Spor Hekimliği Dergisi, 57(2):67-72; 2022
Turkish Journal of Sports Medicine
Turk J Sports Med. DOI: 10.47447/tjsm.0620

Research Article / Araştırma Makalesi

Is femoral cartilage thickness associated with rectus femoris thickness and thigh muscle strength in adolescent female basketball players?

Adolesan kadın basketbolcularda femoral kıkırdak kalınlığı rektus femoris kalınlığı ve uyluk kas kuvveti ile ilişkili midir?

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ABSTRACT

Objective: To measure femoral cartilage (FC) thickness and to evaluate the association between FC thickness and isokinetic muscle strength and rectus femoris (RF) muscle thickness in adolescent female basketball players.

Materials and Methods: A total of 31 female adolescent basketball athletes with a mean age of 12.3 years (SD: 0.9) were included. Isokinetic measurements were performed on quadriceps and hamstring muscles bilaterally using a dynamometer. Bilateral RF and FC thicknesses were evaluated by ultrasonography. For FC thickness, three mid-point measurements were taken bilaterally from each knee as follows: lateral condyle, intercondylar area, and medial condyle. Mean FC thickness for each knee was calculated by values pertaining to the medial and lateral condyles, and the intercondylar area.

Results: Right and left mean FC thickness values were 0.23 (SD: 0.03) cm and 0.22 (SD: 0.03) cm. While there was a significant positive correlation between right and left FC thicknesses ($r = 0.79$, $p < 0.001$), no correlations were observed between FC and RF thicknesses or between the FC thickness and isokinetic quadriceps and hamstring strength.

Conclusion: The mean FC thickness does not seem to correlate either with the RF thickness or with the thigh muscle strength in adolescent female basketball players.

Keywords: *Cartilage, knee, quadriceps, muscle thickness, muscle strength, ultrasonography*

ÖZ

Amaç: Adolesan kadın basketbolcularda femoral kıkırdak (FC) kalınlığını ölçmek ve FC kalınlığı ile izokinetik kas kuvveti ve rektus femoris (RF) kas kalınlığı arasındaki ilişkiyi değerlendirmek.

Gereç ve Yöntemler: Bu çalışmaya yaş ortalaması 12,3 yıl (SS: 0.9) olan toplam 31 kadın adolesan basketbol sporcusu dahil edildi. Kuadriseps ve hamstring kaslarında iki taraflı olacak şekilde dinamometre ile izokinetik ölçümler yapıldı. Bilateral RF ve FC kalınlıkları ultrason ile değerlendirildi. FC kalınlığı için her dizden iki taraflı olarak alınan üç orta-nokta ölçümleri şu şekildeydi: lateral kondil, interkondiler alan ve medial kondil. Her diz için ortalama FC kalınlığı, medial ve lateral kondillere ve interkondiler alana ait değerlerle hesaplandı.

Bulgular: Sağ ve sol ortalama FC kalınlık değerleri 0.23 (SS: 0.03) cm ve 0.22 (SS: 0.03) cm idi. Sağ ve sol FC kalınlıkları arasında anlamlı pozitif bir korelasyon varken ($r = 0.79$, $p < 0.001$), FC ve RF kalınlıkları arasında veya FC kalınlığı ile izokinetik kuadriseps ve hamstring kuvveti arasında herhangi bir korelasyon gözlenmedi.

Sonuç: Adolesan kadın basketbol oyuncularında, ortalama FC kalınlığı RF kalınlığı ya da uyluk kas kuvveti ile ilişkili görünmemektedir.

Anahtar Sözcükler: *Kıkırdak, diz, kuadriseps, kas kalınlığı, kas kuvveti, ultrasonografi*

INTRODUCTION

Adolescence is a transitional phase of physical and psychological development from childhood to adulthood (1). The Center for Disease Control and Prevention and World Health Organization recommend increasing physical activity for adolescents to ensure healthy musculoskeletal and cardiovascular systems, neuromuscular awareness, and psychological benefits (2,3).

