Turk J Phys Med Rehab 2017;63(2):124-132
DOI: 10.5606/tftrd.2017.198

Original Article

Acute effects of cyclic versus static stretching on shoulder flexibility, strength, and spike speed in volleyball players

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Received: February 2016 Accepted: April 2016

ABSTRACT

Objectives: This study aims to examine the acute effects of cyclic stretching versus static stretching on the shoulder flexibility, rotator cuff muscle strength, spike speed, and spike hit rate on target in adolescent volleyball players.

Materials and methods: A total of 36 female volleyball players aged between 13 and 15 years were included in this study. Volleyball players were randomly divided into three groups: cyclic stretching group, static stretching group, and control group. Shoulder flexibility, rotator cuff muscle strength, spike speed, and spike hit rate on target were measured before and after the intervention.

Results: Shoulder flexibility increased in cyclic stretching and static stretching groups after the intervention. Internal rotation strength increased in cyclic stretching group after the stretching intervention, compared to the control group. A significant reduction was observed in the scapular plane abduction strength in static stretching group after the intervention.

Conclusion: Our study results suggest that cyclic stretching may be beneficial, as it increases both the shoulder flexibility and strength of young female volleyball players. In terms of volleyball performance, it can not be declared both cyclic stretching and static stretching have any effect.

Keywords: Adolescent; hand dynamometer; shoulder flexibility.

Flexibility and shoulder strength are very important while playing volleyball, particularly in regards to spiking, since the spike is the most explosive movement form of the overhead volleyball skills. It is a complex movement pattern requiring flexibility, muscular strength, coordination and neuromuscular efficiency.[1] The major shoulder motion is the external/internal rotation for volleyball players.[2] Flexibility is defined as the range of motion (ROM) of a joint. Range of motion of the hitting hand may affect the power of the spike.[3,4] Static stretching (SS) is one of the most frequently used methods for the increase of acute flexibility,[5] stretching increases joint ROM.

Further, stretching is applied in different forms: static and cyclic stretching. While, static muscle stretching is the most common form of pre-exercise stretching used in the athletic population, static stretching involves stretching the muscle to the point at which further movement is limited by the muscle's own tension.[3] Although static stretching increases the shoulder flexibility, it also has the risk of inhibiting strength. Since it is applied for a long-term, it can be useful to use different methods to prevent the negative inhibition of SS. Another method is called cyclic stretching, which is practiced in addition to SS. It is a stretching method with short duration and repetition[6-8] Although the importance of warming up before training and matches is undisputable, there are many studies comparing different stretching types using different protocols.[9-11]

Although there are many studies related to the acute effect of static stretching on the various performance measurements, there is not a general consensus on the effect, duration and the number of repetitions.[10,12-14] Many studies have shown the relationship between the increase of flexibility and the length of the stretching period. Although it is not certain yet,[15,16] in general,

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Cite this article as:
Çelik A. Acute effects of cyclic vs static stretching on shoulder flexibility, strength, and spike speed in volleyball players. Turk J Phys Med Rehab 2017;63(2):124-32.

it is advised that static stretches duration should be between 30 and 60 sec.

This study found that static stretching decreases strength performance.[17,18] On the other hand, there are several studies that show static stretching does not change strength performance.[10,13,19] Kay et al.[5] reported some results that static stretching had positive effects with regard to duration and the number of repetitions and increases ROM. In literature, there are a limited studies about cyclic stretching duration and the number of repetitions.[6,7,20] Recent studies have provided some evidence that the response of the musculo-articular complex to cyclic and static stretching may be different.[6,20] There are no studies about how the upper extremities were effected by cyclic stretching as compared to static stretching. It can be expected that the stretching method should increase ROM and have a positive effect on the strength without any negative effects.

In recent years, many studies were performed about the lower extremities with few studies about upper extremities[9,21,22] Kay et al.[12] declared that they have clear evidence about lower extremities assuming that a stretch did not affect higher-speed force production when the stretch lasted 45 sec.

The hypotheses of this study were; *(i)* SS would enhance performance regarding flexibility, and spike hit rate on target. In contrast, SS would decrease shoulder strength and spike speed, *(ii)* - CycS (cyclic stretching) would also enhance performance regarding flexibility, and spike hit rate on the target, in addition CycS would enhance or have neutral effects on both shoulder strength and spike speed.

