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Investigation of the relationship between sit-and-reach flexibility and the height, the leg length and the trunk length in adolescent athletes

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Abstract

Background: Background: The aim of this study is to investigate the relationship between the Sit-and-Reach (SR) test and the height, the leg length, and the trunk length of the male and female adolescent athletes, and to obtain relative SR test results using these anthropometric values. Material and methods: Fifty-six adolescent athletes were included in the study. The athletes' trunk, hip, and hamstring flexibility were evaluated with the SR test (traditional). The height-relative SR, leg length-relative SR and trunk length-relative SR test values were calculated by proportioning each data with the SR test values. Pearson/Spearman correlation analysis were used according to the distribution status. Statistical significance was taken as p<0.05. Results: There was a very strong positive correlation between the traditional SR and all relative SR in female and male athletes (r:0.991/0.996; p<0.05). Traditional values of SR flexibility were similar between genders; however, relative SR according to the height, the trunk length, and the leg length were found to be higher in female athletes. Conclusions: We think that the height-relative SR, leg length-relative SR and trunk length-relative SR values will give more accurate results in comparing trunk, hip, and hamstring flexibility. Therefore, we suggest that flexibility should be evaluated with relative SR tests, and its practical use should be increased.

Keywords

anthropometry, flexibility, hamstring, muscle, sports

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Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

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Results: There was a very strong positive correlation between the traditional SR and all relative SR in female and male athletes (r:0.991/0.996; $p<0.05$). Traditional values of SR flexibility were similar between genders; however, relative SR according to the height, the trunk length, and the leg length were found to be higher in female athletes.

Conclusions: We think that the height-relative SR, leg length-relative SR and trunk length-relative SR values will give more accurate results in comparing trunk, hip, and hamstring flexibility. Therefore, we suggest that flexibility should be evaluated with relative SR tests, and its practical use should be increased.

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INTRODUCTION

Flexibility, one of the components of physical fitness, is the ability of a joint to move throughout the range of motion (ROM) without restriction [1]. Factors such as the joint structure, connective tissue elasticity, body weight, age, gender, and body type directly affect flexibility [2], and it is stated that some factors, such as muscle strength and sports discipline, indirectly affect flexibility [1]. Flexibility is an essential factor for sports performance. Optimal muscle flexibility allows the muscle to move safely within the ROM without reducing the strength of the muscle and allows the muscle tissue to adapt to the applied stress [3, 4]. In terms of intrinsic risk factors, low muscle flexibility is accepted as one of the most common risk factors for the occurrence of muscle injuries [5, 6].

Flexibility measurements are made to evaluate the ability of skeletal muscle and muscle-tendon unit [7, 8]. Flexibility can be measured statically and dynamically [7–10]. Static flexibility is defined as the ROM for a joint. In addition to muscle flexibility, it also depends on the joint capsule and ligaments [3, 4, 7]. Dynamic flexibility means ease of movement within the available ROM. Sit-and-reach (SR) and toe-touch tests are the well-known tests used in static flexibility measurement [13]. These tests are highly reliable [9–15]. In addition to these tests, there are also measurement methods where numerical data are obtained using a goniometer or a ruler [7, 9–15].

It is known that muscles with a high density of fast-twitch muscle fibers, crossing more than one joint, and having less flexibility have a higher risk of injury [3, 8]. Hamstring muscles have a high rate of fast-twitch muscle fibers, cross more than one joint, and are the most frequently injured muscle group in the human body [3]. Evaluation of hamstring muscle flexibility is frequently used in evaluations of athletes' health and performance [8]. Low hamstring muscle flexibility causes decreased sports performance, hamstring muscle injuries, and low back pain [8, 9]. In addition, a short hamstring muscle has been associated with patellofemoral pain syndrome and patellar tendinopathy [9].

The sit-and-reach test is a field test commonly used to measure trunk, hip, and hamstring flexibility [10]. As a result of studies comparing the SR test with a modified SR test, the toe-touch test, the back saver SR test, the chair SR test, the V-SR test, and the passive straight leg raise test, it was stated that the validity of all SR test protocols was similar [10–15]. In studies on the validity and reliability of SR test protocols, it is stated that the SR test protocols have moderate validity for hamstring flexibility and poor validity for trunk flexibility [10, 16–18]. The most common assumption of SR test results is that subjects with higher scores are more flexible than subjects with lower scores [19]. However, studies have shown that anthropometric variables are associated with the SR test. Physical characteristics, such as the arm and leg length, may affect the results of the SR test [17–20].