Received / Geliş: 21.09.2021 · **Accepted / Kabul:** 23.10.2021 · **Published / Yayın Tarihi:** 15.03.2022

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Cite this article as: Torgutalp SS, Babayeva N, Donmez G, Ozkan O, Karacoban L, Ozcakar L. Is femoral cartilage thickness associated with rectus femoris thickness and thigh muscle strength in adolescent female basketball players? *Turk J Sports Med.* 2022, 57(2):67-72; https://doi.org/10.47447/tjsm.0620

Mechanical stimulation through activity causes functional adaptation of connective tissues by generating changes in the morphology and quality which are otherwise determined primarily by genetics (4). Similarly, joint cartilage has the ability to adapt to the level of physical activity during adolescent development (5,6). The effect of increased vigorous physical activity on articular cartilage is a controversial issue, and there is ongoing debate as to whether it has beneficial or detrimental effects on cartilage. Herein, sports participation that causes loading on the joints may increase the volume and thickness of the articular cartilage (7,8). Accordingly, studies evaluating knee cartilage with magnetic resonance imaging showed that vigorous physical activity during childhood supports the development of knee cartilage in the absence of significant injury and/or pain (9,6). Contrary to the aforementioned health benefits, increased vigorous physical activity in athletes and young individuals exposes the joints to repetitive impact and loading - possibly/eventually causing articular cartilage damage (10). There is a positive linear dose-response relationship between repetitive loading and articular cartilage function in the healthy athlete (11). However, when the threshold of this dose-response curve is reached, articular cartilage damage can occur with impaired adaptation (11). Hence, repetitive stress on the articular cartilage during sports or vigorous physical activity might cause progressive deterioration of the articular cartilage.

The effect of physical and sports activity on the knee articular cartilage has not been clarified yet, and to the best knowledge of the authors, this is the first study evaluating the femoral cartilage (FC) thickness in the knee joint of adolescent athletes with ultrasound (US). The purpose of this study was two-fold; first we aimed to assess the FC thickness in adolescent basketball athletes with US, and second, we aimed to investigate its association with RF muscle thickness and quadriceps/hamstring muscle strength.

MATERIALS AND METHODS

Design

A retrospective cross-sectional descriptive study was conducted on female adolescent basketball athletes who applied to the Sports Medicine Outpatient Clinic for pre-participation examination in the 2018 - 2019 season. The Local Research Ethics Committee approved the study protocol (Decision number: GO 2020/17-34).

Participants

The sample size was calculated to require at least 16 persons to determine the expected relationship with 80% power and 5% type-1 error (8). A total of 31 athletes were included in this study. The mean age of athletes was 12.3 (SD: 0.9) years. They were professional and active in competition in leagues for their age groups. Athletes were excluded if they reported: smoking tobacco/cigarette; history of injury and/or orthopaedic surgery involving the areas to be measured; current knee pain; heavy physical activity within the last 48 hours; or chronic diseases that may affect musculoskeletal health.

Age was used as a demographic variable. The athletes' height and weight were measured with a digital scale (Seca 769, Hamburg, Germany), and their body mass index (BMI) was calculated by dividing their body weight by height squared (kg/m^2). Total and regional fat distributions were assessed using a bioelectrical impedance analysis (BIA) device (TANITA BC 545N InnerScan, Netherlands). The Turkish version of the International Physical Activity Questionnaire (IPAQ) - Short Form, which is a reliable and valid scale, was completed to measure the physical activity level (12).

Isokinetic Measurements

Isokinetic measurements were performed on quadriceps and hamstring muscles bilaterally at angular velocities of $60°\cdot s^{-1}$ and $180°\cdot s^{-1}$ using a Biodex System Pro3 isokinetic dynamometer (Biodex Corp., Shirley, NY), as published elsewhere (13). Measurements were preceded by a 10 min warm-up consisting of running on a treadmill. Each athlete was seated in an upright position and stabilized with chest and thigh straps. The lateral epicondyle of the knee was adjusted to the axis of rotation of the dynamometer, and the lever arm was positioned to the lower leg, 2 cm above the lateral malleolus. The range of motion was established at 90° of flexion from active maximum extension. Bilateral isokinetic (concentric/concentric) knee flexion/extension at 60° per second (5 repetitions) and 180° per second (10 repetitions) were performed. Peak torque to body weight ratio (Nm, Newton-meter / kg) was used for the analyses.

Ultrasonographic Measurements

Detailed US assessment of the FC and RF thicknesses has been published elsewhere (8,14). All measurements were completed using a 5-12 MHz linear probe (Logiq P5, General Electrics Medical Systems, Wisconsin, USA). Water-soluble transmission gel was used for coupling the transducer to the tissue to prevent artifacts on the US images. All US measurements are given in centimeters.

FC thickness has diurnal variation, and studies have reported a decrease in cartilage thickness from morning to evening within the same day. Therefore, we performed all FC thickness measurements between 8:00 and 9:00 (a.m.) in the morning (15–17). Bilateral FC thickness measurements were performed while the athletes were lying supine with their knees at maximum flexion. The probe was placed axi–

ally on the extremity just above the superior margin of the patella and perpendicular to the femoral articular surface. Lateral condyle, intercondylar area, and medial condyle thicknesses were measured from the midpoints bilaterally (Figure 1a). Additionally, the mean cartilage thicknesses for each knee were calculated from these measurements.