MATERIALS AND METHODS

This study used a randomized-controlled trial design with repeated measures. We evaluated the effects of two different stretching protocols on shoulder flexibility. Before the experimental procedures were undertaken, each volleyball player visited the sport center to receive instruction about the study and to participate in a familiarization trial to practice back scratch test, spike skill assessment[23] where the spike speed data of the participants were recorded in another session to be used for the reliability statistics followed by the rotator cuff muscle strength test[24,25] on a volleyball court. These familiarization trials were preceded by CycS and SS protocols. The participants were randomly divided into three groups: cyclic stretching group (CycSG), static stretching group (SSG) and control group (CG).

The back scratch test was performed to assess the shoulder flexibility level using a measuring tape. Upper extremity length was measured from acromion to ulnar styloid. The rotator cuff muscle strength was measured via a hand dynamometer.

Spike hit rate on the target and the spike speed were calculated during the assessment of spike skills test. Dominant arms of volleyball players were used for spike skills and all other evaluations. Measurements were applied before (pre) and after (post) stretching assessment. Volleyball players from each stretching group practiced both tests randomly over two days. We started the first day with the measurements of the strength assessments. Firstly, back scratch test and strength test were measured. After these pre-tests, volleyball players practiced CycS and SS methods. After stretching practices, back scratch test and strength test were applied successively. On the second testing day measurements related to spike skill assessments were performed. Here we started with the back scratch test. Afterwards, all participants tried to spike the ball at the target. CycSG and SSG practiced stretching according to previously determined stretching procedures. The back scratch test and spike skill assessments were applied successively. The evaluations took nearly 30 min. All data was collected, at the same time of day: between 15:00-17:00.

Study participants

Thirty-six young female volleyball players aged between 13 and 15 years voluntarily participated in this study. All participants were free from musculoskeletal injuries, and able to perform stretching protocols. All participants abstained from vigorous physical activity 48 hours before each experimental session. This study was approved by the Dokuz Eylül University Research Ethics Committee (protocol approval number 2015/15-2). Since all participants were younger than 18 years old, the parents or legal guardians provided the participation approval. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Procedures

The participants were randomly divided into three equal groups: CycSG, SSG and CG. CycSG performed two sets of three 15-sec stretches (2x3x15 sec) with a 10-sec rest between repetitions and a 15-sec rest between sets. Static stretching group performed two sets of 45-sec stretches (2x45 sec) with a 15-sec rest between sets. Control group performed no stretching exercises (sitting still for 90 sec). The participants did not warm up prior to the stretching assessment. Stretching was performed actively by the volleyball players. CycS and SS consisted of slow active movement (maneuver) of shoulder for internal rotation. A summary of experimental and testing procedures are shown in Figure 1.

During CycS and SS tests the dominant arm was at the internal rotation and the dorsal side of the hand was at the back. Every stretching trial was applied according to the farthest point that could be reached in at least two sec. The participants reported a feeling of maximal stretch without pain.

Shoulder flexibility

In the back scratch test; the dominant arm was measured via a tape measure during both pre-test and post-test. The distance measured between the middle fingers of the hands is the test score. If the fingers were overlapped, the value is positive "+", otherwise, it was negative "-". The best two successive trials were considered. Results were recorded with an accuracy of 0.5 cm.[26]

Strength tests

Rotator cuff muscle strength was measured with a Powertrack II (JTech, New York, ABD) hand dynamometer. The mean of the three successive tests were calculated. All participants were measured in a sitting position with knees at 90° flexion, sitting upright. External rotation strength was tested while elbow is at 90° flexion, 0° abduction, at the direction from wrist forming external rotation (Figure 2-A1). Internal rotation strength is tested while elbow is at 90° flexion, 0° abduction, at the direction from wrist forming internal rotation (Figure 2-A2). Scapular plane abduction strength is tested while the shoulder is at 90° elevation, external rotation and elbow extension, resistance is tested from the wrist in a downward direction (Figure 2b).[25,27]

Spike skill assessment

All participants hit spike five times and the mean values was used for analysis.[28] The volleyball players were oriented to hit the diagonal spike as fast as possible towards the 16 m² (4x4 m) target. Spike direction is limited to this target. The participant hit spike with the volleyball ball from position 4 to position 5. The ball used for the test was a FIVB official match ball. The net height was 2.10 m during all measurements. A radar gun was used to measure the speed of the ball (Stalker Sport 2, Applied Concepts, Inc. Texas, USA).[29] A radar gun was placed 50 cm behind the opposite corner of the court in a diagonal position (Figure 3).

