Fizyoterapi Rehabilitasyon. 2013;24(1):17-25

Farklı yaş gruplarındaki bayan adölesan voleybol oyuncularında izokinetik kas kuvveti, sıçrama performansı ve hormon seviyelerinin karşılaştırılması

Gizem İrem KINIKLI, Gülcan HARPUT, Gül BALTACI, Filiz ÇOLAKOĞLU

[Kınıklı Gİ, Harput G, Baltacı G, Çolakoğlu F. Farklı yaş gruplarındaki bayan adölesan voleybol oyuncularında izokinetik kas kuvveti, sıçrama performansı ve hormon seviyelerinin karşılaştırılması. Fizyoter Rehabil. 2013;24(1):17-25. *Comparison of isokinetic knee muscular strength, jump performance, and hormone levels in female adolescent volleyball players of different ages.*]

Research Article

Amaç: Farklı yaş gruplarındaki bayan adölesan voleybol oyuncularında diz kas kuvveti, sıçrama performansı ve hormon seviyeleri arasındaki ilişkiyi incelemek ve karşılaştırmaktır. **Yöntem:** Altmış bayan adölesan voleybol oyuncusu 11-13 yaş arası Grup 1 (N=29) ve 14-16 yaş arası Grup 2 (N=31) olmak üzere iki gruba ayrıldı. Sıçrama performansı, tek bacak üzerinde sıçrama ve dikey sıçrama testi ile, bilateral izokinetik kas kuvveti izokinetik dinamometre ile, östrojen ve prolaktin konsantrasyonları ise radioimmunoassay ve enzime bağlı immunoassay ile değerlendirildi. **Sonuçlar:** Grup 1, tek bacak üzerinde sıçrama testi performansında Grup 2'den daha fazla sıçrama eğilimindeydi. Gruplar arasında sıçrama performansı simetri indeksi açısından anlamlı fark yoktu ($p>0.05$). Konsentrik diz ekstansiyon kontraksiyonları açısından Grup 2 daha iyiyken; zirve tork, zirve iş ve toplam iş değerleri açısından Grup 1 daha yüksek konsentrik diz fleksiyon kontraksiyonlarına sahipti ($p<0.05$). Grup 2'deki östrojen seviyesi Grup 1'dekinden daha yüksekti ($p<0.05$). **Tartışma:** Fizyoterapistler, farklı yaş gruplarındaki bayan adölesan voleybol oyuncularında egzersiz rejimlerini planlarken kas kuvveti, sıçrama performansı ve hormon seviyeleri açısından var olması beklenen farklılıkları göz önünde bulundurmalıdır.

Anahtar kelimeler: Kas kuvveti, Hormon, Adölesan, Voleybol.

Comparison of isokinetic knee muscular strength, jump performance, and hormone levels in female adolescent volleyball players of different ages

Purpose: The aim of this study was to evaluate and compare the relationships between knee muscular strength, jump performance and hormone levels among female adolescent volleyball players of different ages. **Methods:** Sixty adolescent female volleyball players were divided into two groups according to age: those with an age between 11-13 years constituted; Group 1 (N=29) and those with an age between 14-16 years constituted; Group 2 (N=31). Jump performance assessed using one-leg hop test and vertical jump test, bilateral isokinetic knee strength by isokinetic dynamometer and concentrations of oestrogen and prolactin via radioimmunoassay and enzyme-linked immunoassay. **Results:** Group 1 had greater distance trend during one leg hop test performance than Group 2. There were no significant differences in symmetry index of jump performances between groups ($p>0.05$). While Group 2 had significantly greater concentric knee extension contractions; Group 1 had significantly greater concentric knee flexion contractions in peak torque, peak work and total work values ($p<0.05$). Oestrogen level of Group 2 was significantly higher than Group 1 ($p<0.05$). **Conclusion:** Physiotherapists should take into account variability for muscular strength, jump performance and hormone levels while planning exercise regimes female adolescent volleyball players of various ages.

