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Effects of a Resistance Training Programme on Isokinetic Peak Torque and Anaerobic Power of 13-16 Years Old Taekwondo Athletes

Running Head: Resistance Training and Taekwondo Athletes

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Abstract. The purpose of this study was to determine the effect of a 12 week (2 days per week) resistance training programme at an intensity of 50% of 1RM in adolescent males (13-16 years old) male taekwondo athletes on their isokinetic peak torque and anaerobic power. The intervention group (n=12) aged 14±1 years, participated in the prescribed resistance training programme along with the existing taekwondo skill/drill training (2 days/week), while the control group (n=11) aged 14±1 years, participated in an existing taekwondo skill/drill training only. Anaerobic power was estimated from Wingate anaerobic test. An isokinetic dynamometer (Biodex multi-joint system 3 pro, New York) was used in the collection of data from the knee (flexion/extension) and hip (flexion, extension, abduction and adduction) joints. Mean anaerobic power and peak anaerobic power in the intervention group increased 9% and 10%, respectively. However, these two variables in the control group significantly decreased from mid training to post training (11.5% and 16% respectively), (p<0.001). There were no significant increase in peak torque, relative peak torque, average torque and average power on knee extension/flexion and hip extension/flexion in the intervention group. However, isokinetic hip average adduction power significantly (32%) increased from pre to mid training (p<0.01) in the intervention group. In the control group, there were significant decreased on isokinetic hip average flexion power (22%) and isokinetic hip average abduction power (34%) from pre to post training and mid to post training respectively (p<0.01). Hence it is concluded that the prescribed resistance training was able to elicit a significant increase in some of the isokinetic strength variables. However, it did not administer any effect on anaerobic power of the taekwondo athletes.

Keywords: Anaerobic power, Isokinetic strength, 1 repetition maximum, Extension, Flexion, Abduction, Adduction

1. Introduction

Resistance training programme has gained great popularity in recent years. It acts as an integral part of a total strength and conditioning programme for the enhancement of athletic performance and also prescribed by many major health organisations, recreational and clinical communities for improving health, fitness and also in rehabilitation. (Pearson *et al.*, 2000; ACSM, 2002; Chetlin, 2002).

Resistance training programme for preadolescents and adolescents age groups, are generally similar (Fleck and Kraemer, 2004). Strength gains have been reported using adult and child sized weight machines, free weights, hydraulic machines, isometric exercises, wrestling drills, modified pull ups and callisthenics (Weltman *et al.*, 1986, Faigenbaum, 1993, Ozmun *et al.*, 1994, Faigenbaum *et al.*,1996). Furthermore, the

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latest research indicates that both children and adolescents can increase muscular strength as a consequence of strength training. This increase in strength is largely related to the intensity and volume of loading and appears to be the result of an increased neuromuscular activation and coordination, rather than muscle hypertrophy (Guy and Micheli, 2001).

Reports indicated that resistance training may improve motor performance; strength of the muscles, ligaments and bones in youth (Faigenbaum, 2000, Faigebaum, 2001). In addition, resistance training helps to prevent or reduce injuries in sports and recreational activities and may favourably alter selected anatomic and psychosocial variables (Faigebaum *et al.*, 1999, Faigenbaum, 1995, Faigenbaum *et al.*, 1996). Resistance training has become popular among prepubescent and adolescents over the last decade and has received attention as an important component of youth fitness programme (Picosky *et al.*, 2002).