It is important to evaluate flexibility in athletes correctly and objectively. In this context, the hypothesis emerges that the SR test, which can be affected by anthropometric factors, may be related to the height, the trunk length, and the leg length. Therefore, the aim of our study is to investigate the relationship between the height, the body length, and the leg length and the SR test which is frequently used in adolescent athletes, and to obtain a relative value by comparing the results of the SR test to these anthropometric values, and to compare these values between genders.

MATERIAL AND METHOD

This study was designed as a cross matched study based on different gender, with similar features according to age, sport discipline and years of sports experience. All athletes who came to the clinic where the study was conducted during the study period for performance measurement and who met the criteria for participation in the study were included.

Participants: A total of 56 (28 females and 28 males) athletes of the same age and sports discipline (six canoeing, eight rhythmic gymnastics, eight artistic gymnastics, four track and field-throwing, four track and field-jumping, ten track and field-running, four fencing, four skiing, eight swimming) were included in the study. The inclusion criteria of the study were being a licensed athlete, not having a lower back and lower extremity injury in the last three months, and volunteering to participate in the study. The exclusion criteria from the study were having leg length difference, low back pain, acute or chronic problems involving the lower extremities. At the beginning of the study, 96 of the 194 athletes were excluded from the study due to the exclusion criteria. 42 of 98 athletes were excluded from the study because the length of their sports experience, gender, age, and sports discipline matches could not be founded. The athletes were informed about the details of the study. Verbal and written consent was obtained from the athletes and their legal representatives. Ethical approval was taken from the University Social and Humanities Ethics Committee (2020/208/25), and the study was conducted in accordance with the 2008 Principles of the Helsinki Declaration.

Study Procedures: The athletes who met the study criteria were evaluated within one day. After obtaining the demographic information of the athletes, their height and leg length were measured. The trunk length of the athletes was calculated by subtracting the leg length from their height. Then, the flexibility of the athletes was evaluated with the SR test. The SR test is performed before doing any other performance tests or sport specific training.

Height Measurement: The athletes' height was measured with a stadiometer (SECA, Mod.220, Germany) by ensuring that the individual stands upright when the feet side by side and the head in a Frankfort plane (eye triangle and the top of the auricle are aligned) and recorded in meters.

Leg Length Measurement: Leg length was measured using a tape measure and recorded in cm. In the first measurement, the distance between the umbilicus and the medial malleolus was measured on the right and left sides. In the second measurement, the distance between the Spina Iliaca Anterior Superior (SIAS) and medial malleolus was measured on the right and left sides of the athletes whose both sides were equal in the first measurement. In the third measurement, the distance between the trochanter major and lateral malleolus was measured on the right and left sides of the athletes whose both sides were equal in the second measurement. The results of the third measurement were recorded as the leg length of the athletes in case of equality on both sides. Athletes with right-left inequality in any of the three measurements were considered to have leg length differences and were excluded from the study.

Trunk Length Measurement: The athletes' trunk length was calculated by subtracting the leg length (cm) from their height (cm) and recorded in cm.

Flexibility evaluation: The sit-and-reach test was used to evaluate trunk and lower extremity flexibility. The Baseline® (Cooper Institute / YMCA, AAHPERD) device was used for evaluation. The athletes were asked to place their heels on the device while in the long sitting position with their trunk flexed at 90°. After the athletes' arm length were determined on the device, they were asked to reach forward as far as they could by pushing the measuring device with their fingertips without lifting their knees. The measurement was performed three times. The average of the results was recorded as the result of the SR test [10]. Then, the relative value of the height was calculated by proportioning this value to the height, the relative value of the trunk length in proportion to the trunk length, and the relative value of the leg length by proportioning to the leg length.

Statistical Analysis: Statistical analysis of the study was performed with SPSS software (version 20.0, SPSS Inc., Chicago, IL). Descriptive statistics of all variables were determined. Analytical methods (Kolmogorov-Smirnov / Shapiro-Wilk's test) were used to define whether the variables were normally distributed or not. The Independent Samples t-test and the Mann Whitney-U test were used in the comparison of data between genders according to the normal distribution status. In order to examine the relationship between variables, the Pearson correlation analysis was used for numerical variables with normal distribution, and the Spearman correlation analysis was used for variables with at least one not showing normal distribution. For this, r=0–0.3 was considered a negligible correlation; r=0.31–0.50 a low correlation; r=0.51–0.70 a moderate correlation; r=0.71–0.90 a strong correlation; and r=0.91–1.00 a very strong correlation [21]. Variables were represented as mean ± standard deviation (X±SD) and median and interquartile range [Median (IQR25–75)]. The statistical error level was set as p<0.05.