Keywords: Muscle strength, Hormone, Adolescent, Volleyball.

Gİ Kınıklı
Hacettepe University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Ankara, Türkiye
PT, PhD

G Harput
Hacettepe University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Ankara, Türkiye
PT, MSc

G Baltacı
Hacettepe University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Ankara, Türkiye
PT, PhD, Prof

F Çolakoğlu
Gazi University, School of Physical Education and Sports, Ankara, Türkiye
PhD, Assoc Prof

Address correspondence to:
Dr. Fzt. Gizem İrem Kınıklı
Hacettepe University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, 06100, Samanpazarı, Ankara, Türkiye
E-mail: gizemirem83@yahoo.com

The successful performance of female volleyball players requires from each player a high level of technical, tactic and physical preparation, as well as many high and long jumps which are specific for the game of volleyball.[1] Female adolescent volleyball players need anthropometric and physical characteristics for successful participation in her level of performance.[2-4] Therefore, knee strength is known to be one of the intrinsic factors associated with sport performance in volleyball. Likewise, an awareness of knee muscular strength and jump performance of elite level volleyball players during adolescent stage specific to the requirements of age may be beneficial in terms of optimizing their training regimes.[5-7] In addition, adolescence stage is an important factor for successful sport performance. Three stages of adolescence-early (11-13 years of age), middle (approximately 14-18 years of age), and late (19-21 years of age) are experienced, but the age at which each stage is reached varies greatly from child to child. Just before puberty the rate of change in height increases markedly, followed by a less growth response until full height is reached at the age of about 16 in girls. As with height, the peak rate of growth in bodyweight occurs at approximately 12.5 years in girls, slightly later than height. During early adolescence, girls experience breast and hip development according with onset of menstruation. On the other hand, during middle adolescence, puberty is completed and physical growth slows for girls. These different rates of maturation are connected to physical performance and hormone balance. For this reason, female adolescent volleyball players with different ages in a team should be separated according to their adolescent stages. It may also provide coaches with information to arrange accurate distribution of training regime for the athlete in her specific position within a team. Moreover, with regard to volleyball, it may be important to decrease risk of injuries. Several studies have examined that numerous factors have been hypothesized to influence this increased injury risk including neuromuscular function and hormonal fluctuations.[8-11] On the other hand, the female hormone levels fluctuate due to the menstrual cycle and show structural and functional changes during adolescent stage.[12-15] Florini et al. stated that these fluctuations in female steroid hormones affect the autonomic nervous system and metabolic functions.[16] In addition, Becker et al. also reported that certain physiological parameters and athletic performance could change along with the menstrual cycle phases.[17] Phillips et al. reported higher adductor pollicis strength during the follicular phase than during the luteal phase with a rapid decrease in strength around ovulation.[18] Authors suggested that oestrogen has a strengthening action on muscle, although the underlying mechanism is not clear. However, previous studies have provided conflicting evidence concerning the influence of the fluctuations in hormone levels on sport performance and muscle strength in women.[19-23] To examine such potential influences of hormone levels on muscle strength and jump performance, it can be assumed that the sport performance of a female adolescent volleyball player could be affected by her knee flexion/extension strength and jump performance during adolescent stage in different ages. It is also important to monitor the hormonal fluctuations in order to plan appropriate exercise interventions for female adolescent volleyball players.[24]

To our knowledge, no studies have continuously investigated the knee muscular strength, jump performance and hormone levels clinically among female adolescent volleyball players in different ages. The purpose of this study was to evaluate and compare the relationships between knee muscular strength, jump performance and hormone levels among female adolescent volleyball players in early (11-13 years) and middle (13-16 years) adolescence stages.