For RF muscle thickness measurements, the athletes were in supine position with their knees in maximum extension. The transducer was placed in the short-axis view, perpendicular to the muscle fibers, along the axis of the muscle at the midpoint between the anterior superior iliac spine and the patella. Muscle thickness was determined as the distance between the upper and lower aponeurosis (Figure 1b).

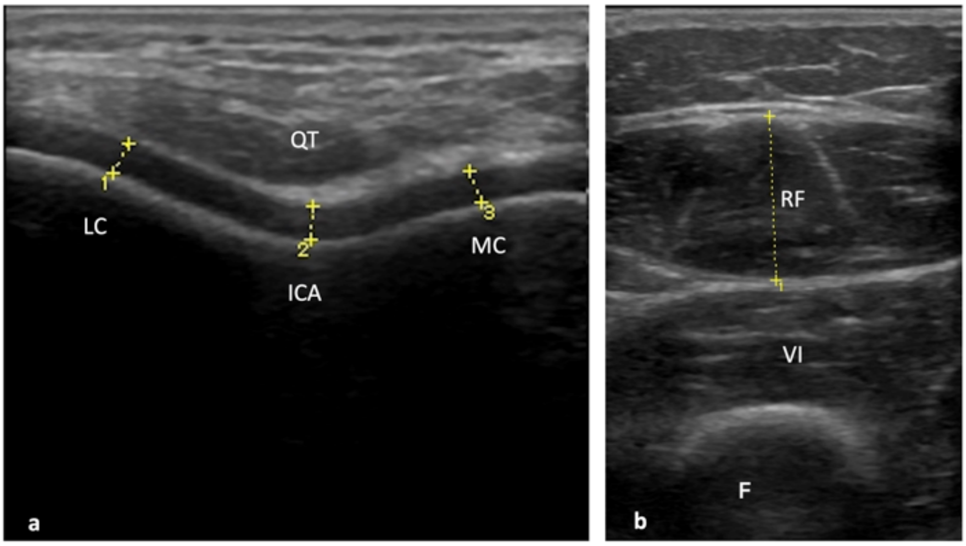

Figure 1. a. Ultrasonographic measurements (suprapatellar axial view) of the femoral cartilage (LC lateral condyle, ICA intercondylar area, MC medial condyle, QT quadriceps tendon). **b.** Ultrasonographic measurements (axial view) of the rectus femoris (RF rectus femoris, VI vastus intermedius, F femur).

Statistical Analysis

Statistical analyses were performed using R version 4.0.0. Age, weight, height, BMI, IPAQ, isokinetic test results, and RF thickness were considered independent variables. FC thickness was considered as the dependent variable. The variables were investigated using visual (histograms and probability plots) and analytical methods (Shapiro-Wilk test) to determine normal or non-normal distribution. Descriptive analyses are presented using mean, standard deviation (SD), median, minimum (min), and maximum (max) values. The associations between the cartilage thickness and other variables were examined using Pearson's rank correlation coefficients. An overall 5% type-I error level was used to infer statistical significance.

RESULTS

Demographic characteristics, anthropometric profile, and physical activity levels of the athletes are presented in Table 1. Isokinetic test results for the quadriceps and hamstring muscles are given in Table 2.

Bilateral RF muscle and FC thicknesses are shown in Table 3. Mean right and left rectus femoris thickness values were 1.93 (0.25) cm and 2.01 (0.25) cm, respectively. Mean femoral cartilage thickness values were 0.23 (SD: 0.03) cm for the right knee and 0.22 (SD: 0.03) cm for the left knee.

There were no significant correlations among the FC thicknesses and other variables (all $p > 0.05$) except for a strong positive correlation between the right and left FC thickness values ($r = 0.79$, $p < 0.001$) (Table 4).

