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Effects of isokinetic versus isotonic training on strength, power and muscular balance of rotator cuff muscles among advanced level of adolescent weightlifters

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Abstract

Weightlifting is a sport that demands dynamic strength and power which involves a multi joint movement and whole body lifts. As an important kinetic chain involved in motions of weightlifting, previous literatures reported shoulder injuries due to muscular imbalance of shoulder rotator cuff muscles. Therefore, the study was conducted to evaluate the effects of isokinetic versus isotonic training on strength, power and muscular balance of the rotator cuff. A total of 24 state-level weightlifters were recruited and randomly assigned (gender- and weight-matched) into either isokinetic or isotonic group. However, only 19 participants successfully completed the intervention programme. Both groups went through 24 sessions of a training program three times per week for eight weeks. The intensity of training was increased progressively in terms of number of repetitions and set. Isokinetic variables of peak torque per body weight, time to peak torque, average power and external to internal rotators muscular strength ratio were recorded before and after the commencement of training and one month following the cessation of training. There was a non-statistically significant trend that indicated positive changes in the biomechanical adaptations of the rotator cuff in the isokinetic group compared to the isotonic group in terms of peak torque/body weight, time to peak torque and average power. In conclusion, both isokinetic and isotonic training specifically for rotator cuff has a potential to be proposed as an additional training among experienced weightlifters to improve their performance.

Key words: weightlifting, strength, shoulder joint, youth

Introduction

Olympic weightlifting requires athletes to lift maximum combined weight during clean and jerk and snatch events. Both of these events are performed in a controlled fashion to ensure a smooth lifting of predetermined loads that were initially resting on the ground (Lavallee & Balam, 2010). These techniques put an extra pressure on the shoulder area especially during the first pull and catch phases whereby the athletes need to maintain a stationary position for a certain period of time before dropping the loads on the ground. Therefore, weightlifting requires great muscle strength and power to lift maximum load in a short period of time.

It was reported that the glenohumeral joint assists the catch and pulls during the snatch lift (Bartonietz, 1996; Chen et al., 2013). In addition, a synchronized activation of the rotator cuff muscles is essential during the humeral elevation to prevent the humeral head from migrating superiorly and thus causing shoulder impingement (DeMey

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et al., 2013; Pabian et al., 2011; Escamilla et al., 2009; Myers et al., 2009; Lugo et al., 2008). This aspect is important in competitive weightlifting because the weight will keep increasing following successful attempt. Consequently, the increasing loads will put more pressure on the shoulder joint. Therefore, the rotator cuff muscles are essential in order to stabilize and maintain the normal position of the shoulder joint during a lift.

Previous literatures reported of more than 36% of weightlifting-related injuries and disorders occur at the shoulder joint complex due to the extra pressure placed on the shoulder muscles particularly during the first pull and catch phases (Keogh et al., 2006; König & Biener, 1990; Goertzen et al., 1989). Furthermore, shoulder injury is also attributed to strength imbalances of rotator cuff muscles which are common among weightlifters (Kolber & Corrao, 2011). The unilateral strength ratio is defined as the quotient between concentric strength values of external rotators (ERs) and internal rotators (IRs) that represent the quality of rotator cuff muscle balance. Imbalance in the strength of the ERs and IRs of the shoulder joint is regarded as a risk factor in shoulder dysfunction (Dauty et al., 2003). The task of lifting and bearing weight needs strength of the arm muscles and stability of all contributing joints. However, typical isotonic weight training that emphasized on large upper extremity muscles such as the deltoid, neglected the necessary training for smaller muscles of joint-stabilizer such as the rotator cuff group (Barlow et al., 2002; Gross et al., 1993).

