominant and non-dominant sides.

Statistical Analysis—The data obtained from the study were evaluated with IBM SPSS 20.0 package program. Whether the variables showed normal distribution was determined by visual (histogram and probability graphs) and analytical methods (Kolmogorov-Smirnov/Shapiro-Wilk tests). Descriptive analyzes mean and standard deviation for numerical variables; The frequency tables for ordinal variables are shown with (n) and rates (%).

Comparisons of lower extremity muscle strength of individuals divided into two groups according to FPI scores and comparisons of FPI scores of swimmers divided into two groups according to gender were made using the Independent sample t-

test or Mann Whitney U test in accordance with the distribution of the data. For statistical significance, type-1 error level was used as 5% ($p < 0.05$).

3. Results

The physical characteristics and mean FPI scores of the swimmers are summarized in table 1. The physical characteristics of the swimmers who participated in the study were similar ($p > 0.05$) (Table 1).

The prone foot posture was observed in 24 patients (10 females, 14 males), and normal foot posture (19 females, 17 males) in 36 patients.

The distribution of FPI scores by gender was shown in Figure 3.

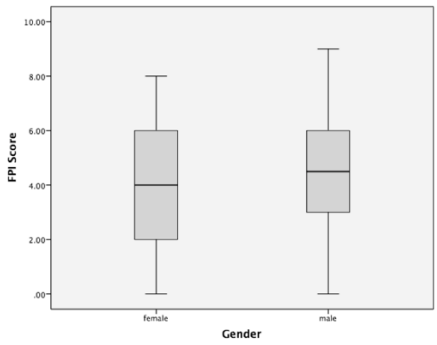

Figure 3. Change of FPI scores by gender.

There was no statistically significant difference between the FPI scores of the swimmers groups according to gender ($p = 0.299$).

The comparison of knee flexion, extension, ankle dorsiflexion, plantar flexion muscle strength with groups divided according to FPI scores is shown in Table 2.

Table 1. Physical characteristics of the swimmers

	Female (n=29)	Male (n=31)	p*
Age (years)	11.06±1.53	11.05±1.68	0.979
Body Mass Index (kg/m²)	17.38±1.97	17.49±2.01	0.826
Swimming experience (years)	4.68±1.95	4.35±1.78	0.493
Foot Posture Index Score	3.90±2.39	4.53±2.85	0.299

**Independent samples t test p>0.05.*

Table 2. Comparison of isometric lower limb muscle strength in swimmers with normal and prone foot posture

	Dominant			Non-dominant		
	Normal foot (n=36) X±SD	Prone foot (n=24) X±SD	p*	Normal foot (n=36) X±SD	Prone foot (n=24) X±SD	p*
Knee (kg)						
FL	21.26±3.79	21.10±4.82	0.608	20.07±3.32	18.87±4.12	0.163
EX	19.92±5.15	20.14±2.81	0.613	18.47±4.69	18.07±3.83	0.862
FL/EX	1.12±0.30	1.05±0.22	0.353	1.14±0.27	1.06±0.23	0.267
Ankle (kg)						
PFL	26.99±6.30	27.02±4.20	0.592	27.00±6.61	26.42±3.83	0.846
DFL	27.56±4.38	28.08±5.04	0.895	26.07±5.19	26.19±4.98	0.938
PFL/DFL	0.98±0.17	0.97±0.15	0.756	1.04±0.20	1.03±0.19	0.975

p<0.05 Independent samples t test; **SD: Standard Deviation; **FL**: Flexion; **EX**: Extension; **PFL**: Plantar flexion; **DFL**: Dorsi flexion.*

There was no statistically significant difference between lower extremity muscle strengths (knee flexion-extension, ankle dorsi, and plantar flexion) between swimmers with normal foot posture and swimmers with the prone foot posture ($p>0.05$) (Table 2).

4. Discussion

The results of this study demonstrated that lower extremity muscle strength was similar in pre-adolescent swimmers with different foot postures, and foot posture did not differ by gender in swimmers of this age group.