Some studies have reported that loads of 45-50% of 1 repetition maximum (1RM) in adults, young men and women, has lead to an increase in dynamic muscular strength following 7 to 20 weeks of resistance training at a rate of 3 days per week (Sale *et al.*, 1990, Stone and Coulter, 1994, Weiss *et al.*, 1999). It appears that resistance training frequency of twice per week was sufficient to can induce strength gains in adolescents. However, the duration and intensity of the training programme varied (Falk and Tenenbaum, 1996). Strength gains of _74% has also been reported in 10 years old children following progressive resistance training for 8 weeks at a rate of 2 sessions/week (Faigenbaum *et al.*,1993). Weiss et al. (1999) found that resistance trained groups were trained three per weeks with 4 sets of squats exercise were significantly increased in knee extension peak torque at 60º/s but not in knee flexion peak torque. The majority of previous pediatric studies have examined concentric isokinetic knee extension and flexion torques only (De Ste Croix *et al.*, 2003). To date, no information is available on isokinetic leg strength of adolescent taekwondo athletes while it has been reported in other sports like soccer, football, wrestles, skiing and gymnastics (Gerodimos *et al.*, 2003). Hence, the objectives of the present study were to investigate the effects of a 50% of 1RM resistance training programme in adolescent male taekwondo athletes of 13 – 16 yrs old on anaerobic power and isokinetic torque production during extension and flexion at knee and hip joint and adduction and abduction of the hip joints. This might have been brought about by the fact that taekwondo fighting (3-5 seconds bouts maximal exercise alternating between 1:3 and 1:4 ratios with low intensity periods) imposes high demands on short term anaerobic performance capacity and the ability to recover, but with little fatigueability during high intensity intermittent exercise. This corresponds to the physiological characteristic of taekwondo athletes (Heller *et al.*, 1998).

2. Method

2.1. Subjects

Twenty three boys of 13-16 years age group having 1 year experience in taekwondo training volunteered to take part in this study. No participant had any prior resistance training experience. Subjects were age and weight-matched before they were randomly assigned to an intervention (n=12) and a control group (n=11). A simple randomisation method of drawing lots was conducted. Subjects were given an explanation on the objectives and the protocol of this research project. The study was approved by the Universiti Sains Malaysia Research and Ethical Committee. Subjects in the control group followed the existing taekwondo skill training (2 times per week) in Lee Taekwondo Academy, Kota Bharu, Malaysia. Subjects in the intervention group had been prescribed with an intervention programme which involved resistance training (2 times per week for 12 weeks) besides continuing with the pre-existing taekwondo skill training. Subjects in the intervention group participated in pre training test and an introductory training session before the resistance training programme. Elastic bands were included into resistance training programme to perform hip adduction and abduction exercises only. During this time, subjects were taught the proper technique for each exercise, one repetition maximum (1RM) and selection of elastic bands for each individual was determined. Then, both the groups continued with their existing taekwondo skill training that was conducted by their taekwondo instructor. However, the intervention group underwent an additional prescribed resistance training programme for 12 weeks. At the end of 6th week, subjects underwent mid training test and new 1RM was determined before the subjects continued with the resistance training programme. The new 50% of 1RM was used for the second 6 weeks. Post training test was conducted at the end of 12th week.

2.2. Procedure

2.2.1 One Repetition Maximum (1RM) Testing Protocol

Subjects in the intervention group were required to undergo one repetition maximum testing a week before resistance training and 6 week after the resistance training programme. 1RM for each exercise was determined for each subject. This was used to determine the training load. 1RM of each taekwondo player has been determined following protocol of Fleck and Kraemer (2004). The subjects were asked to perform 10RM testing i.e. (the heaviest load that can be lifted 10 times with proper technique). Then 1RM was estimated from the 10RM using a table.

2.2.2 Resistance Training Programme

Subjects in the intervention group were required to follow a prescribed resistance programme (Table 1) for 12 weeks. Prior to each resistance training session, the subjects were required to perform a warm up session. This session consisted of 15 min of low intensity aerobic and stretching exercises. All the subjects were given a form to record relevant information regarding the resistance training programme. The appropriate loads for each individual were stated in the forms. Subjects followed the alternate upper and lower body exercises principle and alternate ‘push’ and ‘pull’ exercise principle (Fleck and Kraemer, 2004). The combination of this method was used because subjects had not done any resistance training before. The push-pull method ensure that the same muscle group will not be used for two exercises in a row, thus diminishing fatigue in the involve muscles (Fleck and Kraemer, 2004). At the end of the training session, the subjects were required to cool down.

