




Comparison of rectus femoris architecture and somatotype between well-trained bodybuilders and soccer players

İyi antrenmanlı vücut geliştiriciler ve futbolcularda rektus femoris mimarisi ve somatotip karşılaştırması

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ABSTRACT

Objective: Training has different adaptive effects on muscle architecture and body types in the long term. The purpose of this study was to compare rectus femoris architecture and somatotypes of well-trained bodybuilders and soccer players.

Material and Methods: A total of thirty male athletes (15 bodybuilders and 15 soccer players, with at least 5 years of training experience) were included in the study. The thickness of the rectus femoris muscle (MT), pennation angle (PA), and fascicle length (FL) were measured using B-mode ultrasound and somatotyping has been performed by the Heath-Carter method.

Results: PA (19.1%, $p=0.007$) and MT (11.5%, $p=0.039$) were greater in bodybuilders than soccer players, while FL was similar (5%, $p=0.220$) between athletes. A moderate effect size (ES) was found at MT (ES = 1.06; 95% CI) and a large ES at PA (ES = 1.55; 95% CI). Somatotyping has revealed that bodybuilders were endomorphic mesomorph (3.01-5.74-2.05) and soccer players were mesomorph-ectomorph (2.52-3.58-3.80).

Conclusion: Training affects muscle morphology and somatotype of athletes with regard to sport specific training patterns in long term. Revealing the adaptive characteristics of muscle architecture and somatotypes may help sports scientists and coaches in train planning and modification.

Keywords: *Bodybuilding, soccer, ultrasonography, muscle morphology, somatotype*

ÖZ

Amaç: Antrenman kas mimarisi ve vücut tipleri üzerinde uzun dönemde farklı adaptif etkilere sahiptir. Bu çalışmanın amacı, iyi antrenmanlı vücut geliştiriciler ve futbolcuların rektus femoris mimarisi ve somatotiplerini karşılaştırmaktır.

Gereç ve Yöntemler: Çalışmaya toplam otuz erkek sporcu (en az 5 yıl antrenman tecrübesi olan 15 vücut geliştirici ve 15 futbolcu) dahil edildi. Sporcular arasındaki farkları araştırmak için rektus femoris kas kalınlığı (MT), pennasyon açısı (PA) ve fasikül uzunluğu (FL) B-mod ultrasonografi ile ölçüldü, somatotip belirleme Heath-Carter yöntemi kullanılarak gerçekleştirildi.

Bulgular: Rektus femoris mimarisinde PA (%19.1, $p=0.007$) ve MT (%11.5, $p=0.039$) vücut geliştiricilerde futbolculara göre daha fazlayken, FL'de benzerdi (%5, $p=0.220$). MT'de orta düzeyde etki (EB = 1.06; %95 CI) ve PA'da yüksek düzeyde etki bulundu (EB = 1.55; %95 CI). Somatotipleme ile vücut geliştiricilerin endomorfik mezomorf (3.01-5.74-2.05) ve futbolcuların mezomorf-ektomorf (2.52-3.58-3.80) oldukları belirlendi.

Sonuç: Spora özgü antrenmanlar uzun dönemde kas morfolojisi ve somatotip özelliklerini farklı şekilde etkilemektedir. Antrenmanların kas mimarisi ve somatotip üzerindeki adaptif özelliklerini ortaya koymak, spor bilimciler ve antrenörlere antrenman planlama ve modifikasyonunda yardımcı olabilir.

Anahtar Sözcükler: *Vücut geliştirme, futbol, ultrasonografi, kas morfolojisi, somatotip*

INTRODUCTION

Several longitudinal studies in the literature have examined the effects of specific training or physical activity on muscle architecture (i.e., muscle thickness, pennation angle, and fascicle length) (1, 2). One of the widely accepted theories is that resistance training changes the muscle architecture (3). In addition, specific exercises such as stretching have been found to produce significant changes in the architectural structures of the muscle (4). Muscle architec-

ture has an adaptive capacity depending on the type of long-term training (5).

The muscle develops different adaptations depending on the type of training in 10 weeks (6). McKendry et al. found that master endurance athletes (67.1±4.1 years) had significantly greater fascial length of the gastrocnemius medialis than the control group (69.8±4.1 years) (7). Brughelli et al. investigated the differences in muscle architecture (vastus

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lateralis) between 9 endurance cyclists and 9 Australian Rules Football players (ARF) (at least 3 years of training) and reported that the ARF players had a significantly smaller pennation angle (19.3 ± 2.0 vs. $24.9 \pm 2.5^\circ$) and greater fascial length (7.9 ± 0.7 vs. 6.2 ± 0.8 cm) compared to the cyclists (8). The studies show that long-term training with different content causes significant differences in muscle morphology of athletes.