Table 1. Demographic characteristics of the athletes

N = 31	Mean (SD)	Median (minimum - maximum)
Age, year	12.3 (0.9)	12.3 (10.4 - 14.2)
Height, cm	164.2 (7.5)	164.0 (147.0 - 178.0)
Weight, kg	53.4 (9.2)	53.2 (39.9 - 78.7)
BMI, kg/cm²	19.7 (2.6)	19.1 (14.8 - 26.1)
BIA		
Total fat (%)	24.5 (3.7)	23.4 (18.7 - 32.1)
Trunk fat (%)	17.6 (3.9)	17.5 (11.7 - 25.5)
Right leg fat (%)	32.7 (3.5)	32.1 (27.5 - 39.8)
Left leg fat (%)	32.2 (3.7)	30.9 (26.6 - 40.7)
IPAQ		
Vigorous (MET-min/week)	5023.2 (1312.7)	4800.0 (2880.0 - 8640.0)
Total (MET-min/week)	7157.0 (1831.3)	6780.0 (3840.0 - 11628.0)

BIA: bioelectrical impedance analysis, BMI: body mass index, cm: centimeter, IPAQ: International Physical Activity Questionnaire, kg: kilogram, min: minute, SD: standard deviation.

Table 2. Right (R) and left (L) extremity isokinetic test results of the athletes

N = 31			PT/BW (Nm/kg) Mean (SD)	Median (minimum - maximum)
Extension	180°·s^{-1}	R	1.23 (0.25)	1.21 (0.46 - 1.66)
		L	1.16 (0.22)	1.21 (0.65 - 1.52)
	60°·s^{-1}	R	1.82 (0.29)	1.79 (1.28 - 2.53)
		L	1.75 (0.29)	1.71 (1.20 - 2.27)
Flexion	180°·s^{-1}	R	0.91 (0.20)	0.88 (0.48 - 1.24)
		L	0.92 (0.19)	0.94 (0.51 - 1.30)
	60°·s^{-1}	R	1.26 (0.23)	1.25 (0.92 - 1.84)
		L	1.24 (0.24)	1.30 (0.71 - 1.62)

PT: peak torque, BW: body weight, Nm: Newton-meter, SD: standard deviation

Table 3. Ultrasound measurements of the athletes

N = 31	Mean (SD)	Median	Minimum - Maximum
Right RF, cm	1.93 (0.25)	1.97	1.28 - 2.32
Left RF, cm	2.01 (0.25)	1.99	1.29 - 2.49
Right FC			
LC, cm	0.23 (0.03)	0.22	0.18 - 0.29
ICA, cm	0.22 (0.04)	0.22	0.12 - 0.30
MC, cm	0.23 (0.04)	0.23	0.17 - 0.31
Mean, cm	0.23 (0.03)	0.22	0.17 - 0.29
Left FC			
LC, cm	0.23 (0.03)	0.22	0.16 - 0.30
ICA, cm	0.22 (0.04)	0.21	0.12 - 0.30
MC, cm	0.22 (0.04)	0.23	0.16 - 0.29
Mean, cm	0.22 (0.03)	0.22	0.16 - 0.30

FC: femoral cartilage, ICA: intercondylar area, LC: lateral condyle, MC: medial condyle, RF: rectus femoris, SD: standard deviation.

Table 4. Correlation analyses between the cartilage thickness values and other variables

	Right mean FC thickness r	p	Left mean FC thickness r	p
Left mean FC	**0.794**	**<0.001**		
Right rectus femoris thickness	0.133	0.492	0.130	0.517
Left rectus femoris thickness	0.169	0.399	0.230	0.229
Total fat %	-0.204	0.288	0.081	0.677
Trunk fat %	-0.194	0.314	0.063	0.747
Right leg fat %	-0.210	0.275	0.129	0.505
Left leg fat %	-0.240	0.209	0.090	0.642
Vigorous physical activity	0.342	0.069	0.299	0.116
Total physical activity	0.306	0.107	0.218	0.257
Right 180°·s^{-1} extension PT/BW	0.009	0.962	-0.036	0.861
Left 180°·s^{-1} extension PT/BW	0.131	0.524	0.028	0.889
Right 180°·s^{-1} flexion PT/BW	0.287	0.139	0.189	0.356
Left 180°·s^{-1} flexion PT/BW	0.311	0.122	0.185	0.345
Right 60°·s^{-1} extension PT/BW	-0.079	0.690	0.102	0.621
Left 60°·s^{-1} extension PT/BW	0.098	0.634	-0.088	0.655
Right 60°·s^{-1} flexion PT/BW	0.295	0.127	0.174	0.396
Left 60°·s^{-1} flexion PT/BW	0.131	0.523	0.007	0.971

BW: body weight, FC: femoral cartilage, PT: peak torque.