Table 1: Resistance training programme

Exercise	Sets /Repetitions/ Intensity
Half Squat	3 / 10/ 50% of 1 RM
Bench press	3 / 10/ 50% of 1 RM
Knee extension	3 / 10/ 50% of 1 RM
Leg curl	3 / 10/ 50% of 1 RM
Lateral pull	3 / 10/ 50% of 1 RM
Hip adduction (exercise band)	3 / 10/Elastic Band
Hip abduction (exercise band)	3 / 10/Elastic Band

2.2.3 Selection of Exercise Band

The facilities did not permit to provide the hip abduction and adduction exercises on the available weight machine. Hence the exercise elastic bands were used. Exercise bands used were acquired from Duraset Equipment Sdn Bhd, Selangor, Malaysia. Various resistance levels of the bands were provided but only three types of exercise bands were used for the subjects which the four exercise bands were color coded according to their resistance level (Table 2). Subjects started with the bands that they can perform the exercise in the correct form and able to achieve one set of 10 repetition. Progression to the higher resistance exercise band depended on individual’s progress and capabilities.

Table 2. The classification of exercise bands

Resistance	Colour	Pull Force (kgf) @ 300% extension
Medium	Green	5.5-5.9
Heavy	Pink	6.5-7.0
Strong	Purple	8.3-8.9
Extra strong	Silver	8.6-8.9

2.2.4 Anaerobic power test

Subjects performed a 30-s maximal cycle exercise test on an Excalibur sport ergometer (Lode Groningen, Netherlands). All the subjects performed the test in the morning on separate days. A warm-up session was suggested for optimal performance on the Wingate anaerobic test. The warm-up included 5 minutes of low to moderate intensity, pedaling at about 50 rpm to 60 rpm, interspersed by four or five all-out sprints of 4-s to 6-s duration. The warm-up serves to increase muscle temperature and blood flow (Malina, 2004).

Immediately before the 30-s Wingate anaerobic test, all subjects completed 1 min of cycling at 50W. Then, the subjects pedalled as rapidly as possible with the range between 80-140 rpm for 30s with verbal encouragement from the researcher. Subjects must remain seated for the entire duration of the test. Participants who lifted the buttocks off the seat create an unfair mechanical advantage and also skews the final results (Bar-Or, 1987). Once the wingate test was completed, the subjects were allowed to cycle without any resistance (braking force) for about 5 minutes as a form of cooling down session.

2.2.5 Isokinetic tests

An isokinetic dynamometer (Biodex multi-joint system 3 pro, New York) was used in the collection of data from the knee (flexion/extension) and hip (flexion, extension, abduction and adduction) joints. Strict adherence to the guidelines of the Biodex isokinetic dynamometer operations manual was followed. A warm-up session as a familiarisation period preceded each action of isokinetic test. Subject's descriptive data (height, weight, age, dominant and undominant leg was keyed into the computer programme prior warm-up session. The warm up session included 3 sub maximal (50% effort) followed by 3 maximal (100% effort) repetitions (Perrin, 1993). After the warm-up, the subjects rested for 10 minutes before performing the actual testing. In the actual test, the subjects were required to do 4 maximal repetitions for each action of isokinetic test. The speed was kept constant at 60 ^{o}/sec in all the measurements. The actions tested were extension and flexion for the knee joint and extension, flexion, adduction and abduction for the hip joint.

2.2.5.1 Knee Extension/Flexion Protocol

Subject sat in a comfortable position on the Biodex accessory chair and was secured using thigh, pelvic and torso straps in order to minimise extravenous body movement during the test. Shoulder straps were applied diagonally across the chest with the subject's arms crossed and their palms touching opposite shoulders to attenuate excessive upper body movement and muscular substitution. Dynamometer was rotated to 90 degrees. Then, it was slided along the travel to position outside leg to be tested. Knee attachment was attached to the dynamometer. Subsequently, the dynamometer shaft red dot was aligned with the red dot on the attachment. The subject was then moved into position. The lateral femoral epicondyle was used as the bony landmark for matching the axis of rotation of the knee joint with the axis of rotation of the dynamometer shaft red dot. The calf pad was placed 2 inches proximal to the lateral malleolus and secured with the padded shin strap. All positions were recorded for consistency and reproducibility for subsequent data collection sessions. Range of motion (ROM) was taken before performing the test. On completion of the test on one leg, thigh strap was unstrapped. Subsequently, the same protocol was followed with the opposite leg.

