

# Effect of long-term training adaptation on isokinetic strength in college male volleyball players

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## Abstract

**Purpose:** Most of this study focused on endurance, power, and anthropometric measurements but no research declared isokinetic strength changes during two years. The purpose of this study was to assess the effect of resistance exercises on two seasonal alters in isokinetic strength of knee muscles at different angular velocities, in college volleyball players.

**Material:** Thirteen college volleyball players, (age: 21.75 years, body mass: 78.60 kg, and height: 187.0 cm) participated in the study. All college volleyball players take part in the two-year (8 month each year) volleyball-specific training and competitions. The measurement of peak isokinetic concentric knee extension and knee flexion torque in both legs were taken at 2 angular velocities of movement, low at 60° s<sup>-1</sup>, and intermediate at 180° s<sup>-1</sup>.

**Results:** The pre- and post-test values of the peak isokinetic strength found that statistical significance difference, at 60° s<sup>-1</sup> and 180° s<sup>-1</sup> for knee extensor-flexor both dominant and non-dominant in favor of post-tests. Significant enhances were observed in the baseline dominant knee extensor-flexor muscle strength (extensor knee strength 60° s<sup>-1</sup>: 19.0%, 180° s<sup>-1</sup>: 20.5%, flexor knee strength, 60° s<sup>-1</sup>: 33.4%, 180° s<sup>-1</sup>: 31.4%) respectively. Non-dominant knee extensor-flexor muscle strength increased significantly over the two-year period (extensor knee strength 60° s<sup>-1</sup>: 21.3%, 180° s<sup>-1</sup>: 23.0%, flexor knee strength, 60° s<sup>-1</sup>: 37.4%, 180° s<sup>-1</sup>: 33.9%) respectively.

**Conclusions:** As a result, our data suggests that the two-year planned program of specific volleyball and resistance training can increase the knee muscle extensor-flexor strength and H:Q ratios of volleyball players. Especially, at a 60° s<sup>-1</sup> and 180° s<sup>-1</sup> angular velocities, whilst the knee muscle extensor-flexor strength and H:Q ratios for dominant and non-dominant legs were increasing, also H:Q ratios disproportion were decreasing. Therefore, these alters indicated that regular specific-volleyball and resistance training can increase knee muscle extensor-flexor strength and H:Q ratios for dominant and non-dominant legs.

**Keywords:** volleyball, strength, training, hamstring, muscle imbalance.

## Introduction

Volleyball is a sport that involves intermittent activity that incorporates active or passive phases of playing and training. Volleyball games and training demand activities such as turning, altering pace, vertical jumping (VJ) and being generally agile where players use explosive strength [1, 2]. VJ is a principal feature of spiking, blocking, and serving. Fontani et al. said that the average number of jumps during in a 5-set match ranges from 65 to 136 [3]. In terms of the average number of jumps during a volleyball match, we have side hitters (65 jumps), opposite hitters (88 jumps), and blocker hitters (97 jumps). Setters are the players with a highest number of jumps (136 jumps). Rapid permutations are also essential when defending and receiving in order to adapt the body position to the ball position in a short time [1, 3]. In addition, the intensity of volleyball matches requires robust contractions to maintain the balance, movement and control of the body. All these activities are mainly characterized by quick or short displacements and vertical jumps. Therefore, the players require well-developed explosive force and power. Muscle strength is one of the key elements in accomplishing sports performance on the part of athletes. Previously research has also shown that, apart from talent, jumping performance in volleyball is a significant result

of knee extension and flexion strength. The strength of hamstrings (H) and quadriceps (Q) is of vital importance for sport performance and injury prevention. Therefore, volleyball players' injuries might arise from imbalances or lack of strength in terms of muscle strength ratios [4-6]. In the literature, *characteristic concentric (hamstring: quadriceps) H:Q ratios range from 0.5 to 0.8, with a higher ratio at faster angular knee velocities during isokinetic testing* [7]. In respect of muscle strength in the dominant versus the non-dominant leg, it has been asserted that there is an increased proportion of injury when a discrepancy of 15% or more in knee flexor-extensor strength exists in collegiate athletes [8, 9]. Also, it has been proposed that H:Q ratios and bilateral leg strength differences may indicate that leg muscle strength demands are sports-specific [10]. College athletes who train for a large number of hours on a weekly basis may present an asymmetry in muscle strength profiles due to specific technical skill requirements in particular sports such as volleyball and basketball [11]. For instance, sports requiring significant jumping and running place a higher demand on the motor abilities of the H-Q strength ratios [12]. Therefore, attempts to strengthen weak hamstring and quadriceps muscles and improve the strength balance between them, appear to be a significant issue for trainers. In fact, players who are exposed to strength training can improve their muscular strength. Some researchers have

discovered that technical and tactical training, games, conditioning and all other activities, combined with strength training, affect the strength levels of players [4, 13].