Common weightlifting training involved isotonic muscle contraction of lifting a fixed weight such as dumbbell and barbell. Examples of this type of training are biceps and triceps curl. In isotonic contraction, the resistance remains constant throughout the ROM with varied angular velocity of the involved joint (Kovaleski et al., 1995; Smith & Melton, 1981). Hence, loading occurs at the weakest point in the system, while the rest of the system is functioning at less than capacity (Smith & Melton, 1981). Furthermore, isotonic weight lifting is unable to maintain the angular velocity at the end of ROM. Thus, power development may be improved only at the initial segment of the range of motion (Kraemer & Ratamess, 2004). On the other hand, isokinetic training mode provides proportional resistance following the amount of force that being exerted. This will allow a constant angular velocity across the full ROM of the involved joint and further avoid the disparaging effect of deceleration phase such as in isotonic movement (Kraemer & Ratamess, 2004). Therefore, a maximal effort can be experienced during isokinetic contraction because the maximal load is applied throughout the whole ROM.

The purpose of the present study was to compare the effects of additional isokinetic versus isotonic training of rotator cuff on shoulder strength, power and unilateral ratio of muscular strength of experienced adolescent weightlifters. The variables were compared before the commencement of the supplementary training, after the training and following one month of its cessation. We hypothesized that both types of training may increase shoulder strength, power and unilateral ratio of muscular strength following training but ceased after its attenuation. We aim to fill the gap in literature regarding different modes of muscle contraction training for advanced level of weightlifters and the effects of cessation.

Methods

Participants

A priori sample size calculation showed that eight participants per group are sufficient to yield 0.8 power of the study with effect size of 0.6 (large sample size according to Cohen, 1988). Participants with at least two years of experience in competitive weightlifting and without previous history of shoulder injury were included. Participants were excluded from the study if they were unable to adhere to a minimum of 85% of training loads during an intervention and/or have undergone rehabilitation for any musculoskeletal injury within the last two years.

It was explained to participants that they will not lose any benefit of trainings if they decided not to participate. Participants were provided with detailed explanation regarding the methodology of the study. Upon agreement, their written consent form was collected. For participants under 18 years old, assent was obtained from their guardians. Participants were enrolled after having fulfilled all of the inclusion criteria and presenting none of the exclusion criteria. The participation in present study was entirely voluntary. Participants were weight-matched into either isokinetic or isotonic rotator cuff training groups. Both groups went through 24 sessions of training program three times per week for eight weeks. All procedures were conducted with compliance to Helsinki Declaration of 1975. Ethical approval was obtained from Human Ethical Committee of USM (USM/JEPeM/14110457).

Testing Procedure

The entire experiment was conducted during the preparatory phase of the weightlifters' training cycle. All participants were recruited from the same pool of weightlifters with a standardized training program provided by their coach. Their standardized program included five strength training sessions and one tactical session per week. The duration of their standardized training session was two hours per session. Meanwhile, the training program prescribed in the current study (e.g., isokinetic and isotonic rotator cuff resistance training) was an additional training for the state-level athletes. Series of isokinetic tests of shoulder joint were conducted before the commencement of the additional training program, immediately after the completion of the additional training program and one month following the cessation of the additional training program.

Muscular strength was measured according to the standard protocol using an isokinetic dynamometer (Multi-Joint System 3 Pro; Biodex Medical Systems, Shirleys, New York, USA). A strict adherence to the guidelines of the Biodex isokinetic dynamometer operations manual was followed such as the positioning of participants, calibration, correction for gravity, familiarization and verbal encouragement. Participants were familiarized with the use of the dynamometer and testing procedure prior to the real measurement. The testing session began following ten minutes of warming up of shoulder area. The dynamometer was calibrated with known weight before each testing and training sessions. A correction for the mass of the limb and lever arm system was made on all torque curves. The preparation of participant on the dynamometer followed the manufacturer's manual closely to ensure safety of the participants.

The seated position of 45° shoulder abduction in the scapular plane was used to evaluate isokinetic variables of peak torque per body weight (e.g., relative peak torque), time to peak torque and average power in external and internal rotation. Previous studies have shown that 45° shoulder abduction in the scapular plane is the best position and its reliability on measuring internal and external rotation of shoulder joint's optimum peak torque had been reported in many high quality studies (Codine et al., 2005; Dauty et al., 2003; Meeteren et al., 2002; Plotnikoff & MacIntyre, 2002; Davies, 2002). In addition, this position offers optimal comfort and a stable physiological position whereby it allows a more consistent measurement of shoulder rotation by placing the muscle in a stable position (Mayer et al., 1994; Hageman et al., 1989).

