

THE EFFECTS OF PLYOMETRIC TRAINING ON KNEE JOINT ANGLE-TORQUE RELATIONSHIP IN ELITE HANDBALL PLAYERS

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The aim of this study was to examine the effects of 8 weeks plyometric training program on knee joint angle-torque relationship in elite handball players. A total of 7 male handball players (Age: 22.0 ± 4.5 years; Weight: 95.7±12.7; Height: 187.4±4.4 cm) participated in the study. Concentric isokinetic peak torque, angle of peak torque and average power was assessed for the knee extensors and flexors at 180°•s⁻¹ before and after training program. No significant difference was found at the angle of peak torque values between pre- and post-test ($p > 0.05$). However difference was detected in peak torque and average power values of knee extensors ($p < 0.05$). It is concluded that plyometric training is not an effective training modality to alter knee joint angle-torque relationship in elite handball players.

KEY WORDS: plyometric training, handball, knee joint, angle of peak torque, power

INTRODUCTION: Handball is a team sport that is highly dependent on muscular properties of players (Gorostiaga et al., 2005; Marques et al., 2007). Handball players need to throw the ball faster and jump higher for better performance. Jump performance correlates with strength of hip and knee muscles (Tsiokanos et al., 2002). One of the most common training method for increasing vertical jump performance is plyometric training (Markovic, 2007).

Plyometric exercise can be defined as a movement that utilizes the stretch-shortening cycle (SSC) to produce force efficiently in the least amount of time. SSC involves an eccentric phase in which muscle-tendon units decelerates the movement by performing negative work before the transition and concentric phases (Nicol et al., 2006). When the muscle-tendon unit actively lengthens it stores elastic energy and with the following shortening it utilizes this stored energy which results in enhanced power and efficiency over pure isometric and concentric muscle actions (Kawakami et al., 2002a; Ishikawa et al., 2003).

Maximizing efficiency in the eccentric phase of SSC may have an important role in sports performance, especially for the sports branches that require this kind of movement commonly. It is reported that training-induced alterations in this phase contribute to jump performance (Cormie et al., 2010). One of the well documented effects of training-induced alterations to eccentric muscle actions is a shift of length-tension relationship (Brughelli & Cronin, 2007). It is an important adaptation for performance and injury prevention because it is believed that athletes who produce peak torque at shorter muscle length are more likely to get injured (Brockett et al., 2004)

Isokinetic dynamometers are widely used to measure length-tension relationship indirectly at single joint level in humans (Brockett et al., 2001; Chen et al., 2007). Joint torque is plotted against joint angle at the single joint level, which gives the angle-torque relationship. Jakeman and Eston reported a rightward shift in angle-torque relationship of knee extensors after a single bout of plyometric exercise in young, active women (Jakeman & Eston, 2013). Rightward shift in angle-torque relationship means maximal force occurs at longer muscle-tendon lengths. This result is in line with the previous studies that used only eccentric muscle actions for training (Brockett et al., 2001; McHugh & Tetro, 2003).

The effects of plyometric training on angle of peak torque may be different between nonathletes and athletes, especially for the sports branches that utilizes SSC commonly such as handball and basketball. However there is a lack of studies about this subject in the athletic population. The aim of this study was to examine the effects of plyometric training on peak torque, angle of peak torque and power of knee flexors and extensors in elite handball players.

METHODS: A total of 7 male elite handball players (Age: 22.0 ± 4.5 years; Weight: 95.7 ± 12.7 kg; Height: 187.4 ± 4.4 cm) were recruited to participate in the study, who had regular training at least 5 years in their sports. All participants did not have any injury in their lower extremity at the time of testing.

Isokinetic Test Protocol: Tests were done before (pre-test) and after (post-test) 8 weeks of training program at Marmara University, Sports Sciences and Athletic Health Research Center. The participants warmed up for ten minutes by running on a treadmill and dynamic stretching before the test session. Subjects were seated upright in the dynamometer, hip flexed 90° and knee also flexed 90° . A waist strap, distal femur strap and two shoulder straps were used to secure the subjects and reduce mechanical assistance from other body parts. During isokinetic measurements, participants were instructed to extend and flex their knees between 0° - 90° without any delay between eccentric and concentric contractions to allow SSC to occur. Concentric isokinetic peak torque was assessed for the knee extensors and flexors from 8 maximum efforts at $180^{\circ} \cdot s^{-1}$ (System 4 Dynamometer; Biodex Medical Systems, Inc, Shirley, NY). A warm-up and familiarization set, consisting of 2 flexion and extension repetitions, were performed prior to testing. Participants received visual biofeedback of the torque values on a monitor. Verbal encouragements were provided to the subjects to help them produce their greatest maximum voluntary contraction (MVC) torque. Participants were instructed to push and pull as hard as possible.