METHODS

Sixty adolescent female volleyball players selected from five different national junior volleyball teams aged between 11 and 16 years (13.77±1.37) who had been free from lower extremity pathology for 12 months and had no previous history of lower extremity injury participated in the study. The study was performed during the early phase of the volleyball season. Their routine volleyball training program included in cardio, strengthening, flexibility, tactic and technical drills emphasizing sport specific skills and team strategies, jumping and speed drills at least two hours a day, six times in a week. Before participating in the study, all players and parents read and signed an informed consent form approved by Hacettepe University Local Institutional Review Board. All measurements were completed in the standardized order described below. All participants underwent jump performance assessments, isokinetic knee muscular strength measurement and hormone analysis. The subjects were divided into two groups according to age: those with aged between 11-13 years; Group 1 (n=29) and those with aged between 14-16 years; Group 2 (n=31). Questions to the athletes included; date of birth, height, weight and menstrual cycle history. Body mass index (BMI) and fat (%) were assessed by TANITA (Tanita TBF-300 GS Pro Body Composition Analyzer, Japan). Leg dominance was identified by asking which leg was habitually used for kicking a ball. The right knees were the dominant side of all the players. All screening was performed on the same day. All subjects were provided appropriate warm-up exercise before testing.

Jump Performance Assessment

Subjects were given a verbal description and visual demonstration of one leg hop test and vertical jump test. Each subject performed three series of jump tasks and the average score was recorded. The players encouraged vocally during the jumps and were watched carefully to ensure that the proper technique was used.

One Leg Hop Test (OLHT): Beginning with the toes immediately behind starting line, all subjects performed three hops to complete the task. A hop was measured from starting line to the end of the toes after completion of a trial (Figure 1).

Vertical Jump Test (VJT): The athlete reached up with the hand closest to the wall. The standing reach height was marked (Figure 1). The athlete leaped vertically as high as possible using both arms and legs to assist in projecting the body upwards. The difference in distance between the standing reach height and the jump height was recorded. [25,26]

Strength Assessment

Bilateral isokinetic knee strength data was collected with an isokinetic dynamometer (IsoMed®2000 D&R GmbH, Germany) to record average peak torque, peak work and total work during maximal voluntary contractions (MVCs) of the knee flexors and extensors. Subjects were seated on the IsoMed chair and secured using thigh and torso straps to minimize compensatory movements during the knee strength test (Figure 2). Starting with the dominant limb, the lateral femoral epicondyle of both limbs was aligned with the dynamometer's laser axis of rotation before testing. All subjects were encouraged to extend and flex the knee at full force throughout the test. Subject setup was standardized and recorded to allow for consistent positioning across the repeated testing sessions. Two submaximal and two maximal practice repetitions were provided to ensure unrestricted movement, comfort, and familiarization. Subjects performed reciprocal quadriceps and hamstring concentric contractions at angular velocities of $60°/s^{-1}$ (five repetitions) and $180°/s^{-1}$ (ten repetitions) with a 1 min rest interval between each set. Average peak torque to body weight (BW) was recorded for each direction with the ratio of hamstrings to quadriceps strength calculated for each speed.

Hormone Analysis

Blood samples were collected at the day of testing to assess hormone levels of all participants. Concentrations of oestrogen and prolactin were assessed via radioimmunoassay (RIA) (Diagnostic Products Corporation, Los Angeles, CA, USA). Progesterone, luteinizing hormone (LH), and follicle-stimulating hormone (FSH) concentrations were determined via enzyme-linked immunoassay. Oestrogen and progesterone values were compared with laboratory reference values to verify correct measurement intervals.

Statistical analysis:

SPSS 11.0 for Windows (SPSS, Inc., Chicago, IL, USA) was used for the statistical calculations. Descriptive data were presented as means±SD. Differences between means were calculated using *Student's t test* for independent groups. The level of significance was set at $p<0.05$ for all analyses. All p values are two-tailed.

Figure 1. One leg hop test (left). Vertical jump test (right).

Figure 2. Isokinetic knee muscular strength measurement.