Firstly, the participants' dominant side was confirmed through verbal query (Ellenbecker et al., 1988). Next, the participant was seated on the chair. The chair was rotated to 15° towards the opposite side of the tested shoulder. Then, the dynamometer was rotated 20° backwards close to the chair. Next, the dynamometer was tilted 50° upward from the neutral position. The shoulder and elbow attachment was attached to the dynamometer and the shaft dot was aligned right or left depending on the side tested and was further secured with locking knob. Then, the dynamometer was raised to align with the axis of rotation of glenohumeral joint which is 45° shoulder abduction in the scapular plane. The chair and seatback was adjusted to accommodate participants' comfort. The elbow was flexed at 90° and a cushion pad was used to support the elbow.

The accuracy of the alignment was checked by allowing the participant to move internally and externally. The elbow was fixed to the cushion pad during the motion. The participant was strapped at the shoulder, waist and thigh to minimized body movement. Shoulder straps were applied diagonally across the chest to attenuate excessive upper body movement. The ROM was set to be 40° internal and 50° external making total ROM to be 90°. The ready position was 40° internal rotation of the shoulder joint. The testing angular velocity was set at 120°.s-1 and the gravity of the shoulder was corrected before the test. The participants were asked to perform two sets of 12 repetitions each with 60s rest intervals between the sets. The order of side testing was randomly selected. Verbal encouragement was provided during the test although visual feedback from the computer screen was not allowed. All movements were performed in concentric mode. Biomechanical data of relative peak torque, time to peak torque, average power and unilateral strength ratio for both shoulders were recorded. Each variable was then averaged across the number of sets and repetitions performed.

Training Program

The duration of the training program was eight weeks. The isokinetic training group had their training sessions three times per week at a sports science laboratory of a local university. The isokinetic training was applied using an isokinetic dynamometer (Multi-joint System Biodex Pro, Shirley, NY, USA). For familiarization, all participants completed one set of 12 reciprocal internal and external shoulder rotations in concentric mode. The training program commenced following at least three days of recovery. For each training sessions, ten minutes of warm-up emphasizing on the shoulder was performed by each participants followed by a minute of active rest.

In this progressive training program, there were several differences in terms of position, number of repetition and angular velocity. For the first until the eighth sessions, participants were trained in the seated position with 45° of shoulder abduction. In this position the scapular was positioned so that equal distribution of external rotators and internal rotators can be trained. The angular velocity was set at $120°.s^{-1}$, with 12-15 repetitions for two sets. From the ninth to the 16th sessions, the seated position with 90° of shoulder abduction was selected. The angular velocity applied was $240°.s^{-1}$ with 10-12 repetitions for three sets. From the 17th to 24th sessions, training was conducted in standing position while diagonally lifting the bar. The angular velocity was set at $360°.s^{-1}$ with eight to ten repetitions for four sets. For all training positions, rest interval between the sets was provided for one minute. Training was conducted for both sides of upper limb. For cool down, the participants performed a proper shoulder stretching and ice pack was applied on the shoulder for ten minutes to reduce muscle soreness. Training was progressive in terms of the number of sets, angular velocity applied and changes of body position to resemble upper limb's movement during weightlifting. Each training sessions was completed in approximately one hour including warming up and stretching sessions. The same lifting positions, duration of rest interval between sets, number of sets and repetitions were applied by the isotonic group however their training was conducted using a constant weight which is about 50% of their upper limb's weight. The participants' upper limb weight was measured using isokinetic device during pre-training isokinetic testing procedure as stated previously. The angular velocity was not fixed in isotonic group. The details of the program were summarized in Table 1.