RESULTS

Physical characteristics and years of sports experience of 56 athletes, 28 females and 28 males included in the study are given in Table 1. It was determined that the age, the body mass index, and years of sports experience of female and male athletes were similar to each other (p>0.05). The height and the leg length of female athletes were shorter than of male athletes, and their body weight was lower (p<0.05). It was determined that the traditional values of the athletes' SR flexibility were similar between the genders (p>0.05). The relative values of the SR test in the height, the trunk length, and the leg length were found to be higher in female athletes (p<0.05) (Table 1).

Table 1. Comparison of physical characteristics, length of sports experience and sit-and-reach flexibility of female and male athletes

		FEMALE (n=28)		MALE (n=28)		p
		X±SD	Median (IQR25–75)	X±SD	Median (IQR25–75)	
Age (year)		15.43±1.35	15.00 (15.00–16.00)	15.64±1.13	15.50 (15.00–16.00)	0.363¥
Height (m)		1.65±0.08	1.64 (1.61–1.72)	1.74±0.07	1.73 (1.69–1.79)	<0.001*
Leg length (cm)		78.78±4.97	78.93 (76.25–82.50)	83.09±4.22	83.15 (80.90–85.00)	0.001*
Trunk length (cm)		85.76±4.20	86.00 (83.25–89.25)	90.85±4.61	91.05 (88.00–93.55)	<0.001*
Body weight (kg)		56.06±7.67	58.55 (52.00–61.00)	65.89±12.51	63.75 (58.05–69.75)	0.003¥
BMI (kg/m²)		20.69±2.41	20.67 (18.85–22.06)	21.65±2.96	21.48 (19.97–23.43)	0.186*
Length of sports experience (years)		6.57±3.17	6.00 (4.00–8.50)	6.34±3.07	7.00 (4.00–9.00)	0.934¥
Sit-and-Reach Flexibility	Traditional Value (cm)	18.50±7.02	19.42 (12.17–23.00)	15.27±7.04	14.92 (10.08–20.84)	0.092*
	Height Relative Value (%)	11.35±4.55	11.47 (7.11–14.29)	8.83±4.15	8.48 (5.53–11.49)	0.035*
	Leg Length Relative Value (%)	23.75±9.55	24.05 (15.34–30.47)	18.49±8.66	17.88 (11.09–24.87)	0.035*
	Trunk Length Relative Value (%)	21.78±8.74	22.23 (13.59–27.30)	16.95±8.02	16.14 (11.01–22.78)	0.035*

*: Independent Samples T test, ¥: Mann Whitney U test, BMI: Body Mass Index, IQR25–75: Inter Quartile Range.

In female athletes, there is a weak and moderate negative correlation between traditional SR flexibility with the height, the trunk length, and the body weight (r = -0.391/-0.403;

$p<0.05$). There is a moderate positive correlation between traditional SR test and years of sports experience ($r = 0.514$; $p<0.05$). Similarly, there is a weak and moderate negative correlation between the relative values of SR flexibility with the height, the leg length, the body length, and the body weight ($r = -0.374/-0.534$; $p<0.05$). There is a moderate positive correlation between relative SR tests and years of sports experience ($r = 0.494/0.505$; $p<0.05$). It was determined that there was a very strong positive correlation between the traditional value of SR flexibility and all three relative values in female athletes ($r = 0.991 /0.985$; $p<0.05$) (Table 2).

Table 2. Analysis of the relationship between female athletes' sit-and-reach flexibility with physical properties, length of sports experience, and relative sit-and-reach flexibility