There are some works in which researchers have looked into pre-season physiological and physical changes over a period of 6-8 weeks. Most of these studies are focused on endurance, power, and anthropometric measurements [14, 15, 16], but a limited amount of research has identified isokinetic strength changes [17, 4]. However, no research has examined the isokinetic strength changes at different angular velocities in college volleyball players during two competitive seasons. Thus, the purpose of this study was to assess the alterations in the isokinetic strength of knee muscles at different angular velocities in college volleyball players over two seasons. We hypothesized that regular training (a) would improve H:Q strength ratios, (b) would increase both the dominant and non-dominant extensor and flexor knee muscle strength of college volleyball players when suitable training programs were chosen.

## Material and Methods

### *Participants*

A total of 16 college male volleyball players from Turkish National Volleyball 3<sup>rd</sup> League were tested following the end of competitive seasons. In order to be included in the study a) players had to play in the Turkish National Volleyball 3<sup>rd</sup> League, b) not having any medical disability which might affect the result of the study (this question asked all players), c) not having chronic injuries and diseases, d) not having lower extremity injuries within two years. Excluding criteria were: a) having any chronic injuries during the seasons, b) missing deliberately at most five training days. Following these procedures, thirteen players (age: 21.75 years, body mass: 78.60 kg, and height: 187.0 cm) met the criteria for further analysis. Before conducting the experiment, all participants were informed on the risks of the study and gave informed consent. The study was approved by the Ethics Committee of the Inonu University and met the conditions of the Helsinki Declaration. All college volleyball players take part in the two-year (8 month each year) volleyball-specific training and competitions.

### *Isokinetic Tests*

Knee extensors and flexors isokinetic strength of the dominant-non-dominant leg was measured with Biodex 3 isokinetic dynamometers (Biodex Medical Systems, Inc., Shirley, NY, USA 2000). The first season pre-test measurement of isokinetic strength was taken in the first week of volleyball training. The first season post-test measurement was done in the last week of the first season. The second season pre-test measurement of isokinetic strength was taken in the first week of volleyball training of the second seasons. The second season post-test measurement was done in the last week of the second season. Before testing, the participants were informed about the machine's specific details and they

warmed up for 15 minutes. The measurements of peak isokinetic concentric knee extension and knee flexion torque in both legs were taken at 2 different angular velocities of movement (low: 60° s<sup>-1</sup> and intermediate: 180° s<sup>-1</sup>). Calibration adjustments of dynamometers were approved regularly in line with the recommendations of the manufacturing company during the data collection period. Subjects were placed safely in a chair at a sitting position for the test. In order to immobilize upper body movements for the subject, he or she was restrained with both a cross-wise pectoral girdle and lap belt. Trunk/Thigh angle was arranged to be 85° and the leg to measure was contacted by means of a belt on the shaft which was on the dynamometer axis. Subjects were asked whether or not they were comfortable. 90° anatomic position of the knee was observed with a goniometer and a joint range of movement (ROM) was 70° [from 90° to 20° knee flexion (0° = full extension)]. Participants started the test with a warning beep from the dynamometer and ended the test with the same noise. Testing conducted from slowest to highest speeds. Players were given five times to warm up at submaximal concentric contractions for both leg and then performed the maximal concentric contractions five times. During all isokinetic tests, players were allowed to rest for 3 minutes between sets and 15 seconds between serials.

### *Training procedures of two seasons*

The 1<sup>st</sup> volleyball-training season lasted 40 weeks, including 13 weeks of pre-season training, 20 weeks of in-season training and 7 weeks post-season training. The 2<sup>nd</sup> volleyball-training season lasted 40 weeks to be completed, including 12 weeks of pre-season training, 16 weeks of in-season training and 12 weeks post-season training. Both training seasons was paused due to Festival of Sacrifice (1 week) and the mid-seasons break (1 week).