Table 1. *Summary of characteristics of isokinetic and isotonic additional training*

Sessions	Body position	Repetitions	Sets	Rest Interval(min)	Velocity (for isokinetic only)($°.s^{-1}$)
1 to 8	seated with 45° of shoulder abduction	12-15	2	1	120
9 to 16	seated with 90° of shoulder abduction	10-12	3	1	240
17 to 24	standing while lifting the bar diagonally overhead	8-10	4	1	360

Statistical Analysis

The data of relative peak torque, time to peak torque and average power of both sides of shoulder were analyzed using the Statistical Package for the Social Science (SPSS) version 22. The normality of data distribution was checked with Shapiro-Wilk test. A general linear model two way analysis of variance (ANOVA) with repeated measure design was used for statistical analysis in which within participants factor was time (e.g., before commencement of additional training program, after the training program, one month after the cessation of the training program) and between participants factor was training groups (e.g., isokinetic versus isotonic). Interaction effects between group and time as well as main time effects were of interest. Post hoc analyses with Bonferroni correction were conducted when there were significant effects of between and within groups. The accepted level of significance was set at $p < 0.05$. All data were expressed as mean ± standard deviation (SD).

Results

Initially, 24 adolescent state-level weightlifters were recruited, however only 19 of them were able to complete the study. Five participants dropped out due to personal problem and non-compliance to the experimental program. Therefore, data analyses were conducted only for the participants who completed the study. They had a mean age of 14.74±1.37 years (range, 13-17 years), mean height of 158±9.61 cm (range, 142-174 cm) and mean weight of 62.82±16.24 kg (range, 45-98 kg).

Table 2 summarizes the descriptive data of demographic and anthropometric characteristics of the participants. The general linear model mixed ANOVA with repeated measure design revealed significant time x group interaction ($df = 2$, $F = 7.137$, $p < 0.05$) and significant main time effect ($df = 2$, $F = 57.19$, $p < 0.05$) on mean body weight. Specifically, body weight was similar across groups at pre-test, however, it increased significantly at post-test and at post-1 month cessation test for both groups.

Table 2. *Physical characteristics of participants (N = 19)*

	Isokinetic Group (n=8)	Isotonic Group (n=11)
Age (Years)	14.36 ± 1.06	14.82 ± 1.60
Height (m)		
Pre-test	1.59±0.07	1.58±0.11
Post – test	1.60±0.07	1.59±0.11
Post1 Month – test	1.61±0.07	1.59±0.11
Body Weight (kg)		
Pre-test	61.92±12.57	57.59±11.20
Post – test	64.53±12.66*	58.70±11.37*
Post1 Month – test	65.42±12.75*	59.31±11.85*
Body Fat Percentage (%)		
Pre-test	33.87±11.30	24.93±5.86
Post – test	36.31±10.57	27.96±6.14
Post1 Month – test	36.31±10.58	26.74±7.18
Fat Free Mass (kg)		
Pre-test	45.44±8.64	46.63±15.47
Post – test	45.54±9.47	45.46±13.59
Post1 Month – test	46.27±9.44	46.67±14.01

*Significant between timeline, p=0.05

Table 3. *Relative peak torque of shoulder joint internal rotation at 120°.s^{-1}*

Groups	Isokinetic		Isotonic	
	Dominant (Nm/kg)	Non-dominant (Nm/kg)	Dominant (Nm/kg)	Non-dominant (Nm/kg)
Pre-test	62.34±22.98	61.95±22.33	82.13±13.01	71.15±20.53
Post-test	59.95±19.05	60.59±15.19	66.7±20.21*	68.67±20.56
1 month after training cessation	68.62±18.46	62.02±14.49	68.09±18.52*	69.03±17.67

*Significant between timeline, p<0.05

Table 4. *Relative peak torque of shoulder joint external rotation at 120°.s^{-1}*

Groups	Isokinetic		Isotonic	
	Dominant (Nm/kg)	Non-dominant (Nm/kg)	Dominant (Nm/kg)	Non-dominant (Nm/kg)
Pre-test	42.36±11.42	43.26±10.43	53.72±13.19	48.14±13.14
Post-test	44.13±16.01	44.02±18.82	49.58±14.51	46.31±14.13
1 month after training cessation	56.67±14.86*	49.28±10.61	54.6±12.63	57.8±12.30*