Females (n=28)		Sit and Reach Flexibility			
		Traditional Value (cm)	Height Relative Value (%)	Leg Length Relative Value (%)	Trunk Length Relative Value (%)
Age (Year)	r	-0.165	-0.146	-0.144	-0.146
	p	0.402	0.459	0.464	0.458
Height (m)	r	-0.403*	-0.517**	-0.534**	-0.499**
	p	0.033	0.005	0.003	0.007
Leg length (cm)	r	-0.317	-0.418*	-0.464*	-0.374*
	p	0.100	0.027	0.013	0.049
Trunk length (cm)	r	-0.391*	-0.486**	-0.465*	-0.505**
	p	0.040	0.009	0.013	0.006
Body weight (kg)	r	-0.400*	-0.475*	-0.471*	-0.476*
	p	0.035	0.011	0.012	0.01
BMI (kg/m^2)	r	-0.179	-0.174	-0.151	-0.193
	p	0.362	0.376	0.442	0.324
Length of sports experience (years)	r	0.514**	0.501**	0.505**	0.494**
	p	0.005	0.007	0.006	0.008
Sit-and-Reach Traditional Value (cm)	r	1	0.991**	0.985**	0.991**
	p	<0.001	<0.001	<0.001	<0.001

BMI: Body Mass Index

In the male athletes, there was not any statistically significant correlation between traditional and relative values of SR flexibility with the age, the height, the leg length, the body length, the body weight, the body mass index, and years of sports experience ($p>0.05$). It was determined that there was a very strong positive correlation between the traditional value of SR flexibility and all three relative values ($r = 0.993/0.996$; $p<0.05$) (Table 3).

Table 3. Analysis of the relationship between male athletes' sit-and-reach flexibility with physical properties, length of sports experience and relative sit-and-reach flexibility

Males (n=28)		Sit and Reach Flexibility			
		Traditional Value (cm)	Height Relative Value (%)	Leg Length Relative Value (%)	Trunk Length Relative Value (%)
Age (Year)	r	-0.249	-0.290	-0.264	-0.314
	p	0.202	0.134	0.174	0.104
Height (m)	r	-0.260	-0.335	-0.330	-0.340
	p	0.182	0.081	0.087	0.076
Leg length (cm)	r	-0.161	-0.213	-0.263	-0.170
	p	0.413	0.276	0.177	0.388
Trunk length (cm)	r	-0.232	-0.294	-0.241	-0.341
	p	0.236	0.129	0.217	0.075

Males (n=28)		Sit and Reach Flexibility			
		Traditional Value (cm)	Height Relative Value (%)	Leg Length Relative Value (%)	Trunk Length Relative Value (%)
Body weight (kg)	r	-0.164	-0.214	-0.22	-0.208
	p	0.405	0.274	0.262	0.287
BMI (kg/m^2)	r	-0.07	-0.094	-0.108	-0.081
	p	0.724	0.635	0.585	0.682
Length of sports experience (years)	r	0.311	0.311	0.311	0.307
	p	0.108	0.108	0.107	0.112
Sit-and-Reach Traditional Value (cm)	r	1	0.996**	0.994**	0.993**
	p	<0.001	<0.001	<0.001	<0.001

BMI: Body Mass Index

DISCUSSION

The aim of the study was to investigate the relationship between sit-and-reach flexibility and the height, the trunk length, and the leg length in adolescent athletes, and to obtain relative SR values according to these anthropometric values, and to compare these values between genders. As a result, it was determined that traditional values of SR flexibility were similar between genders; however, relative SR values according to the height, the trunk length, and the leg length were found to be higher in female athletes. In addition, it was determined that the height, the trunk length, the leg length, and the body weight were negatively related to all SR flexibility in female athletes, while years of sports experience were positively related to SR flexibility. In male athletes, it was determined that there was no relationship between traditional and relative values of sit-and-reach flexibility with the age, the height, the trunk length, the leg length, the body weight, and years of sports experience. It was determined that there was a very strong positive correlation between the traditional SR flexibility and all three relative SR flexibility in female and male athletes.

There are many factors affecting muscular flexibility, which plays an important role in athletes' physical performance [22]. Gender is one of the factors that affect flexibility. In the literature, it is stated that females have more muscle flexibility than males [23–25]. It is thought that this difference may be caused by anatomical, neurophysiological, biomechanical, and hormonal characteristics between the genders [1, 23, 26]. High levels of estrogen in females cause the body to retain water, have a higher proportion of adipose tissue, and have a lower muscle mass, and these factors positively affect muscular flexibility [23]. In our study, it was determined that the results of traditional SR flexibility were similar between genders; however, consistent with the literature, the results of three relative SR flexibility values were found to be higher in female athletes.