Somatotype represents body type and is classified as endomorphy, mesomorphy, and ectomorphy (9). It has been found that the components of somatotype are different in athletes with many years of sports experience and different training content (10). For example, Bayios et al. found the somatotype scores of elite Greek female athletes in volleyball as (3.4-2.7-2.9), basketball as (3.7-3.2-2.4), and handball as (4.2-4.7-1.8) with at least 8.8 years of training experience (11). In another study examining highly experienced athletes at the international level, kayakers were predominantly endomorphic, basketball players were endomorphic, and soccer players were ectomorphic (12). When examining the long-term effects of sport on somatotype components, dominant energy metabolism can be cited as the mechanism of action. After a 12-week aerobic training program (two sessions per week), a significant interaction was found between somatotype and aerobic training ($p < 0.001$), the meso-ecto and meso groups showed the greatest improvements in aerobic capacity (13). A positive correlation was found between mesomorphy and anaerobic performance (3 RM bench press and squats; $r = 0.560$; $r = 0.550$, $p < 0.001$, respectively) (14). Training content influences athletes' phenotypes and this effect can be more pronounced in the long term. To our knowledge, no previous studies have compared muscle architecture and somatotype components between highly trained male soccer players and body builders.

The purpose of this study is to compare the muscle architecture and somatotype components of athletes with different training contents, and it was hypothesized that muscle architecture and somatotype components would differ by sport branch.

MATERIALS and METHODS

Study design

A cross-sectional study was conducted to investigate the differences between bodybuilders and soccer players. The study consisted of measuring muscle architecture and somatotype components. Before the ultrasonography and anthropometric measurements, participants were asked not to exercise for at least 72 hours and to maintain their daily eating habits. Both measurements were performed on the same day.

Participants

Sample size was determined by a priori power analysis using G-Power (3.1.9.3). The effect size was based on previous studies that reported an effect size of fascial length of the lateral vastus (ES = 2.27), pennation angle (ES = 1.96), and muscle thickness (ES = 0.91) between 100-m sprinters and long-distance runners (15). An effect size of 1.7 was considered a reasonable and conservative starting point for determining the sample size. The type I error (α) was 0.05, and the power ($1-\beta$) was 0.80 with an in a two-tail independent t-test. The model indicated a minimum total sample size of 22 subjects, but considering a miss rate of 30%, we decided to have a total of at least 30 participants. A total of fifteen bodybuilders (age = $22.88 \pm .92$ years) and fifteen soccer players (age = 22.44 ± 1.13 years) were included in the study. Participants had no musculoskeletal problems, lower extremity surgeries, or injuries that could affect architecture and had regular, branch-specific training habits for at least 5 years. This study was approved by Inonu University (2017/60). Each participant voluntarily provided written informed consent prior to participation. All procedures were in accordance with the 2008 Declaration of Helsinki.

Determination of Body Composition

All measurements were performed with minimal clothing and no shoes. Participants' height was measured with a portable stadiometer (Seca Ltd., Bonn, Germany) with an accuracy of 0.1 cm, with the head in the Frankfort plane, while the body was upright and the weight was evenly distributed on both legs. Weight and body fat percentage were measured using a body composition scale with a capacity of 270 kg and a sensitivity of 100 g (Tanita SC -330S, Amsterdam, The Netherlands). Skinfold thickness was determined using the Skinfold Thickness Meter (Holtain, UK) to calculate the somatotype component. Circumference and bi-condylar width were determined on the right side of the body using a Gulick anthropometric tape and a Lafayette anthropometric caliper, respectively.

Determination of Somatotype Components

In determining the somatotype, the Heath-Carter method was used (9), and 3 general body types were determined.

Endomorph =

$$-0.7182 + 0.1451(X) - 0.00068(X^2) + 0.0000014(X^3)$$

where X = sum of triceps, subscapular and suprailliac skinfold and for height corrected endomorph multiplied by 170.18/body height in cm.

$$\text{Mesomorph} = (0.858 \cdot \text{humerus breadth}) + (0.601 \cdot \text{femur breadth}) +$$

$$(0.188 \bullet \text{corrected arm girth}) + (0.161 \bullet \text{corrected calf girth}) - (0.131 \bullet \text{height}) + 4.5$$

Corrected arm girth: arm girth (cm) – (triceps skinfold/10) (mm);

Corrected calf girth: calf girth – (calf skinfold/10) (mm).