*Significant between timeline, p<0.05

Table 5. *Time to peak torque of shoulder joint internal rotation at 120°.s^{-1}*

Groups	Isokinetic		Isotonic	
	Dominant (ms)	Non-dominant (ms)	Dominant (ms)	Non-dominant (ms)
Pre-test	396.42±204.26	578.75±213.17	521.11±269.52	564.50±252.05
Post-test	477.14±231.49	605.5±302.18	542.22±283.62	603.63±319.80
1 month after training cessation	212.86±150.63	466.87±305.97	533.89±302.19	548.18±282.11

Table 3 summarizes the descriptive data and the results of relative peak torque of dominant and non-dominant shoulder internal rotation at 120°.s^{-1}. The general linear model mixed ANOVA with repeated measure design revealed significant time x group interaction (df = 2, F = 4.747, p = 0.01) and significant main time effects (df = 2, F = 3.575, p = 0.04) on relative peak torque of dominant shoulder internal rotation at 120°.s^{-1}. The differences were statistically significant for the isotonic group only at the post-test compared to the pre-test value and at the post-1 month cessation test compared to the post-test value. However, there were no significant interaction and main time effects on relative peak torque of non-dominant shoulder internal rotation at 120°.s^{-1}.

Table 4 summarizes the descriptive data and the results of relative peak torque of dominant and non-dominant shoulder external rotation at 120°.s^{-1}. The general linear model mixed ANOVA with repeated measure design revealed significant time x group interaction and significant main time effects (df = 2, F = 5.069, p = 0.01) on relative peak torque of dominant shoulder external rotation at 120°.s^{-1}. Only in isokinetic group, the relative peak torque increase significantly at one month after training cessation, compared to the post test. However, for relative peak torque of non-dominant shoulder external rotation at 120°.s^{-1}, there were no significant time x group interaction, although there were significant main time effects (df=2, F=5.079, p=0.02) in isotonic group at one month after

Table 6. *Time to peak torque of shoulder joint external rotation at 120°.s^{-1}*

Groups	Isokinetic		Isotonic	
	Dominant (ms)	Non-dominant (ms)	Dominant (ms)	Non-dominant (ms)
Pre-test	619.37±234.45	481.87±312.49	583.12±298.71	454.54±252.97
Post-test	469.37±251.60	444.37±330.41	550.00±418.53	539.09±237.94
1 month after training cessation	570.00±282.41	445.00±291.73	353.12±287.04	277.73±237.72

Table 7. *Average power of shoulder joint internal rotation at 120°.s^{-1}*

Groups	Isokinetic		Isotonic	
	Dominant (W)	Non-dominant (W)	Dominant (W)	Non-dominant (W)
Pre-test	47.81±17.80	48.14±17.47	59.75±36.13	54.20±30.78
Post-test	45.51±14.07	42.86±13.07*	50.66±30.43	45.67±24.17*
1 month after training cessation	47.65±15.77	43.98±10.36	47.48±23.58	47.13±22.66

*Significant between timeline, $p<0.05$

Table 8. *Average power of shoulder joint external rotation at 120°.s^{-1}*

Groups	Isokinetic		Isotonic	
	Dominant (W)	Non-dominant (W)	Dominant (W)	Non-dominant (W)
Pre-test	27.86±9.93	26.74±9.56	32.83±16.12	31.00±14.66
Post-test	27.94±10.89	25.88±9.49	28.31±16.10	27.05±15.07
1 month after training cessation	31.60±8.06	28.93±8.06	32.02±12.09	29.50±14.22

training cessation.

Table 5 summarizes the descriptive data and the results of mean dominant and non-dominant shoulder internal rotation time to peak torque at 120°.s^{-1} following isokinetic and isotonic training. The general linear model mixed ANOVA with repeated measure design revealed no significant time x group interaction and no significant main time effects on mean dominant and non-dominant internal rotation time to peak torque at 120°.s^{-1}.