2.2.5. 2 Hip Extension/Flexion (supine) Protocol

Subject laid supine on the chair and was secured using single shoulder strap which was applied diagonally across the chest. The subject's arms were crossed and their palms touching opposite shoulders to attenuate excessive upper body movement. Left or right hip attachment was attached to dynamometer shaft. Subsequently, the dynamometer shaft red dot was aligned with the red dot on the attachment. The chair and dynamometer were adjusted so that shaft aligned with the axis of rotation of the hip. The axis of rotation of the hip in this pattern was slightly superior and anterior to the greater trochanter. Hip attachment length was adjusted so that thigh support was just superior to the popliteal fossa. The pad were positioned anteriorly on the thigh and secured by wrapping the padded strap snugly around the thigh. Subject moved his leg through a range of motion to check for proper alignment and subject's comfort. The same protocol was applied for the opposite side.

2.2.5. 3 Hip Abduction/Adduction (Lying on side) Protocol

Subject laid side way on the chair with hip to be tested on top. The left or right hip attachment was attached to the dynamometer shaft. Subsequently, the dynamometer shaft red dot was aligned with the red dot on the attachment. Subject was required to face away from dynamometer with hip axis of rotation aligned with dynamometer input shaft. The dynamometer shaft was aligned with axis of rotation for the upper hip. After that, the attachment length was adjusted so that the pad was positioned just superior to the popliteal fossa and secured by wrapping the padded strap snugly around the thigh. Subject moved his leg through range of motion to check for proper alignment and subject's comfort. The same protocol was applied for the opposite side.

2.3. Statistical Analysis

Repeated measure ANOVA was used to determine the differences in isokinetic strength variables and anaerobic power over time between trials. Bonferroni adjustment for multiple comparisons was used to locate the differences when repeated measures analysis of variance revealed a significant main effect of time.

The Statistical Programme for Social Sciences (SPSS) software version 12.0.1 was used for statistical analysis. The accepted level of significant was set at p<0.05. Results were reported as mean ± standard deviation (SD).

3. RESULTS

The physical variables for intervention and control groups are shown in Table 3.

Table3. Physical characteristics of the intervention and control groups during the experimental period. Values are Mean ± SD

	Intervention Group (n = 12)			Control Group (n = 11)		
	Pre training	Mid training	Post training	Pre training	Mid training	Post training
Height (cm)	160.0 ± 7.1	160.5 ± 6.9	161.4 ± 6.6	162.1 ± 8.9	162.6 ± 9.2	163.6 ± 8.9
Weight (kg)	47.7 ± 9.4	48.2 ± 9.2	48.6 ± 8.8	49.8 ± 7.4	50.8 ± 7.6	51.7 ± 7.8
Body Fat (%)	20.6 ± 6.7	20.8 ± 7.0	20.2 ± 6.6	18.3 ± 4.1	18.7 ± 3.8	18.5 ± 4.2
Body Mass Index	18.6 ± 3.7	18.8 ± 3.6	18.7 ± 3.3	19.0 ± 2.1	19.2 ± 2.1	19.3 ± 2.1

3.1. Wingate Anaerobic Test

Table 4 displayed the peak and average anaerobic power data for the intervention and control groups. The peak anaerobic power and the mean anaerobic power of the control and experimental subjects during pre, mid and post training are shown in Table 4. The peak anaerobic power in the control group decreased significantly to 15% from mid training to post training (p<0.05). However, there were no significant changes in peak anaerobic power in the intervention group at the three times points. Nevertheless, the intervention group gained 9% on peak anaerobic power after 6 weeks of resistance training programme and this gain was sustained for the following 6 weeks. However, this gain was not statistically significant. The mean anaerobic power in the control group also decreased significantly by 11.5% from mid training to post training (p<0.05). Intervention group gained 9% on mean anaerobic power after 6 weeks and it was maintained until week 12 with resistance training.