Ectomorph = (0.732 • HWR) – 28.58 where HWR - height-weight ratio:

HWR = height (cm) / cube root of weight (kg)

If HWR was found as 38.25 < RPI < 40.75,

Ectomorph = (HWR • 0.463) – 17.63

If HWR was found as equal to or less than 38.25, gave a rating of 0.1.

Muscle Architecture Measurements

A real-time B-mode ultrasound device (Logiq P5, Diasus Dynamic Imaging Ltd, Scotland, United Kingdom) was used to measure muscle architecture with a 40 mm, 8-MHz linear-array transducer to measure pennation angle, fascicle length and muscle thickness of the rectus femoris. Imaging was conducted supine, with the rested leg supported in passive extension. Rectus femoris muscle thickness and pennation angle were measured with the probe placed transversely and longitudinally, respectively. The transducer was placed with adequate use of contact gel and minimal pressure to avoid excessive compression of the muscle at 50% of the distance from the superior border of the patella and great trochanter. Pennation angle was determined as the angle between the muscle fascicles and the deep aponeurosis. Muscle thickness was determined as the distance

between the superficial and deep aponeurosis. Fascicle length across the deep and superficial aponeurosis was estimated from isolated muscle thickness and pennation angle using the following equation:

$$\text{Fascicle length} = \text{muscle thickness} \cdot \sin \alpha^{-1}$$

where α is the pennation angle of the muscle as determined by ultrasound (16). Three ultrasound images were acquired from each trial, and the average of the three values for each variable was used for further analysis. All measurements were performed by the same experienced ultrasonographer. Intra-rater reliability for muscle architecture was assessed using the intra-class correlation coefficient (ICC). ICCs were 0.997 for PA and 0.999 for MT and 0.989 for FL.

Statistical Analysis

All statistical analyses were performed with SPSS statistical software version 23 (SPSS, Chicago, IL, USA). The distribution of data was assessed with the Shapiro-Wilk test. A student T-test for independent samples was performed to compare architectural and somatotype values between soccer players and bodybuilders. Effect sizes (Cohen's d) and 95% confidence intervals (CI) were calculated to evaluate the difference between groups. Effect size values (ES) were: < 0.2 trivial, 0.2-0.6 small, 0.6-1.2 moderate, 1.2-2.0 large, and >2.0 very large and >4.0 extremely large. The alpha level for statistical significance was set at p < 0.05.

RESULTS

There was no significant difference between groups in terms of demographic parameters and training history (p > 0.05) (Table 1).

Table 1. Comparison of demographic parameters between the groups

Parameters	Soccer Players (n=15)		Bodybuilders (n=15)		t value	p value	ES
	min max	Mean ±SD	min max	Mean ±SD			
Age (years)	21- 24	22.44 ±1.13	22- 25	22.88 ±.92	.912	0.375	0.42
Weight (kg)	60- 76.4	66.40 ±5.34	60.4-84.6	70.92 ±7.94	1.417	0.176	0.66
Height (cm)	1.70- 1.83	1.78 ±.04	1.61- 1.85	1.72 ±.08	-1.654	0.125	0.94
BMI (kg/m ²)	19.56- 24.22	21.74 ±1.65	21.30 27.75	23.30 ±1.89	1.859	0.081	0.87
BFP (%)	6.1- 14.35	9.88 ±3.22	5.56-17.61	10.26 ±3.97	.225	0.825	0.10
Training experience (years)	5- 9	6.44 ±.88	5- 7	6.33 ±1.22	.828	0.573	0.10
Training frequency (session/week)	4- 6	5.22 ±.66	3- 6	4.66 ±1.00	-1.387	0.185	0.66
Training frequency (hours/week)	6- 9	7.50 ±1.22	4.5- 9	6.33 ±1.58	-1.750	0.099	0.82

BMI: Body mass index; BFP: Body fat percentage; ES: Effect size with 95% confidence interval

Table 2. Comparison of body composition and somatotype components between the groups