Table 6 summarizes the descriptive data and the results of mean dominant and non-dominant shoulder external rotation time to peak torque at 120°.s^{-1} following isokinetic and isotonic training. The general linear model mixed ANOVA with repeated measure design revealed no significant time x group interaction and no significant main time effects on mean dominant and non-dominant external rotation time to peak torque at 120°.s^{-1}.

Table 7 summarizes the descriptive data and the results of mean dominant and non-dominant shoulder internal rotation average power at 120°.s^{-1}. The general linear model mixed ANOVA with repeated measure design revealed no significant time x group interaction and no significant main time effects on mean dominant internal rotation average power at 120°.s^{-1}. However, there were no significant time x group interaction but significant main time effects (df=2, $F=5.665$, $p=0.01$) was observed on mean non-dominant internal rotation average power at 120°.s^{-1}. In both groups, average power decreased significantly at post-test compared to the respective pre-test values.

Table 9. Unilateral external to internal rotators muscular strength ratio at 120°.s^{-1}

Groups	Isokinetic		Isotonic	
	Dominant (%)	Non-dominant (%)	Dominant (%)	Non-dominant (%)
Pre-test	70.15±9.25	72.51±10.47	66.13±10.60	68.95±9.53
Post-test	78.47±24.71	72.14±21.30	73.76±18.29	68.63±10.08
1 month after training cessation	83.23±10.00	80.76±14.86*	76.79±9.75	87.68±26.92*

*Significant between timeline, $p<0.05$

Table 8 summarizes the descriptive data and the results of mean dominant and non-dominant external rotation average power at 120°.s^{-1}. The general linear model mixed ANOVA with repeated measure design revealed no significant time x group interaction and no significant main time effects on mean dominant and non-dominant external rotation average power at 120°.s^{-1}.

Table 9 summarizes the descriptive data and the results of mean dominant and non-dominant external to internal rotators muscular strength ratio at 120°.s^{-1}. The general linear model mixed ANOVA with repeated measure design revealed no significant time x group interaction but significant main effects of time (df=2, F=3.74, p=0.034) was observed on mean dominant external to internal rotators muscular strength ratio at 120°.s-1. Similarly, there were no significant time x group interaction but significant main effects of time (df=2, F=3.817, p=0.032) was observed on mean non-dominant external to internal rotators muscular strength ratio at 120°.s-1. The ratio increased significantly at one month after training cessation in both groups at both dominant and non-dominant sides.

Discussion

The main finding of the present study is there were no statistically significant differences in terms of strength, power and muscular strength ratio balance of rotator cuff muscles among advanced level of adolescent weightlifters following isokinetic and isotonic upper limb resistance training. Specifically, there was a trend of decrement in the right shoulder internal rotation peak torque/body weight, increment of time to peak torque and decrement of average power following isotonic training. In contrast, the right shoulder external rotation showed opposite results whereby the isokinetic group showed an increase of peak torque/body weight, a decrease of time to peak torque and an increase of average power. Furthermore, the present study found that both training resulted in decrement of the left shoulder internal rotation peak torque/body weight, increment of time to peak torque and decrement of average power.

In the previous study, Ellenbecker et al., (1988) reported an increase of peak torque and torque acceleration energy (e.g., muscle explosiveness) among recreational tennis player after six weeks of shoulder internal and external rotation isokinetic training at 60°.s^{-1}, 180°.s^{-1} and 210°.s^{-1} angular velocity. Similarly, it was reported that a significant increase of average power in both concentric and eccentric mode of muscle contraction were observed among sedentary females following eight weeks of training focusing on shoulder internal rotators (Heiderscheit et al., 1996). Their findings was similar to the present study as the high angular velocity applied for the training (e.g., 90°.s^{-1}, 120°.s^{-1}, 180°.s^{-1} and 240°.s^{-1}) showed an improvement in average power when tested at lower velocity (e.g., 120°.s^{-1}). It seems that high velocity training could significantly increase muscular power at both slow and fast velocity as concurred in previous studies (Coyle et al., 1981; Pipes & Wilmore, 1975; Moffroid & Whipple, 1970). However, only physically active participants were recruited in those researches, instead of advanced-level of weightlifting athletes as recruited in the present study. Therefore, the muscular adaptation may be different from advanced-level athletes. An advanced-level athlete may show small increment of power improvement since they had already developed their strength because further increment of power can only be achieved through increment of strength (Cormie et al., 2010).