Table 4. Peak and average anaerobic power (Values are presented as Means ± SD).

	Intervention Group (n=12)			Control Group (n11)		
	Pre training	Mid training	Post training	Pre training	Mid training	Post training
Peak Anaerobic Power (Watt)	451.42 ± 70.70	491.25 ± 89.33	495.92 ± 74.74	538.45 ± 95.17	550.73 ± 97.63	464.00 ± 88.02
Mean Anaerobic Power (Watt)	343.22 ± 91.66	373.00 ± 101.31	373.65 ± 87.22	432.57 ± 96.73	439.56 ± 82.4	389.46 ± 70.10

3.2. Isokinetic Peak Torque

3.2.1 Knee flexion

The isokinetic knee peak flexion torque of the control and experimental subjects during pre, mid and post are shown in Figure 1. No significant differences in isokinetic knee peak flexion torque were observed between groups at all time points.

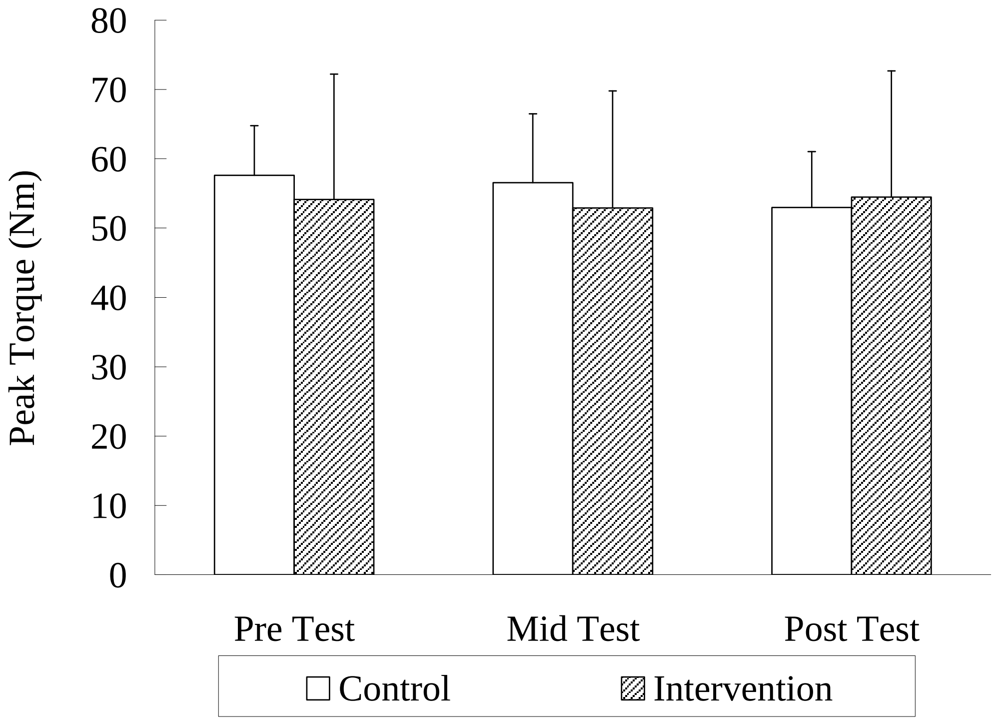

Figure 1: Peak torque during knee flexion at pre, mid and post training.