RESULTS

Anthropometric data of the volleyball players is summarized in Table 1. As expected, according to age differences, independent samples test showed quite significant differences for weight and height ($p<0.05$). However, there were no significant differences in mean BMI and fat (%) between Group 1 and Group 2 ($p>0.05$).

Jump Performance Assessment

Mean values of vertical jump test and one leg hop test are presented in Table 2. Leg symmetry index was calculated for jump tasks with percent ratio of dominant side to non-dominant side. There were no significant differences in symmetry index of jump performances between groups ($p>0.05$). Although it was not significant, Group 1 had greater distance trend during one leg hop test performance than Group 2.

Isokinetic Knee Muscular Strength Assessment

Table 3 shows the significant differences in peak torque, peak work and total work during bilateral isokinetic knee flexion and extension concentric contractions at angular velocities of $60°/s^{-1}$ and $180°/s^{-1}$ between groups ($p<0,05$). Group 2 was significantly greater concentric knee extension contractions for peak torque, peak work and total work ($p<0.05$). On the other hand, Group 1 had significantly greater concentric knee flexion contractions in peak torque, peak work and total work values ($p<0.05$).

Hormone Analysis

Fifty-two subjects of 60 adolescent volleyball players (86.6%) had regular menses without using oral contraceptives. There were no significant differences in the blood sample analysis for LH, progesterone, FSH, prolactin between groups except serum oestrogen level ($p>0.05$). Oestrogen level of Group 2 was significantly higher than Group 1 ($p<0.05$) (Table 4).

DISCUSSION

The present study provides variability profile of isokinetic knee flexion/extension strength, performance and hormone levels in adolescent female volleyball players throughout developmental years. Our findings have shown that there was no significant difference in jump performance and hormone levels. The only significant measurement influenced by age

Table 1. Anthropometric characteristics of the players.

	Grup 1 (N=29) (11-13 years) X±SD	Grup 2 (N=31) (14-16 years) X±SD
Height (cm)	167.38±6.71	172.71±7.12
Body weight (kg)	55.88±8.31	61.62±6.88
Body mass index ($kg.m^{-2}$)	19.81±1.95	20.63±1.67
Fat (%)	22.37±6.27	24.53±3.52

Table 2. Vertical jump test and one leg hop test performance characteristics of groups.

	Grup 1 (N=29) X±SD	Grup 2 (N=31) X±SD
Vertical jump distance (cm)		
Right	20.79±4.74	22.0±4.54
Left	22.0±4.82	23.5±4.50
One leg hop test (cm)		
Right	173.69±13.09	169.39±22.72
Left	176.09±16.29	172.37±20.27

Table 3. Comparison of isokinetic measurement of peak torque, peak work and total work in knee extensors and flexors between groups at 60°/s^{-1} and 180°/s^{-1}.

	Grup 1 (N=29) X±SD	Grup2 (N=31) X±SD	
Peak torque (Nm)			
Knee flexion 180°/s^{-1}	73.95±9.94	67.47±15.43	*
Knee extension 180°/s^{-1}	137.54±18.08	159.23±52.57	*
Peak work			
Knee flexion 180°/s^{-1}	85.54±10.74	76.36±20.66	*
Knee extension 180°/s^{-1}	118.72±15.10	145.59±61.62	*
Total work (J)			
Knee flexion 180°/s^{-1}	97.91±13.98	89.61±17.44	*
Knee extension 180°/s^{-1}	475.69±124.37	536.64±110.41	*
Knee flexion 60°/s^{-1}	239.75±71.64	276.00±63.62	*
Knee extension 60°/s^{-1}	277.93±75.88	345.22±83.31	*

* $p<0.05$.

Table 4. Comparisons of serum hormone concentrations of oestrogen, progesterone, prolactin, FSH, LH between Group 1 and Group 2.