Volleyball training procedures included both seasons volleyball training activities (technical and tactical training, games and matches) and conditioning (strength, agility, coordination, plyometric, stretching, flexibility, endurance and strength development) during the pre-season, in a season and as well as post-season. The average duration of practice sessions was 90-120 min. All specific volleyball training procedures indicated in table 1.

### *Statistical Analysis*

Statistical analysis procedures started with "Skewness and Kurtosis" scores, visual explanations of histogram plots and "Kolmogorow Smirnov" tests within normality analysis in order to test whether data were homogenous. The testing times of volleyball players were evaluated by "Repeated Measures" analysis, which was used to test for significant differences between tests. All statistical analyses were calculated with SPSS 17.0 software program and the significance level is recognized as  $p < 0.05$ . The reliability of each isokinetic test was evaluated by intra-class correlation coefficient (ICC) as suggested by Weir 2005 [18]. The ICC values were found to be highly repeatable (ICC= between 0.91 – 0.96).

### Results

Changes in primary peak isokinetic extensor-flexor strength measures over the examined time period (two year) are presented in Tables 2, 3. A significant ( $p<0.05$ ) improvement in the knee strength of quadriceps and hamstrings were registered. The pre- and post-test values

of the peak isokinetic strength found that there was a statistically significant difference, at  $60^\circ \text{ s}^{-1}$  and  $180^\circ \text{ s}^{-1}$  for knee extensor-flexor in terms of both dominant and non-dominant legs in favor of post-tests ( $p=0.00$ , Tables 2, 3). Significant enhancement was observed in the baseline dominant knee extensor-flexor muscle strength (extensor

**Table 1.** Overview of two season volleyball specific training outline.

Type of activity	Exercise	Set x repetition	1-RM%	Days
Resistance training	Barbell bench press	2x 8-10	60	Tues., Thurs
	Machine long pull	(20 weeks, Aug, Sep, Oct,		
	Dumbbell shoulder press	Nov, Dec)		
	Standing barbell curl	3x10-12		
	Machine leg extension	(20 weeks, Jan, Feb, Mar,		
	Machine leg curl	Apr, May)		
Specific volleyball training	Barbell half squat	Exercise	Duration (min)	Days
	Stretching and flexibility	Warm up, cool down,	15	Every day
	Sprint and agility	Before technical training	10	Tues., Thurs
	Plyometric	Before technical training	12	Wed.
	Technical training	Main training	20	Wed., Fri
	Tactical preparation	After technical training	15	Wed., Fri
	Games	After tactical training	20	Friday
<b>Match Days</b>	Competitions			Satur., Sun
<b>Regeneration Day</b>	Jogging, Pilates, sauna		55	Mon

**Table 2.** Changes in different angular velocity peak isokinetic knee strength of quadriceps for both legs.

Extensor Peak Torque (Nm)				
n=13				
	$60^\circ \text{ s}^{-1}$		$180^\circ \text{ s}^{-1}$	
Times	Dominant	Non-dominant	Dominant	Non-dominant
1 <sup>st</sup> Pre-test	228.33±19.15	218.66±15.64	184.75±16.29	171.00±16.61
1 <sup>st</sup> Post-test	254.50±18.95*	248.53±15.75*	206.50±14.21*	193.08±14.61*
	*p=0.00	*p=0.00	*p=0.00	*p=0.00
2 <sup>nd</sup> Pre-test	239.66±16.55	235.33±14.86	194.16±12.94	181.75±13.49
2 <sup>nd</sup> Post-test	271.75±18.14*†	265.25±16.66*†	222.50±15.28*†	210.41±15.69*†
	*p=0.00, †p=0.00	*p=0.00, †p=0.00	*p=0.00, †p=0.00	*p=0.00, †p=0.00

\*: differences between pre- and post-test, †: differences between post- and post-test