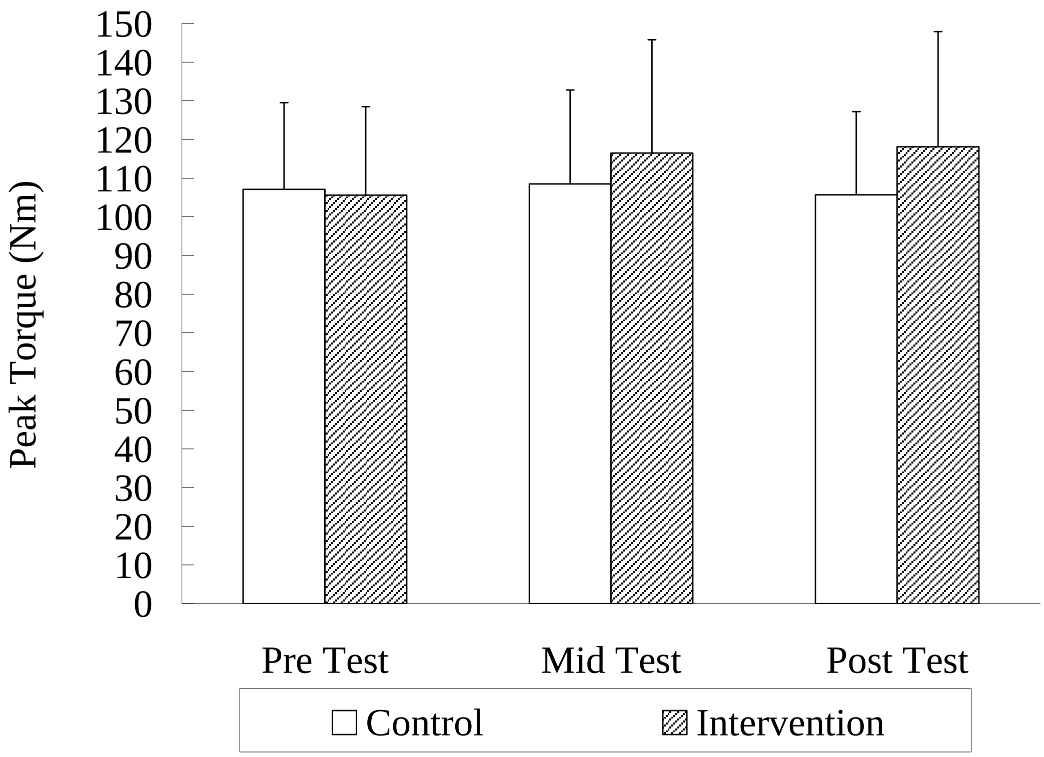

Figure 2. Peak torque during knee extension at pre, mid and post training

3.2.2 Knee extension

The isokinetic knee peak extension torque of the control and experimental subjects during pre, mid and post training are shown in Figure 2. No significant main effect of time on isokinetic knee peak extension torque was observed (F=2.678; df =1.48, 31.08; p=0.098). In addition, there was also no interaction between time and intervention on isokinetic knee peak extension torque (F=2.963; df =1.48, 31.08; p=0.08). Compared to pre training, isokinetic knee peak extension torque increased 10% in the intervention group after 6 weeks and 2% following another 6 weeks of training. However, these changes were not statistically significant. Isokinetic knee peak extension torque in the control group remained almost same after 12 weeks.

3.2.3 Hip flexion

The isokinetic hip peak flexion torque of the control and experimental subjects during pre, mid and post training are shown in Figure 3. ANOVA for repeated measures showed that there was no significant main effect of time on isokinetic hip peak flexion torque (F=1.069; df =1.476, 30.99; p=0.337). However, there was a significant interaction between time and intervention (F=3.726; df =1.476, 30.99; p<0.05) on isokinetic hip peak flexion torque. Pairwise comparison, corrected by using a Bonferroni adjustment revealed that there were no significant differences during three tests for both groups.