Plyometric Training Program: Training program involved two sessions per week and lasted for 8 weeks. Athletes continued their regular handball training throughout eight weeks. Each plyometric training session was initiated via a 15-20 minutes warm up and finished before athletes' handball training session. In total 12 different lower body plyometric exercises were chosen for training program and 4 of them were incorporated in each training session. There was 3 groups of 4 exercises throughout 8 weeks, which were ordered according to the guidelines (Chu, 1998). Each training session included 90-100 jumping movements. Athletes performed one exercise after another in a circuit fashion. 3 circuits were completed in each session. 30 seconds rest was given between exercises and 2 minutes rest was given between circuits.

Analysis of Data: Participants' take off leg in 1 legged jumping movements, was chosen for evaluations.

Recorded torque values during flexion and extension motions were ordered according to the knee angle. 0° represents the knee in extended position (lower leg parallel to the floor) and 90° represented the knee in the flexed position (lower leg vertical to the floor). MVC torque values were divided by body weight for normalization. MVC torque and angle values were extracted and decimated averaging every 10 successive data points, and plotted. To find the angle of peak torque, a Gaussian curve was fitted to the top 10% of the curve in accordance with the methods of Brockett et al (Brockett et al., 2001).

The measurements of average power were provided by the Biodex software program by dividing the amount of total work to the time to complete that total work.

Statistical Analyses: Wilcoxon Signed Ranks test was used to determine differences in the peak torque, angle of peak torque and average power, between pre-tests and post-tests.

RESULTS: Table 1 gives a summary of the results. Analyses of the data for angle of peak torque showed that there was no statistical difference between pre- and post-test values for

both extension and flexion ($p > 0.05$). Significant difference was found only in peak torque and average power values at extension ($p < 0.05$).

Table 1
Peak torque, angle of peak torque and average power values before and after training

	Before	After
Peak torque (N.m)		
Extension	185.74 ± 24.59	209.49 ± 27.50*
Flexion	106.72 ± 23.01	102.41 ± 11.66
Angle of peak torque (°)		
Extension	58.11 ± 6.86	61.32 ± 7.78
Flexion	64.57 ± 26.04	47.43 ± 22.62
Average power (Watts)		
Extension	284.24 ± 41.56	312.77 ± 33.35*
Flexion	150.49 ± 32.84	167.10 ± 28.57

Values are expressed as means ± SD

* Represent significant difference between pre-test and post-test ($p < 0.05$)

DISCUSSION: In our study, contrary to the Jakeman and Eston's findings, significant changes were not found in angle of peak torque of either extensor or flexor muscles (Jakeman & Eston, 2013). This could be due to the several differences between two studies. Firstly $60^{\circ}\cdot s^{-1}$ was chosen for their isokinetic test protocol. As documented previously, angle of peak torque changes at different velocities (Kawakami et al., 2002b). Secondly their training protocol included a single session with only one exercise, which was the drop jump. Whereas in our study 16 sessions were done during eight week period with various plyometric exercises. Maybe the most significant difference between two studies was the selection of research population. In Jakeman and Eston's study; young, active women were selected as research group while in our study elite handball players, which had been playing this sport at least for 5 years, were recruited. Handball constantly requires movements that utilize SSC, which means these athletes had been already performing plyometric movements in their regular training and competition. Therefore it may be harder to see any structural changes in this population in response to plyometric training and higher intensities may be required (Ahtiainen et al., 2003). The observed difference in peak torque and average power of knee extensors may be explained by the kinesiology of jumping movement. Bobbert and Van Ingen Schenau documented that knee extensors are activated more than knee flexors during counter movement jumps (Bobbert & Van Ingen Schenau, 1988). This may lead to higher recruitment of knee extensor muscles during plyometric exercises and thereby greater adaptations in muscle strength and power. Previous studies on plyometric training are in line with these findings (Markovic & Mikulic, 2010).

Positive changes in peak torque and average power of knee extensors, in the absence of any difference in angle of peak torque, may be attributed to improvements in neuromuscular properties of muscles more than structural changes in our study (Kraemer & Newton, 2001). Future studies must be conducted to verify this with higher number of participants in the athletic population.

CONCLUSION: The effects of plyometric training on the joint torque-angle relationship may be different between nonathletes and athletes, especially for the sports branches that utilizes SSC commonly. If the aim is to induce structural changes in muscle-tendon unit, plyometric training programs with higher intensities or eccentric training programs may be necessary for elite handball players.

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