Parameters	Soccer Players (n=15)		Bodybuilders (n=15)		t value	p value	ES
	min	Mean	min	Mean			
	max	±SD	max	±SD			
Triceps skinfold (mm)	14	±2.69	15.3	±3.43	-.427	.673	0.20
Subscapular skinfold (mm)	9.1	10.83	12	14.36	3.651	.002*	1.72
Suprailiac skinfold (mm)	3.1	5.91	2.2	6.85	.683	.504	0.32
Medial calf skinfold (mm)	5.1	7.10	5.2	7.61	.567	.579	0.26
Flexed upper arm girth (cm)	28.4	30.75	32	36.01	5.632	.001**	2.66
Medial calf girth (cm)	33.2	35.55	34.7	38.22	2.187	.044*	1.03
Bi-Humeral breadth (cm)	6	6.55	6.1	6.61	.233	.819	0.12
Bi-Femoral breadth (cm)	7.3	±.37	7.9	±.60	-.196	.847	0.08
Endomorphy	2.00-3.50	2.52	1.80-4.50	3.01	1.504	.152	0.71
Mesomorphy	2.40-4.40	3.58	4.80-7.10	5.74	6.544	.001**	3.11
Ectomorphy	3.00-4.40	3.80	1.10-3.50	2.05	-5.082	.001**	2.41

*p<0.05; **p<0.01; ES: Effect size with 95% confidence interval

Table 2. shows that bodybuilders had significantly greater skinfold at the subscapula (ES = 0.26; 95% CI), arm circumference (ES = 2.66; 95% CI), and calf circumference (ES = 1.03; 95% CI) compared with soccer players. In addition, bodybuilders were endomorphic-mesomorph (3.01-5.74-2.05) and soccer players were mesomorph-ectomorph (2.52-3.58-3.80) with respect to somatotype components.

PA (19.1%, p=0.007) and MT (11.5%, p=0.039) were significantly greater in bodybuilders than in soccer players, while FL (5%, p=0.220) was similar between athletes. (Figure 1., Table 3.) A moderate ES was found at MT (ES = 1.06; 95% CI) and a large ES at PA (ES = 1.55; 95% CI).

Table 3. Comparison of muscle architectural parameters between the groups

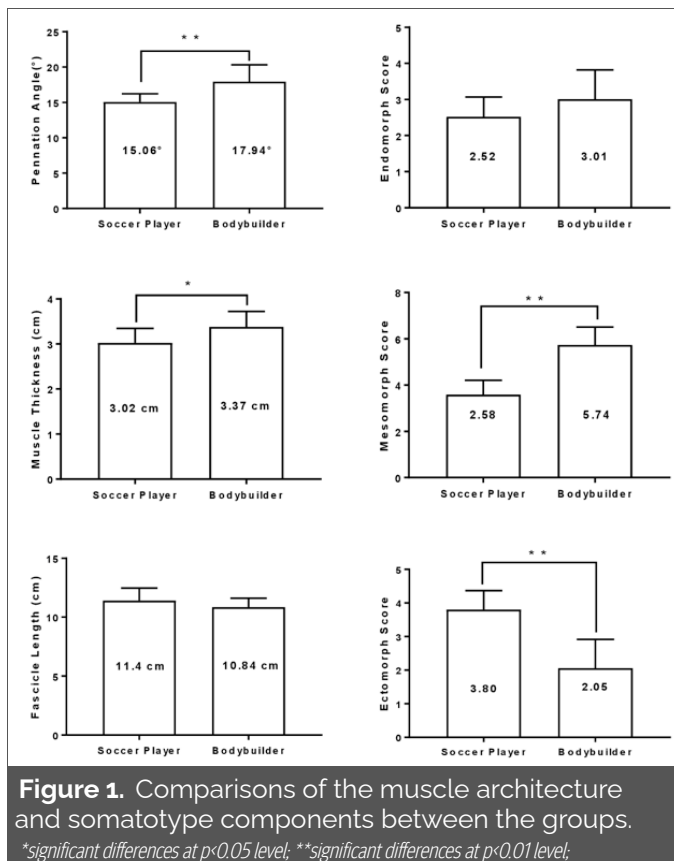
Parameters	Soccer Players (n=15)		Bodybuilders (n=15)		t value	p value	ES
	min	Mean	min	Mean			
	max	±SD	max	±SD			
MT (cm)	2.61	3.02	2.86	3.38	2.254	.039*	1.06
PA (°)	13.30	15.06	14.60	17.94	3.277	.007**	1.55
FL (cm)	10.40	11.40	9.70	10.84	-1.275	.220	0.60

*p<0.05; **p<0.01; MT: Muscle thickness; PA: Pennation angle; FL: Fascicle length; ES: Effect size with 95% confidence interval