DISCUSSION

The objective of this study was to analyze FC thickness of adolescent basketball players and to evaluate its association with the quadriceps/hamstring isokinetic strength and the RF muscle thickness. To the best of our knowledge, this is the first study demonstrating FC thickness of adolescent athletes with US. In this sense, the important aspect of our study would be the fact that it provides mean FC thickness values for adolescent female basketball players and that it reports the absence of any correlations between the FC thickness and the thigh muscle strength. Similarly, there were no correlations between FC thickness values and rectus femoris muscle thickness, total and regional fat percentage, and physical activity level.

There is limited data on this issue among adolescents and the similar findings pertaining to adults are conflicting in the literature. In subjects (with a mean age of 52 years) who had knee osteoarthritis, Tuna et al. reported positive weak to moderate correlations between FC thickness and isometric/isokinetic knee muscle strength (18). In another study investigating FC thickness in patients with poliomyelitis, positive weak correlations were observed between FC thickness and quadriceps muscle strength (19). On the other hand, a study conducted among adult professional athletes showed that flexor and extensor moments did not correlate with the FC thickness evaluated by magnetic resonance imaging (20). It was suggested that during early and mid-adolescence, both females and males tend to have increased fat mass and fat free mass. However, females in early adolescence tend to show a gradual improvement in muscle strength compared to male counterparts (21). Based on this information and the age range of athletes involved in our study, it might be noteworthy that the athletes were in the muscle strength development phase.

Changes in muscle cross-sectional area were suggested to be positively associated with cartilage - therefore inducing a chondroprotective effect on the knee FC. However, we observed no correlations between RF and FC thickness values. In one magnetic resonance imaging study, muscle cross–sectional areas were found to be highly correlated with knee-joint cartilage morphology (22). These findings are in line with a previous study among athletes and sedentary individuals, where significant positive but very weak correlation was observed between the right FC and the ipsilateral RF thickness values (8). Our results conflict with the findings of the abovementioned studies in adult athletes possibly due to the fact that although fat-free mass gains increase in early and middle adolescence, according to some studies cartilage growth and maturation may continue until late adolescence (23).

The cartilage of the knee joint is a unique tissue with viscoelastic properties, the main function of which is the ability to withstand repetitive loads and to provide a surface without friction during movement (24). According to the literature, a significant increase in articular cartilage volume oc–

curs at Tanner stage two (age range of 8-15 years), similar to the age range of the athletes in our study (5). In a longitudinal study, Zhang et al. assessed the effects of snow sports on the knee cartilage maturation in adolescents using magnetic resonance imaging (25). The authors reported that the cartilage thickness of the sports group was higher than the control group, and concluded that snow sports training might have a positive effect on the cartilage maturation of adolescents. On the contrary, we observed no correlations between the FC thickness and physical activity level in our study. One of the reasons for this might be that the players from the same team who had similar levels of physical activity were included in our study. Additionally, the cross-sectional nature of this study and the non-inclusion of age-matched sedentary controls would be other limitations to promptly interprete the study results. Similar to our findings, a recent review reported insufficient evidence about the association between increased loading and increased cartilage thickness in elite athletes (26). To this end, rather than those mentioned above, genetics might have stronger contribution to cartilage morphology, and lack of evolutionary pressure and decoupling of mechanical competence and tissue mass might be counted as possible causes for the inability of cartilage to adapt to mechanical stimuli (26).

There is conflicting evidence in the literature regarding the relationship between sex and knee articular cartilage morphology (27–29). Because our study was limited to evaluating female adolescent players, further data collection for male adolescent athletes is needed to determine the correlations among males as well.

CONCLUSION

This pilot study reports on the FC thickness values of professional adolescent female basketball players. While the right and left side cartilage thickness values are strongly correlated; FC thickness appears to be not correlated either with the isokinetic quadriceps/hamstring strength or with the RF muscle thickness. Further similar studies on different genders and sports athletes will, for sure, help to provide better insight into understanding the complex relationship between cartilage maturation and nearby acting muscle forces.

Ethics Committee Approval / Etik Komite Onayı

The approval for this study was obtained from Hacettepe University Clinical Research Ethics Committee (Decision no: 2020/17-34 Date: 20.10.2020).

Conflict of Interest / Çıkar Çatışması

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

Financial Disclosure / Finansal Destek

The authors received no financial support for the research and/or publication of this article.

Author Contributions / Yazar Katkıları

Concept All authors; Design All authors; Supervision GD, LÖ; Materials All authors; Data Collection and/or Processing ŞŞT, NB, GD, ÖÖ, LK; Analysis and Interpretation ŞŞT, NB; Literature Review ŞŞT, NB; Writing Manuscript ŞŞT, NB; Critical Reviews All authors.

All authors read and approved the final version of the manuscript.

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