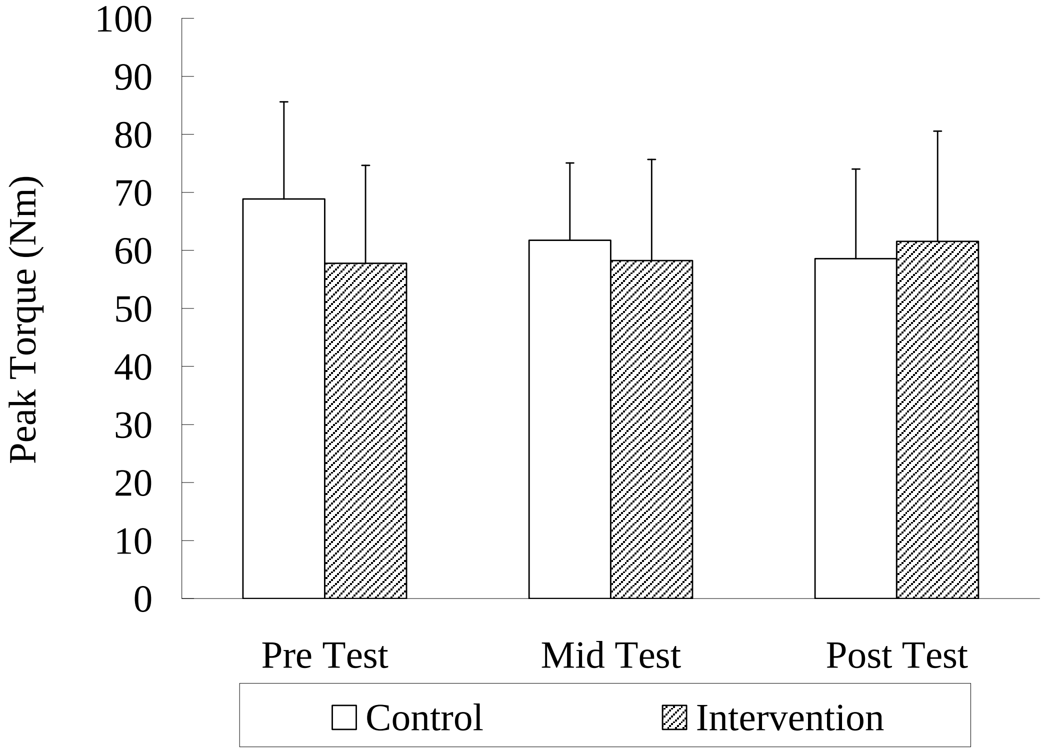

Figure 3: Peak torque during hip flexion at pre, mid and post training

3.2.4 Hip extension

Peak torque and relative peak torque in the intervention group increased 17% and 14% respectively after 6 weeks and it was maintained for another 6 weeks with resistance training. On the other hand, relative peak hip extension torque in the control group decreased 13% after 6 weeks. Compared to the pre test, average torque and power significantly increased 23% and 26%(p<0.05) in the intervention group after 12 weeks and 6 weeks respectively. Table 4 showed that the average power data for the intervention and control group

The isokinetic hip peak extension torque of the control and experimental subjects during pre, mid and post training are shown in Figure 4.16. From ANOVA with repeated measures, there was no significant main effect of time on isokinetic hip peak extension torque (F=0.115; df =2, 42; p=0.892).