	Grup 1 (N=29) X±SD	Grup2 (N=31) X±SD	
FSH (i.u. l^{-1})	6,02±2,49	6,51±2,75	
Prolactin (ng/mL)	10,54±5,35	9,86±4,48	
LH (i.u. l^{-1})	3,97±2,58	5,23±3,27	
Oestrogen (pmol l^{-1})	52,86±42,13	77,32±56,05	*
Progesteron (nmol l^{-1})	0,90±1,82	1,19±2,61	

* p<0.05.

difference was knee muscular strength and serum estrogen level parameters among female adolescent volleyball players in different ages. Melrose et al. suggest that age, experience, lean body mass; shoulder, hip, and thigh girths, strength, and balance are key physical performance characteristics of adolescent girls who play volleyball.[27] The results of Sheppard's study indicate trainers of elite women volleyball players should consider including techniques to reduce percentage of body fat and increase vertical jumping distance.[28] In our study it is not surprising to find similarities for BMI and fat (%) between age groups since most volleyball players are relatively tall and heavy, and therefore it is important to match groups according to anthropometric characteristics to compare their knee muscular strength and jump performance although they were in different ages. Potentially, this type of information will allow coaches and athletes to identify physical and performance data specific to age groups for purposes of evaluation and player development. We found that although physical anthropometries are similar in adolescent female volleyball players; knee muscular strength and hormone levels can vary between age groups. Normal levels of estradiol and progesterone were identified within each of the appropriate phases of the menstrual cycle and were consistent with other research.[29-31] Given the improvements in lower-body muscular power, agility, and estimated maximal aerobic power with increased playing level, and given the importance of these qualities to competitive performances, conditioning coaches should train these qualities to improve the playing performances of junior volleyball players. Moreover, in our younger group consisting of eight individuals who doesn't have regular menstrual cycle might be the reason of significant difference in estrogen level between groups. This finding is difficult to explain, but theoretically, the cross-sectional design of the present study is not enough to show differences between age groups in blood analysis for hormone levels. It is well known that hormone levels during adolescent stage might have fluctuation. In addition, it could be possible during our study and also might exhibit in follow up later on. Therefore, similarities or differences in serum hormone levels of estrogen in the current study are to be expected. With this in mind, it is difficult to say that significant difference between age groups in estrogen level may have an effect on muscular strength and jump performance in female adolescent volleyball players. We found significant differences in isokinetic knee muscle strength between age groups. These strength differences may be related to the different technical and tactical demands placed on players in different positions rather than their age. On the other hand, it was interesting to notice that there was no difference in jump performance between age groups in the current study. Although the number of volleyball players is not much in the current study, there was a small, but statistically not significant, trend supporting the younger group performed higher jumps in one leg hop test. This could be explained by higher mean peak torque, peak work and total work flexion contractions of younger group. Therefore, it can be speculated whether significant difference in isokinetic knee muscle strength between age groups is not the only parameter of jump performance in female adolescent volleyball players. In addition, specific training adaptations that might have the explanation to produce similar jump performances among groups. Düzgün et al. found better flexibility in adolescents who participate in regular sports activities. Arvas et al. suggested that athletes who practice jumping performance regularly had better isokinetic peak torques in lower extremity.[32,33] This paper is the first that compares the isokinetic knee muscular strength, jump performance and hormone levels between female adolescent volleyball players in different ages.