**Table 3.** Changes in different angular velocity peak isokinetic knee strength of hamstring for both legs.

Flexor Peak Torque (Nm)				
n=13				
	$60^\circ \text{ s}^{-1}$		$180^\circ \text{ s}^{-1}$	
Times	Dominant	Non-dominant	Dominant	Non-dominant
1 <sup>st</sup> Pre-test	127.66±17.74	121.16±16.24	104.91±15.17	101.91±15.86
1 <sup>st</sup> Post-test	155.16±15.28*	148.56±14.00*	122.41±13.96*	120.83±13.04*
	*p=0.00	*p=0.00	*p=0.00	*p=0.00
2 <sup>nd</sup> Pre-test	144.00±16.55	136.00±14.13	116.50±13.06	111.08±12.53
2 <sup>nd</sup> Post-test	170.08±16.74*†	166.50±15.91*†	138.00±12.76*†	136.16±13.04*†
	*p=0.00, †p=0.00	*p=0.00, †p=0.00	*p=0.00, †p=0.00	*p=0.00, †p=0.00

\*: differences between pre- and post-test, †: differences between post- and post-test

**Table 4.** Changes in H:Q for both legs.

H:Q (%) n=13	60° s <sup>-1</sup>		180° s <sup>-1</sup>	
	Dominant	Non-dominant	Dominant	Non-dominant
1 <sup>st</sup> Pre-test	39.30±3.50	38.70 ±4.10	46.50±5.55	43.75±5.85
1 <sup>st</sup> Post-test	49.90±3.10* *p=0.00	48.50±3.90* *p=0.00	57.40±6.95* *p=0.00	55.80±5.00* *p=0.00
2nd Pre-test	47.00±4.25	44.35±4.10	53.25±6.60	51.05±6.55
2nd Post-test	57.75±4.15*† *p=0.00, †p=0.00	58.45±5.65*† *p=0.00, †p=0.00	66.00±7.10*† *p=0.00, †p=0.00	62.15±6.70*† *p=0.00, †p=0.00

\*: differences between pre- and post-test, †: differences between post- and post-test

knee strength 60° s<sup>-1</sup>: 19.0%, 180° s<sup>-1</sup>: 20.5%, flexor knee strength, 60° s<sup>-1</sup>: 33.4%, 180° s<sup>-1</sup>: 31.4%) respectively. Non-dominant knee extensor-flexor muscle strength increased significantly over the two-year period (extensor knee strength 60° s<sup>-1</sup>: 21.3%, 180° s<sup>-1</sup>: 23.0%, flexor knee strength, 60° s<sup>-1</sup>: 37.4%, 180° s<sup>-1</sup>: 33.9%) respectively. A comparison of the H:Q ratios of both dominant and non-dominant legs found a significant difference in mean values at 60° s<sup>-1</sup> and 180° s<sup>-1</sup> in favor of post-tests (Table 4). Significant improvements were monitored in the baseline dominant and non-dominant H:Q ratios (H:Q dominant 60° s<sup>-1</sup>: 46.94%, 180° s<sup>-1</sup>: 41.9%, H:Q non-dominant 60° s<sup>-1</sup>: 51.0%, 180° s<sup>-1</sup>: 42.1%) respectively.

### Discussion

The primary finding of this research is that isokinetic strength performance increased at the end of training and match seasons over a two-year period. Our study has indicated great changes in isokinetic strength values at different angular velocities. The findings of this study demonstrated that regular resistance and specific-volleyball training may improve extensor-flexor knee muscle strength and the H:Q strength ratio of male college volleyball players. Although previous research has investigated countermovement jumping and spike jumping [16] of volleyball players, and extensor-flexor knee muscle strength and H:Q [4] of football players, no studies have investigated the effect of long-term training adaptations on isokinetic strength values in volleyball. The results of this research are original in that our study investigates just such an effect. This research provides coaches and players with the basis of a rationale to prioritizing:

- 1) implementing resistance training at least twice a week,
- 2) carrying out sprint and agility training at least twice a week,
- 3) performing plyometric training at least once a week.