FPI is a method used to evaluate foot posture in different branch athletes. According to FPI scores; total scores between 0 and +5 are considered normal/neutral foot stance, ≥ +6 values are accepted as prone foot, values below 0 are accepted as the supinated foot (Taha & Feldman, 2015). 40% of the swimmers in our study had a prone foot posture according to their FPI scores. The probable reason for this high rate may be the incomplete development of the foot arches.

The mean foot posture index scores of the individuals in our study were 4.21. In terms of gender, the average score was 3.90 for females; 4.53 for males. Data on foot posture in swimmers are limited in the literature. Lopezosa et al. (Lopezosa-Reca et al., 2018) found the FPI scores in swimmers (mean aged 17.21±1.72) as 4.42, similar to the score in our study. In studies in other sports branches in the literature, Nova et al. (Martínez-Nova et al., 2014) the FPI score was 3.9 ± 4.1 for basketball players (mean aged 32.1±8.9), 2.9 ± 2.8 for runners (mean aged 40.2±7.3), and -0.4 ± 6.9 for handball players (mean aged 21.8±3.2); de Groot et al. (De Groot et al., 2012) 4 ± 3.5 in volleyball players (mean aged 26±5.5), Cain et al. (Cain et al., 2007) 5.3 ± 2.9 in indoor soccer players (mean aged 14.5±1.67) and Bums et al. (Burns et al., 2005) found it to be 5.1 ± 3.9 in athletes (mean aged 33.7 ± 10.3). These different scores between sports branches may be due to the difference in the application surfaces and techniques of the sport. In water sports, less resistance is applied to the extremity, and body weight is reduced than in land sports. Therefore, the muscle activity of the lower extremities decreases (Liebenberg et al., 2011).

Movements affecting the foot consist mainly of internal rotation, plantar flexion, and inversion of the ankle, regardless of swimming style, and the knee remains in a slight flexion position. This pattern of movement can trigger muscle weakness in the ankle and facilitate the pronation of the foot (Aspenes & Karlsen, 2012). Although a high rate of prone posture was observed in this study (40%), the results showed that swimmers with different foot postures had similar muscle strength. These results may suggest that foot posture does not affect muscle strength in swimmers in this age group. This may be due to the low average age of the swimmers evaluated. However, it may not be correct to generalize these results. Because of the low age group, the fact that swimmers have not yet completed the muscular development specific to the sport may have caused these results. For this reason, the long-term follow-up of these swimmers starting from the pre-adolescence period may be important in detecting the foot posture disorders that may occur later.

Males and females in our study had a similar foot posture. This result of our study may indicate that gender does not affect foot posture in swimmers in this age group and that these swimmers show a balanced development specific to sports regardless of their gender. However, this situation may create a difference between the genders with the effect of hormonal changes during and after puberty with the growth in the later periods. Contrary to the results of our study,

Nova et al. (Martínez-Nova, Gijón-Noguerón, Alfageme-García, Montes-Alguacil, & Evans, 2018), found that the FPI scores of normal swimmers in the 5-11 age range were different according to gender. However, they found that there was a decrease in the FPI scores after three years of follow-up and no significant difference was seen by gender. The foot has a dynamic structure and its development continues depending on the age. Especially the development of foot posture shows significant changes in individuals in the 10-11 age group (Targett & Mathieson, 2010). For this reason, it may be important to perform long-term follow-up to determine whether there is a difference between the genders.

5. Practical Applications.

An important limitation of this study is that it did not include a control group. The data to be obtained from non-swimmers of similar age group would be good for a more accurate interpretation of the results of our study. Another limitation of this study is that it includes the developmental period of the age groups of the swimmers in the study. This age group can affect the actual position of the foot. Therefore, future studies should be expanded to include older age groups in which foot posture development is complete. However, despite these limitations, our results may be of interest to both clinicians and researchers interested in swimming.

6. Conclusions

In conclusion, we examined foot posture by gender in pre-adolescent swimmers and compared the muscle strength of swimmers with different foot postures. We found that pre-adolescent swimmers with different foot postures had similar lower extremity muscle strength and that foot posture did not differ by gender.

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Conflicts of Interest: The authors declare no conflict of interest.

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