Limitations

Limitations to the current study include the measurement during throughout the menstrual cycle at time points deliberately chosen to coincide with varying levels of estradiol and progesterone. Many technical issues arise when attempting to construct a consensus regarding menstrual cycle and performance. Despite testing the subjects at the identified time points relative to ovulation, the testing between the menses and post-ovulatory phases, early luteal phase, and late luteal phase may account for intersubject variability in fluctuating hormonal patterns or delayed response patterns. The cross-sectional design of the present study does not permit us to generalize the results for a larger population. Another confounding factor is the possible variability among subjects in hormone levels, strength and any impact on performance. There appears to be no clear explanation for the serum estrogen level differences found in the present study between age groups and additional prospective research designs are needed to explain. During early adolescence stage, rapid body changes as puberty is in full swing. There is a tremendous physical growth with gaining height and weight. On the other hand, during middle adolescence stage physical growth slows. Girls don't experience such a rapid acceleration of muscle growth at puberty, but their muscle mass does continue to increase, although much slower, to about 40% of their total body weight as adults. This difference is largely attributed to hormonal differences at puberty. Because of these physical variabilities, findings of the current study imply that physiotherapists need to be aware of the specific requirements in volleyball teams in terms of age difference. During early adolescent stage training regimes can follow supporting programs for muscle performance and preventing risk of injuries due to overuse. During middle adolescent stage, training regimes can include muscle strengthening and enhancing performance with increasing sports-related abilities. Overall, such information may be useful for planning age specific training regimes that correctly consider the performance variables, physical traits and abilities of volleyball players. Physiotherapists need to be aware of the processes of growth and development, and evaluate how these processes affect the responses and adaptations to exercise and also motor ability and sports performance, including the consideration of special issues relating to training of female volleyball players. Further research is required to validate our findings in a longitudinal prospective study among larger subjects. Prospective studies on this group of volleyball players will have to clarify the importance of age difference which can affect the muscular strength and jump performance in teams. Physiotherapists might be taken into consideration when evaluating and planning exercise programs during training and rehabilitation. The study findings suggest that it is necessary to implement a well-designed training regime for each athlete in order to age, may allow improvement the playing performances of female adolescent volleyball players.

REFERENCES

1. Coutts K. Biomechanics of volleyball jumping techniques. Volleyball Tech J. 1979;5: 49–50.
2. Ferris DP, Signorile JF, Caruso JF. The relationship

between physical and physiological variables and volleyball spiking velocity. J Strength Cond Res. 1995;9: 32–36.