One study declared the effect of pre-season strength training on improving knee muscle strength values [14]. Another study reported that a combination of football and strength training (3 times a week, 85% of 1 RM) increased power strength [19]. Eniseler et al. asserted that

implementing football specific-football training during the season improved the strength values of football players [4]. Our current findings support previous results that show the significance of knee muscle strength in volleyball players. The results indicate the need to: (a) perform strength training at least twice a week, and (b) perform specific-volleyball training at least three times a week. Another possible clarification to ensure a significant alteration might be that college volleyball players have very low pre-season knee extensor-flexor knee muscle strength levels. Improvements in knee muscle strength values after two specific volleyball training and competition seasons might arise mainly from significant increments in the neural adaptation of muscles as a result of a specific training regimen [4]. Behm and Sale asserted that high velocity training adaptations might improve substantial neural conformations [20]. However, strength and conditioning coaches should be aware of the debate that neural adaptations may be restricted to the early stage of strength training [21]. Moreover, such conformations may progress throughout the later stages of the strength training period [4, 22]. As a consequence of our study, we would recommend that during the season, a planned program of specific-volleyball and resistance training might improve the knee muscle strength of volleyball players.

In this research, the outcomes indicate that specific-volleyball and resistance training were influential in decreasing the disproportion between dominant and non-dominant legs. This could be helpful to volleyball players in increasing their performance and, most substantially, minimizing the risk of injury in the lower limbs. It has been suggested that strength disparities of the knee is one of the most significant risk factors for lower limb injuries in amateur and competitive athletes [8, 11, 23]. The H:Q ratio should be between 0.50 and 0.80, depending on varying knee-angles and angular velocities [7, 24, 25]. In this study was found values of H:Q (60° s<sup>-1</sup>) ratios for the dominant leg in the 1<sup>st</sup> pre-season was 39.30%, and in the 2<sup>nd</sup> pre-season it was 47.00%. For the non-dominant leg in the 1<sup>st</sup> pre-season it was 38.70%, and in the 2<sup>nd</sup> pre-season it was 44.35%. The values of H:Q (180° s<sup>-1</sup>) ratios for the dominant leg in the 1<sup>st</sup> pre-season was 46.50%, and in the

2<sup>nd</sup> pre-season it was 53.25%. For the non-dominant leg in the 1<sup>st</sup> pre-season it was 43.75%, and in the 2<sup>nd</sup> pre-season it was 51.05%. The results of this study have been shown that there are no suitable reference H:Q values in the literature [7, 24, 25]. However, the H:Q values of college volleyball players found that there were suitable reference values after two years of specific-volleyball and resistance training (for 60° s<sup>-1</sup>: 2<sup>nd</sup> post-season 57.75% dominant, 2<sup>nd</sup> post-season 58.45% non-dominant, for 180° s<sup>-1</sup>: 2<sup>nd</sup> post-season 66.00% dominant, 2<sup>nd</sup> post-season 62.15% non-dominant). In summary, in the current research, there was a statistically significant increase in H:Q ratios in terms of both 60° s<sup>-1</sup> and 180° s<sup>-1</sup>. On the other hand, the H:Q disproportion decreased significantly. The previous studies' findings indicate the significance of H:Q ratios in athletes and the reliable correlation between developing H:Q and decreasing lower limb injuries [8, 9]. In the present study, H:Q ratios increased after two year specific-volleyball and resistance training. In addition, trainers should consider increasing H:Q ratios as a significant training priority in volleyball players.

As a result of this research, our data suggests that a two-year planned program of specific volleyball and resistance training can increase the knee muscle extensor-flexor strength and the H:Q ratios of volleyball players. In particular, at 60° s<sup>-1</sup> and 180° s<sup>-1</sup> angular velocities, whilst the knee muscle extensor-flexor strength and H:Q ratios for dominant and non-dominant legs were increasing, the H:Q ratios disproportion were also decreasing.

### Conclusion

Throughout the pre-season period, trainers should aim to increase their players' muscular strength. This is necessary in particular to minimize disproportionate

H:Q ratios in volleyball players. Regular resistance and specific-volleyball training is a method that enhances the muscle strength situation. We also suggest that performing regular specific-volleyball and resistance training can increase knee muscle extensor-flexor strength and H:Q ratios for dominant and non-dominant legs. The changes in knee muscle extensor-flexor strength and improvements in the H:Q ratios can be realized in already well-trained volleyball players. These outcomes provide the trainers with the basis of a rationale for prioritizing:

1) implementing resistance training at least twice a week,

2) carrying out sprint and agility training at least twice a week,

3) performing plyometric training at least once a week.

Volleyball players should be encouraged to improve their knee muscle extensor-flexor strength and H:Q ratios for dominant and non-dominant legs. This can be preventing lower limb injuries on the part of volleyball players.

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### Conflicts of interest

There no conflicts of interests.

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