Power can be defined as the ability to perform work in a short period of time. The explosive muscular power is emphasized in weightlifting sport (Calhoon & Fry, 1999). It was found that fast velocity isokinetic training was able to increase the rate of force development in the early phase of muscle contraction (de Oliveira et al., 2013). In our study, the data showed a trend of improvement due to decrement of time to peak torque after the training cessation but not at the post-test. This might be due to the delayed adaptation of the rotator cuff musculature immediately after the pre-test. Furthermore, following the power equation whereby power the product of force and velocity (Coyle et al., 1981; Kovaleski, 1995; Zatriosky, 2003), hence power increased when force (e.g., relative peak torque) was exerted in shorter duration (e.g., time to peak torque).

Previous studies had highlighted the importance of having a coordinated and synchronized action of the rotator cuff in order to achieve balanced strength throughout the whole ROM (Cools et al., 2002; Ludewig & Cook, 2000; Wadswoth & Bullock-Saxton, 1997). Malliou and colleagues (2003) noted that isokinetic is the most effective type of training in changing the ratio of the rotator cuff muscles compared to multi joint dynamic resistance training and dumbbell isotonic training. Besides, shoulder joint instability which is common among weightlifters due to extreme overhead shoulder flexion may be improved by balancing the strength of the rotator cuff muscles group (Calhoon & Fry, 1999). Furthermore, balance muscular strength is crucial to minimize the risk of getting shoulder injury and joint dysfunction (Ellenbecker & Roetert, 2003). In line with this view, Kang and colleagues (2013) agreed that the balance muscular strength of rotator cuff is critical especially when athletes need to maintain a heavy load above their head for a few seconds immediately after the jerk motion.

Several studies based on unilateral sports such as tennis and badminton had shown that the normative values of ER/IR ratio range between 66 and 75% (Cingel et al., 2007; Schlumberger et al., 2006). In the present study, the ratio values of ER/IR before the commencement of the intervention was found to be from 68.95±9.53% to 72.51±10.47% which is within the range of the normative values as described in previous literature. At post-test, the ratio values were ranged from 68.63±10.08% to 78.47±24.71% which was slightly higher than the prescribed values. However, after one month of training cessation, the ratio values were found to be out of the range (76.79±9.75% to 87.68±26.92%) although it was statistically not significant compared to the post-test value. This might be due to the shoulder muscular adaptation whereby the external rotation muscle is getting stronger as compared to the already strong internal rotators muscle. Our data showed a higher peak torque values of internal rotation compared to the peak torque values external rotation at pre-test and the gap in values tend to be closer at post-test and after one month of training cessation although the result was not statistically significant. Inclusion of EMG to evaluate muscle activity of the external and internal rotators may further clarify our findings.

Researches that involved advanced-level weightlifters participants are lacking, therefore more research should be carried out to investigate the effects of different modes of training and it cessation effects in this specific population. Additionally, since both groups were consisted of advanced-level weightlifters, therefore even a small percentage of differences are crucial in impacting their performance. Furthermore, studies regarding rotator cuff activity during clean and jerk are scarce. This might be due to over emphasized of muscle activity studies during snatch as it is more technically demanding than clean and jerk. Therefore, more research should be done in investigating the role and activation patterns of the rotator cuff in both events of competitive weightlifting.

Conclusions

There was a trend that indicated positive changes in the biomechanical adaptations of the rotator cuff in the isokinetic group compared to the isotonic group in terms of peak torque/body weight, time to peak torque and average power. Despite that these changes are not significant, among advanced level of athletes, even a small change may distinguish their performance outcomes. In conclusion, both isokinetic and isotonic training specifically for rotator cuff has a potential to be proposed as an additional training among experienced weightlifters to improve their performance.

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