3. Grgantov Z, Katić R, Janković V. Morphological characteristics, technical and situation efficacy of young female volleyball players. Coll Antropol. 2006;30:87-96.
4. Lidor R, Ziv G. Physical and physiological attributes of female volleyball players--a review. J Strength Cond Res. 2010;24:1963-73.
5. Katić R, Grgantov Z, Jurko D. Motor structures in female volleyball players aged 14-17 according to technique quality and performance. Coll Antropol. 2006;30:103-12.
6. Lidor R., Ziv G. Physical characteristics and physiological attributes of adolescent volleyball players-a review. Pediatr Exerc Sci. 2010;22:114-34.
7. Carcia CR, Shultz SJ, Granata KP et al. Knee ligament behavior following a controlled loading protocol does not differ by menstrual cycle day. Clin Biomech. 2004; 19:1048–54.
8. Myer GD, Ford KR, Khoury J, Succop P, Hewett TE. Development and validation of a clinic-based prediction tool to identify female athletes at high risk for anterior cruciate ligament injury. Am J Sports Med. 2010;38:2025-33.
9. Sorenson SC, Arya S, Souza RB, Pollard CD, Salem GJ, Kulig K. Knee extensor dynamics in the volleyball approach jump: the influence of patellar tendinopathy. J Orthop Sports Phys Ther. 2010;40:568-76.
10. Tiemessen IJ, Kuijer PP, Hulshof CT, et al. Risk factors for developing jumper's knee in sport and occupation: a review. BMC Res Notes. 2009;8:127.
11. Van Lunen BL, Roberts J, Branch JD, et al. Association of menstrual-cycle hormone changes with anterior cruciate ligament laxity measurements. J Athl Train. 2003;38:298–303.
12. Duncan MJ, Woodfield L, al-Nakeeb Y. Anthropometric and physiological characteristics of junior elite volleyball players. Br J Sports Med. 2006;40:649-51.
13. Eliakim A, Portal S, Zadik Z, et al. The effect of a volleyball practice on anabolic hormones and inflammatory markers in elite male and female adolescent players. J Strength Cond Res. 2009;23:1553-1559.
14. Hertel J, Williams NI, Olmsted-Kramer LC, et al. Neuromuscular performance and knee laxity do not change across the menstrual cycle in female athletes. Knee Surg Sports Traumatol Arthrosc. 2006;14:817–822.
15. Lowe DA, Baltgalvis KA, Greising SM. Mechanisms behind Estrogen's beneficial effect on Muscle strength in Females. Exerc Sport Sci Rev. 2010;38:61-67.
16. Florini, J.R. Hormonal control of muscle growth. Muscle and Nerve. 1987;10:577-598.
17. Becker D, Creutzfeldt OD, Schwibbe M, et al. Changes in physiological, EEG and psychological parameters in women during the spontaneous menstrual cycle and following oral contraceptives. Psychoneuroendocrinology. 1973;7:75-90.
18. Phillips SK, Sanderson AG, Birch K, et al. Changes in maximal voluntary force of human adductor pollicis muscle during the menstrual cycle. J Physiol. 1996;496:551-557.
19. Burgess KE, Pearson SJ, Onambele GL. Menstrual cycle variations in oestradiol and progestrone have no impact on in vivo medial gastrocnemius tendon mechanical properties. Clin Biomech. 2009;24:504-9.
20. Constantini NW, Dubnow G, Lebrun CM. The menstrual cycle and sport performance. Clin Sports Med. 2005;24:e51-e82.
21. Janse de Jonge XA, Boot CR, Thom JM, et al. The influence of menstrual cycle phase on skeletal muscle contractile characteristics in humans. J Physiol. 2001;530(Pt1): 161–166.
22. Kishali NF, Imamoglu O, Katkat D, et al. Effects of menstrual cycle on sports performance. Int J Neurosci. 2006;116:1549-63.
23. Kubo K, Miyamoto S, Tsunado N, et al. Muscle and tendon properties during menstrual cycle. Int J Sports Med. 2009;30:139-143.
24. Heitz NA, Eisenman PA, Beck CL, et al. Hormonal changes throughout the menstrual cycle and increased anterior cruciate ligament laxity in females. J Athl Train. 1999 34:144–149.
25. Aragon-Vargas LF. Evaluation of four vertical jump tests: methodology, reliability, validity, and accuracy. Meas Phys Educ Exerc Sci. 2000;4:215–228.
26. Ziv G, Lidor R. Vertical jump in female and male volleyball players: a review of observational and experimental studies. Scand J Med Sci Sports. 2010;20:556-567.
27. Melrose DR, Spaniol FJ, Bohling ME, Bonnette RA. Physiological and performance characteristics of adolescent club volleyball players. J Strength Cond Res. 2007; 21:481-6.
28. Sheppard JM, Cronin JB, Gabbett TJ, et al. Relative importance of strength, power, and anthropometric measures to jump performance of elite volleyball players. J Strength Cond Res. 2008;22:758-65.
29. Friden C, Hirschberg AL, Saartok T, et al. Knee joint kinaesthesia and neuromuscular coordination during three phases of the menstrual cycle in moderately active women. Knee Surg Sports Traumatol Arthrosc. 2006;14:383–38.

30. Malousaris GG, Bergeles NK, Barzouka KG, et al. Somatotype, size and body composition of competitive female volleyball players. J Sci Med Sport. 2008;11:337-44.
31. Lebrun CM, Rumball JS. Relationship between athletic performance and menstrual cycle. Sports Med Orthop. 2001;1:232–240.
32. Düzgün İ, Baltacı G. Düzenli spor yapan ve yapmayan adolesanlarda esneklik test sonuçlarının yaş ve cinsiyete bağlı değişimi. Fizyoter Rehabil. 2009;20:184-189.
33. Arvas B, Elhan A, Baltacı G, et al. Sıçrama aktivitesini kullanan ve kullanmayan sporcularda ayak bileği kas kuvvetlerinin karşılaştırılması. Fizyoter Rehabil. 2006;17:78-83.