Day 1	Day 2
Shoulder flexibility	Shoulder flexibility
Rest time: 1 min	Rest time: 1 min
Strength test (10 p)	Spike skill assesment
Rest time: 1 min	Rest time: 1 min
CycSG: Cyclic stretching group or SSG: Static stretching group or CG: Control group	CycSG: Cyclic stretching group or SSG: Static stretching group or CG: Control group
Rest time: 1 min	Rest time: 1 min
Shoulder flexibility	Shoulder flexibility
Rest time: 1 min	Rest time: 1 min
Strength test (10 p)	Spike skill assessment

Figure 1. A summary of the experimental method.

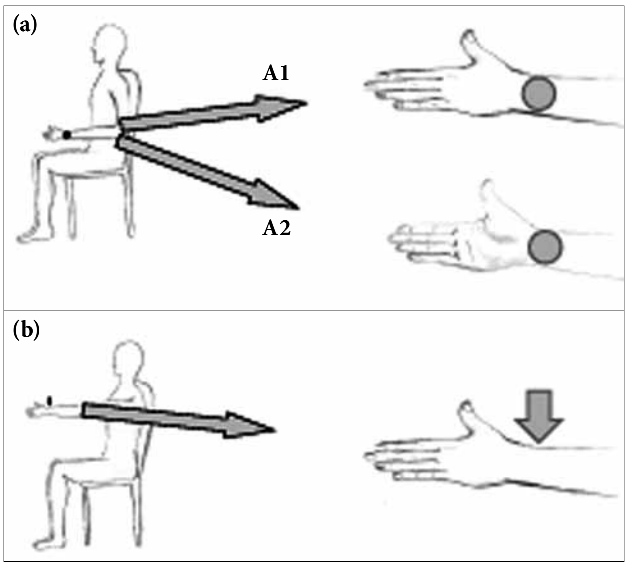

Figure 2. Strength test. **(a)** A1: Participant positioned on a chair for external rotation strength test (A1) and internal rotation (A2) (A1 and A2: circles indicate the arm location where perpendicular force was applied). **(b)** Participant positioned on a chair for scapular plane abduction strength test (b: vertical arrow indicates the direction of applied force)

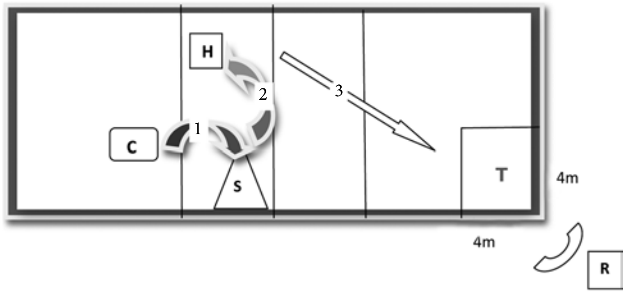

Figure 3. Spike skill assessment test. Here, the ball was thrown by the coach to the setter. All participants hit to the diagonal spike towards the 16 m^2 (4×4 m) target. C: Coach; H: Hitter; S: Setter; T: Target; R: Radar (The numbers indicate the sequence of ball movement.

Statistical analyses

The statistical analyses were performed using IBM SPSS version 22.0 software (IBM Corp., Armonk, NY, USA). Shapiro-Wilk test was performed to check for normality and assumption of homogeneity of variances was tested using Levene's test. Descriptive statistics were reported either by mean ± standard deviation or median [minimum - maximum] values depending on the type of performed statistical analyses tests (parametric or non-parametric test). 3x2 (group x time) mixed design analyses of variance (ANOVA) were used to investigate the interaction effect of time and intervention on dependent performance variables. Then, the effects of intervention/control on performance measures were investigated using paired Student's t-test within each group. Wilcoxon signed-rank test was used where parametric test assumptions were violated. Possible differences in performance changes (Δ) after interventions between study groups were checked using one way ANOVA with post-hoc Tukey's test. Kruskal-Wallis test together with Mann-Whitney U test was used in the case of violation of parametric test assumptions. Baseline performance measures and reliability levels were evaluated according to intraclass correlation coefficient (ICC) with 95% confidence intervals. A p value of ≤0.05 was considered statistically significant.

RESULTS

Age, height, mass, body mass index (BMI), upper extremity length did not differ between study groups. (p>0.05) (Table 1).

The test-retest ICCs (test reproducibility results) for the stretching test (the results of the first and the second days measurements were evaluated) and spike speed (the results of the familiarization and the first days measurements were evaluated) were 0.78 (0.62-0.88) and 0.92 (0.87-0.95), respectively. These values were classified as being in strong agreement. CG did not demonstrate any statistically significant change in any of the dependent variables both in strength assessment day (Table 2) and spike skill assessment days (Table 3) (no time effect).