Several studies in the literature claim that anthropometric factors, such as height, trunk length, and leg length, may affect the results of the SR flexibility test because the limbs may be disproportionate to the trunk [17, 20, 25]. Since the SR test includes many body movements, its score and validity may be affected by many anthropometric factors in the upper extremity, the spine and the lower extremity, and joint flexibility [27]. For example, when applying the SR test, individuals with long legs and/or short arms have a structural disadvantage and have a lower score than individuals with short legs and/or long arms that provide the same degree of hip flexion [19, 25]. In a study conducted with male amateur soccer players, it was observed that there was a negative relationship between the height and hamstring flexibility, and the athletes with long legs also had lower SR test results than those with long arms [26]. Consistent with the literature, although the traditional SR test results were similar between the genders, the relative scores according to the height, the leg length, and the body length of the SR test were higher in females than in male athletes.

If we did not examine the relative SR flexibility in our study, we would conclude that SR flexibility was similar in male and female athletes. However, when we examined the relative SR flexibility of male and female athletes with differences in anthropometric characteristics, we determined that the relative SR flexibility of the athletes was different.

In some previous studies, it was shown that the athletes' age did not affect hamstring muscle flexibility [24, 26, 28]. In our study, it was determined that there was no relationship between traditional and relative SR flexibility and age in both male and female athletes. In one of these studies, it was found that there was no relationship between the body weight and the SR flexibility in male amateur football players; however, a significant relationship was found between the athletes' body mass index and the SR flexibility [26]. In our study, it was determined that there was no relationship between body mass index and the SR flexibility in both male and female athletes, and the body weight did not affect the SR test in male athletes. However, a moderate negative correlation was found between the body weight and traditional and relative SR flexibility in female athletes.

It has been reported that physical activity positively affects muscular flexibility [29, 30], and elite athletes are more flexible than non-elite athletes [31, 32]. However, it is known that each sports discipline can cause increased flexibility specific to different joints and muscle groups [8, 33]. In a study, it was found that the shoulder external rotation flexibility of young elite tennis athletes was higher than the internal rotation flexibility of the shoulder. The sit-and-reach flexibility of tennis athletes was lower than the other sports disciplines involving the lower extremities. It was stated that the possible reason for this difference might be a sport-specific adaptation [34]. In the light of this information in the literature, in order to avoid the differences that may be caused by sport-specific adaptations, our study was composed of controlled male and female athletes who practiced the same sport discipline and had the same length of sports experience. As a result of our study, it was determined that the flexibility of the SR test increased as the length of sports experience of female athletes increased and that there was no relationship between SR flexibility and years of sports experience in men.

The most common assumption when interpreting the SR flexibility test results is that participants with higher scores have higher trunk, hip, and hamstring flexibility than participants with lower scores [19]. In our study, it was determined that the traditional SR test value of female athletes with shorter height, trunk length, and leg length was like that of male athletes. This result suggests that the flexibility of the male and female athletes included in our study are similar. However, in the present study, it was determined that three different relative SR values obtained by proportioning the results of SR test to the height, the trunk length, and the leg length were found to be higher in female athletes. In our study, it was also determined that there is a very strong relationship between the traditional value of SR flexibility and the three relative values in male and female athletes, and as the traditional SR test value increases, the relative values increase. This result suggests that the sit-and-reach test value may not be accurate in comparing trunk, hip, and hamstring flexibility in athletes with a different leg length, trunk length, and height. However, we think that the relative SR test results obtained by proportioning the leg length, the trunk length, and the height will give more accurate results in comparing trunk, hip, and hamstring flexibility.

The limitations of our study were the low number of athletes included in our study and the fact that regression analysis could not be performed due to the distribution status. At the same time, the fact that the arm lengths and arm relative SR flexibility of the athletes were not evaluated in our study is another limitation of our study. Therefore, we suggest investigating anthropometric features that may affect SR flexibility and examining these anthropometric features and relative SR flexibility in future studies. However, the fact that our study was matched for age and sports disciplines and that the relative value was calculated with three different lengths are the strengths of our study. The fact that our study was conducted with adolescent athletes and with different sports disciplines makes it wrong to generalize the results of our study to all athletes. For this reason, we think that there is a need for sport-specific studies involving different age groups.

CONCLUSIONS

In conclusion, this study shows that traditional SR measurements may not give accurate results in comparing the SR flexibility of athletes of different genders, and SR flexibility assessments relative to the body length, the leg length, and the height will give more accurate results. We think that the relative SR test results obtained by proportioning the results of the SR test to the trunk length, the leg length, and the height will give more accurate results in comparing trunk, hip, and hamstring flexibility. Therefore, we suggest that SR flexibility should be evaluated with relative SR tests, and its practical use should be increased in clinics

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