DISCUSSION

In the present study, it was found that the values of PA and MT were significantly smaller in soccer players (p<0.05). This result could be due to the fact that parameters such as strength, speed, and agility are considered necessary basic skills in soccer (17). The smaller PA increases the potential for overall muscle shortening velocity, as muscles with longer fibers shorten at greater absolute velocities than a similar muscle with shorter fibers (18). Similar results were also found in a study comparing sprinters and long-distance

runners. Elite male sprinters were found to have a greater fascicle length and a smaller PA than elite male long-distance runners (15). A larger angle may be associated with a slower contraction velocity. Therefore, a higher PA value of a muscle may negatively affect its potential to produce maximal velocity (19). Therefore, soccer players with a smaller pennation angle may have a mechanical advantage at the point of force transmission to the tendon (20).



On the other hand, PA and MT were reported to have a positive correlation with muscle strength scores (21). Muraki et al. found a significant positive correlation between muscle strength and muscle thickness in adult males (22). Stragier et al. found that the increase in 1RM load was associated with the increase in muscle thickness ($r_2=0.38$; $p<0.001$) (23). In terms of bodybuilding, greater muscle thickness could be beneficial in lifting heavier loads and in power output. Bodybuilders with higher MT and PA values may have an advantage for force output. Following 10-12 weeks of strength training, the MT and arm circumference of bodybuilders were increased (24).

Intense physical activity plays a role in body shape (25). The morphological structures of top athletes characterize the typical somatotype in certain sports (26). The somatotypes of long-time trained Iranian elite bodybuilders were determined to be balanced mesomorph (0.92-6.86-1.84) (27). Tykhorskyi et al. tracked the changes in the somatotype of 19-26-year-old bodybuilders after the 3-month period of weight gain and found that the bodybuilders' mesomorphy scores significantly increased and ectomorphy scores significantly decreased. In the same study, the somatotype of the bodybuilders was reported as balanced mesomorph before and after the study (28). Cárdenas-Fernández et al. found that the dominant somatotype of soccer players was meso-ectomorphic in goalkeepers, central in fullbacks, balanced ec-

tomorph in central defenders, balanced mesomorph in midfielders, and meso-ectomorph in strikers (29). Another study revealed that elite young soccer players from Kosovo had an ecto-meso somatotype (2.4-3.4-3.3) (30), and the other one found that elite South American soccer players had a balanced mesomorph (2.2-5.4-2.2) (31).

In this study, a very large effect size for mesomorphy ($ES=3.11$) and ectomorphy ($ES=2.41$) was found between the groups. It is believed that the values obtained in relation to somatotype and architectural structures also influence each other. In a study, underweight individuals were found to have a smaller PA and cross-sectional area than overweight individuals (32). In another study, it was found that the MT and PA values of five muscles were significantly higher in obese participants than in non-obese participants (33). The relationship between muscle architecture and somatotype components was not examined in this study. However, the fact that soccer players have smaller PA and MT and are also ectomorphic may be a noteworthy finding to be investigated in further studies. Energy metabolism in each sport could also influence the expression of the dominant body type. Bodybuilding has a large proportion of training content based on explosive strength for muscle hypertrophy, which includes high repetitions with few rests between sets (34). More than 90% of energy expenditure in soccer is aerobic (35). Somatotypes may be related with the predominant energy metabolism in these two sport branches. Many other parameters can be mentioned (contraction type, race, nutritional status, etc.), but the predominant energy system related to the training content should also be considered in terms of somatotyping.

There are several limitations of this study. Muscle architecture can be influenced not only by training practices but also by dietary habits, sleep patterns, and muscle diseases. Therefore, it is recommended to standardize these factors between groups in longitudinal studies. In addition, we were not fully informed about the actual training content of the groups. Despite these limitations, this study provides some evidence that skeletal muscle and body composition changed in athletes with different training characteristics in long term.

CONCLUSION

The present study shows the differences between the muscle architectures and somatotype components of athletes in different sports. The research findings support that long-term training has different effects on muscle architectures and somatotype components. The adaptive characteristics of muscle architecture and somatotypes can provide useful tips in train planning and modification.

Ethics Committee Approval / Etik Komite Onayı

Approval for this study was obtained from the Institutional Ethics Committee of Inonu University, Malatya, Turkey (Decision No: 2017/60 Date: 10/05/2017).

Conflict of Interest / Çıkar Çatışması

The authors declared no conflicts of interest with respect to authorship and/or publication of the article.

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Author Contributions / Yazar Katkıları

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