Mixed design ANOVA results revealed that there was a significant group × time interaction effect for internal rotation strength ($F[2,33]=3.33$, $p=0.048$, $\eta p^2= 0.168$) indicating that the performance changes were not parallel within the study groups. In contrast, no significant interaction effect was detected for external rotation strength ($F[2,33]=0.377$, $p=0.689$, $\eta p^2=0.022$) and spike speed ($F[2,33]=1.43$, $p=0.253$, $\eta p^2=0.080$) (Table 2).

There was a significant change in back scratch test between the pre-test and the post-test on strength assessment day in both CycSG and SSG (p=0.002 and p=0.009, respectively). Also, a significant change in scapular plane abduction strength between pre-test and post-test on strength assessment day in SSG (p=0.012) was observed in addition to a significant difference in internal rotation strength change (Δ) between CycSG and CG (p=0.038) (Table 2).

None of the study groups showed statistically significant change in internal, external rotation strength after interventions (p>0.05). There was

Table 1. Descriptive statistics of participants

	CycSG (n=12)			CG (n=12)			SSG (n=12)			
	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	*p*
Age (year)	14.0±0.9			13.8±0.8			13.8±1.6			^{A}0.26
Height (cm)	169.0±9.2			170.0±10.1			168.0±9.4			^{A}0.14
Weight (kg)		57	48-68		56	47-66		58	49-69	^{K}0.17
BMI (kg/m^2)	21.5±2.2			20.6±1.9			22.8±2.1			^{A}0.25
Arm length (cm)	53.9±3.1			55.5±3.1			54.3±2.7			^{A}0.39

CycSG: Cyclic stretching group; CG: Control group; SSG: Static stretching group; Min: Minimum; Max: Maximum; p value of ANOVA or Kruskal Wallis; SD: Standard deviation; BMI: Body mass index; ^{A} ANOVA [p value]; ^{K} Kruskal Wallis.

Table 2. Pre and post shoulder flexibility and rotator cuff muscle strength (strength assessment day)

					p value of Student's t-test or Mann-Whitney U test		
	CycSG (n=12)	CG (n=12)	SSG (n=12)	P value of ANOVA or Kruskal Wallis	CycSG-CG	CycSG-SSG	SSG-CG
Scratch test (cm)							
Pre	7.6 (-1/15)	8.6 (1/13)	4.1 (-8/12)				
Post	8.7 (0/18)	7.9 (0/13)	5.7 (-6/12.50)	^{K}0.40			
Δ	1.08 (0/4)	-0.67 (-2/1)	1.58 (-1/4)	^{K}<0.001*	<0.001*	0.24	<0.001*
p for Δ	0.002*	0.06	0.009*				
Internal rotation strength (kg)							
Pre	9.3±2.1	10.8±2.2	10.4±2.2				
Post	10.6±2.2	10.1±1.7	10.7±1.9	^{A}0.68			
Δ	1.32±2.20	-0.71±1.06	0.31±2.26	^{A}0.048*	0.04*	0.42	0.41
p for Δ	0.08	0.07	0.93				
External rotation strength (kg)							
Pre	6.8±1.3	7.3±1.8	6.9±1.5	Since no interaction effect was detected, ANOVA and post-hoc tests for ANOVA were not performed.			
Post	6.9±1.7	6.9±1.1	6.9±0.8				
Δ	0.01±1.23	-0.36±0.99	-0.04±1.17				
p for Δ	0.81	0.18	0.81				
Scapular plane abduction strength (kg)							
Pre	6.0 (4.90/7.26)	6.4 (4.08/7.80	6.8 (4.31/9.07				
Post	5.8 (4.45/7.26)	6.1 (4.54/7.53)	6.4 (4.08/9.07)	^{K}0.47			
Δ	-0.25 (-1.91/1.36)	-0.73 (-4.60/1.90)	-0.44 (-1.91/0)	^{K}0.87	0.84	0.59	0.84
p for Δ	0.29	0.17	0.012*				

CycSG: Cyclic stretching group; CG: Control group; SSG: Static stretching group; Δ: Post-test score-pre-test score; ^{A} ANOVA [p value]; ^{K} Kruskal Wallis (Median [Min-Max] value).

Table 3. Pre and post scratch test, spike hit rate on target and spike speed (spike skill assessment day)

	CycSG (n=12)	CG (n=12)	SSG (n=12)	P value of ANOVA or Kruskal Wallis	P value of Student's t-test or Mann-Whitney U test		
					CycSG-CG	CycSG-SSG	SSG-CG
Scratch test (cm)							
Pre	6.4 (-12/17)	8.2±3.7	4.1 (-8/12)				
Post	7.4 (-11/19)	8.3±3.3	5.7 (-7/15.50)	K0.58			
Δ	1.0 (0/3)	0.2 (-1/2)	1.6 (-1/8)	K0.80	0.07	0.67	0.07
p for Δ	0.01*	0.52	0.02*				
Spike hit rate on target (%)							
Pre	0.4 (0.2/0.6)	0.3±0.2	0.3 (0/0.6)				
Post	0.4 (0/1)	0.3±0.2	0.4 (0/0.8)	K0.67			
Δ	0.03 (-0.4/0.6)	0.05 (-0.4/0.2)	0.10 (-0.6/0.8)	K0.22	0.41	0.88	0.49
p for Δ	0.72	0.37	0.43				
Spike speed (km/h)							
Pre	41.5±9.3	39.9±9.4	40.4±7.2		Since no interaction effect was detected, ANOVA and post-hoc tests for ANOVA were not performed.		
Post	39.7±9.1	40.1±9.8	40.9±6.7				
Δ	-1.8±3.2	0.2±3.4	0.5±4.1				
p for Δ	0.07	0.69	0.40				

CycSG: Cyclic stretching group; CG: Control group; SSG: Static stretching group; Δ: Post-test score-pre-test score; A ANOVA [p value]; K Kruskal Wallis (Median [Min-Max] value).

no significant change in scapular plane abduction strength between pre-test and post-test on strength assessment day in CycSG (p>0.05). Also, no significant difference in external rotation strength change (Δ) between study groups (p>0.05) occurred in addition to an absence of significant change between pre-test and post-test, both on strength and spike skill assessment days (p>0.05) (Table 2).

There was a significant change to a similar extent in back scratch test after intervention on spike skill assessment day both in CycSG (p=0.010) and SSG (p=0.022). There was no significant change after interventions in spike speed and spike hit rate on the target in any of the study groups (p>0.05) (Table 3).

DISCUSSION

Our study is the first one to specifically examine the acute effects of CycS and SS interventions on strength level (internal rotation strength, external rotation strength and scapular plane abduction strength) and spike skill level (spike speed, spike hit rate on target).

The results revealed that both SS and CycS protocol applied in this study were effective to increase shoulder flexibility. Scapular plane abduction strength decreased after SS intervention. As described previously, SS reduces muscular performance for instance; strength and power production of the stretched muscle group.[14,30,31] Present study results that are supported by previous findings,[21,28] suggest that CycS and SS did not significantly affect rotator cuff muscles and spike speed and spike hit on the target.

The main finding of this study supported our hypothesis that 90 sec (2 set of 3×15 s) CycS intervention increased internal rotation strength. This data support the hypothesis of enhancing or having no negative or neutral effects on the shoulder strength following CycS.

Gonzalez et al.[32] used a stretching protocol similar to that which was used in CycSG and reported an improvement in performance after stretching exercise for jump performance (three stretches for 15 sec). CycSG stretching procedure implementation produced similar characteristics with Gonzalez's findings. According to this study's results, it can be declared that CycS has similar effects both on lower and upper limb.[20]

The decrease in scapular plane abduction strength after 90 sec (2 set of 45 s) SS intervention supported the previous results in literature[8,14] and provided evidence that the decrease following SS could be explained primarily by the acute increases in muscle resting length.[3,6] Several studies showed that SS which is longer than 60 s decreases strength performance[17,18] Kay et al.[5] declared that they have clear evidence for lower extremity that static stretch did not affect higher-speed force production if the stretch duration was <45-sec. It cannot be denied that stretching duration is as important as stretching type in improving volleyball player's performance.

However, several studies have reported no differences in strength and power performance following SS.[19,21,33] The reason why SS does not change internal and external strength can be its short-term effect on the viscoelastic properties of the rotator cuff muscle group. It is still not absolutely certain whether it enhances muscle strength according to the stretching duration.

Magnusson et al.[34] showed that three sets of 45 sec stretches did not affect the hamstring muscle in the external strength and scapular plane abduction strength. CycS did not manifest the expected stretching effect on these muscles in terms of assessment process and repetition. Here, planning and implementation of further studies including the different duration and number of repetitions will enable us to have clearer evidence.

In the study about the effects of different stretching methods (static, dynamic and combined stretching) on upper body muscular performance, Torres et al.[22] reported that different stretching methods do not change performance. Mascarin et al.[28] reported that the total speed during the handball throwing test was not influenced by SS. Other researchers found that in upper body muscles, SS does not have any effect on serve speed.[35,36] Similarity this study and previous studies showed that CycS and SS did not affect volleyball players spike speed. In contrast to our hypothesis, the reason why it does not change is related to the fact that the spike is a complex movement pattern requiring flexibility, muscular strength, coordination and neuromuscular efficiency.

Cohen et al.[37] reported that it could be possible for a tennis player to increase serve velocity by means of specifically directed muscular strengthening or stretching regimens. Results of Cohen's study revealed that strength and flexibility are related to serve velocity. Sufficiently large ROM before hitting the ball is the main factor of spiking technique.[4] Active stretching exercises are commonly performed in sports and the mechanisms that suggested such changes are not well-known.

It is known that the strength performance of the dominant shoulder (internal rotators) is correlated with spike velocity.[30,38] However strength and spike speed may be connected and it cannot be said that strength affects the performance in volleyball skill. Performing the movements, including SS, before strength training is not suitable, as shown by this study.

Nordez et al.[6] reported that the musculo-articular complex response to CycS and SS may be different. Different mechanisms can be effective depending upon the type of stretching procedure performed and analyzing the stretching and muscular strengthening physiological mechanisms according to the skill level of volleyball players will give more detailed information.[9,30]

Several studies showed that static stretching increased flexibility.[15,16,39] Even if there are limited studies on cyclic stretching, it has been pointed out that it causes ROM rise for lower limbs.[7] These findings[4,7] support the hypothesis of shoulder flexibility increase in both CycSG and SSG. According to these results, it is considered that the effects of cyclic and static stretching are similar. It has been suggested that static and cyclic stretching increased ROM by increasing the stretch tolerance while the viscoelastic characteristics of the muscle remain unaltered.[40] There are two main ideas (viscoelastic effects and neural effects) to describe the acute effects of stretching[28] Both these effects implications, but the mechanism for the stretching in performance remains unknown. Since few studies have focused primarily upon the upper limbs, many more studies are needed to clarify whether stretching influences performance or not.

Despite the increase in shoulder flexibility, there is no change in both CycSG and SSG for spike hit rate on target. Actually, the increase of shoulder flexibility in elite volleyball players affects performance positively,[4] because the studied group is at young age and spike is a close-kinetic chain skill. In addition, these results show that there is a strong connection between maximal isometric strength production and explosive strength performance changes produced in a short period of time.

Nonetheless, this study has some limitations. Firstly, each group consists of 12 volleyball players. Additionally, spike speed and spike hit rate on target are not the only factors determining spike performance. Another study limitation was the young age of the volleyball players because elite volleyball players may have increased the probability of finding statistical significances, particularly spike hit rate on the target. Our aim was to analyze the effects of acute CycS and SS on the rotator cuff muscle, so the leg muscles were not stretched. In addition, Knudson et al.[35] showed in his results that the SS of the upper body did not have any effect on tennis serve velocity and accuracy.

In conclusion, both CycS and SS interventions were effective in improving shoulder flexibility. Static stretching increased shoulder flexibility but decreased scapular plane abduction strength. CycS is likely beneficial because it increases both shoulder flexibility and strength in young female volleyball players. In general, one of the aspects that needs to be clarified is the acute effects of CycS related to strength and spike speed. Overall, more finding are necessary to determine the optimal stretching duration as well as stretching method to be chosen for upper extremity analysis.

CycS and SS can be used interchangeably to increase the flexibility of young female volleyball players, but during isometric strength training using CycS instead of traditional stretching exercises will be more suitable since it does not cause strength inhibition. Both, SS and CycS application is considered neutral on the volleyball performance.

Acknowledgements

I thank Ekim Pekünlü (PhD) for his contributions to the statistical analyses and the drafting of the manuscript. I would also like to thank Sevgi Sevi Yeşilyaprak (PhD, Assist. Prof.) for her valuable feedback on the drafts of this article and her contribution to the muscle strength assessment. I would like to thank Şule Düzdemir and Harun Muayad Said (Ph.D, Assist. Prof.) for reviewing the English version of the manuscript.

Declaration of conflicting interests

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

Funding

The author received no financial support for the research and/or authorship of this article.

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