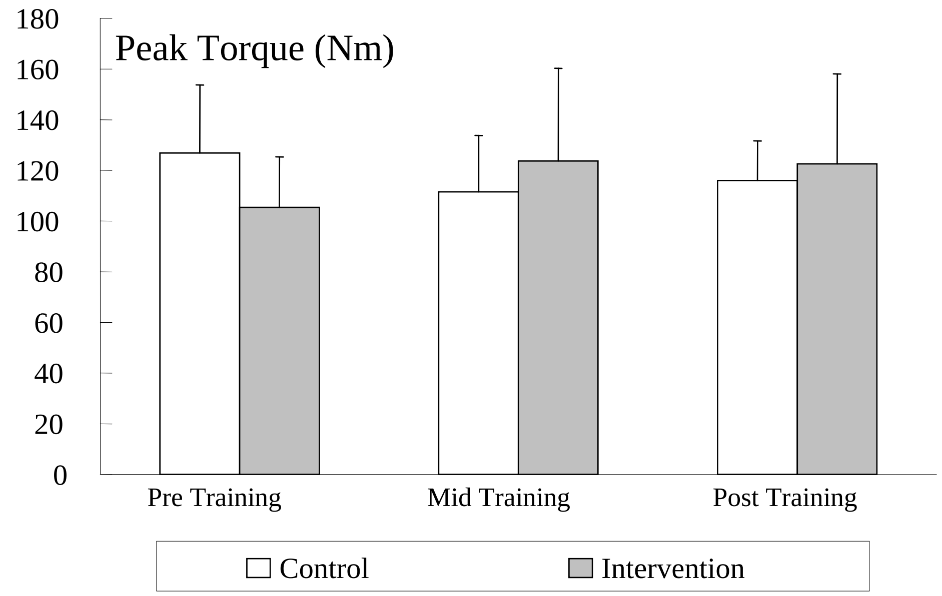

Figure 4. Peak torque during hip extension at pre, mid and post tests

Bonferroni adjustment indicated that there were no significant differences for both groups across tests. Compared with pre test, isokinetic hip peak extension torque in the intervention group increased 17% after 6 weeks and it was maintained for another 6 weeks with resistance training. On other hand, isokinetic hip peak extension torque in the control group did not change during the experimental period.

3.2.5 Hip adduction

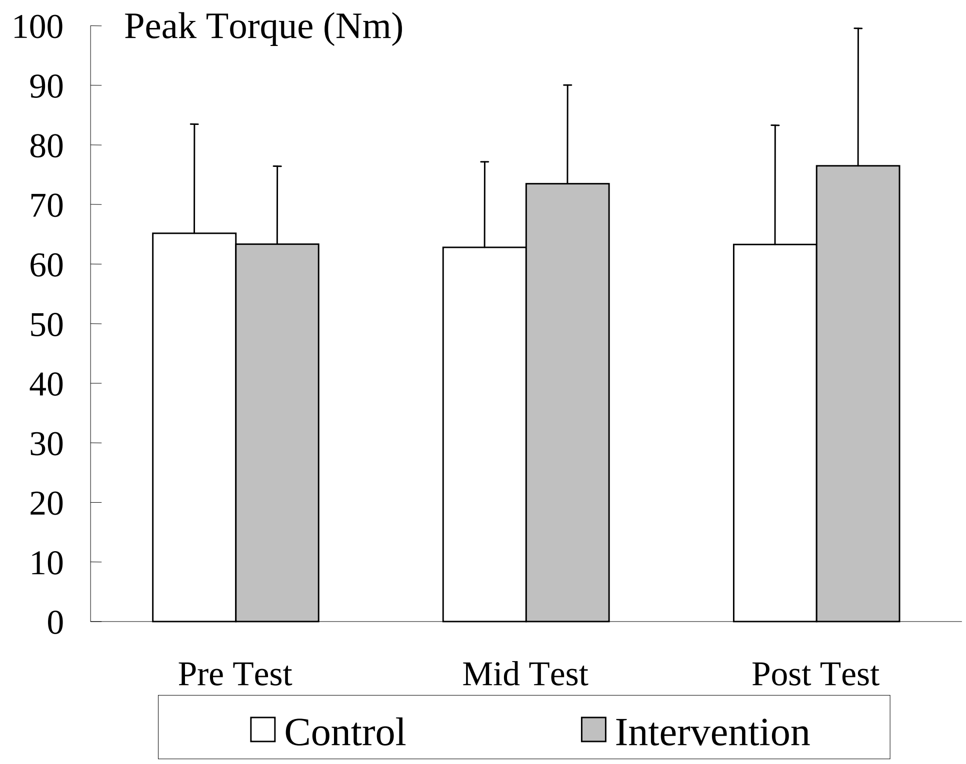

Figure 5. Peak torque during hip adduction at pre, mid and post tests

The isokinetic hip peak adduction torque of the control and experimental subjects during pre, mid and post training are shown in Figure 4.20. ANOVA for repeated measures indicated that there was no significant main effect of time on isokinetic hip peak adduction torque (F=0.640; df =2, 42; p=0.532) and there was no significant interaction between time and intervention (F=1.254; df =2, 42; p=0.296) on isokinetic hip peak adduction torque. Compared to pre training, isokinetic hip peak adduction torque in the intervention group increased 16% in mid and 21% in the post training period. On the other hand, isokinetic hip peak adduction torque in control group did not change after 12 weeks of experimental period.

3.2.6 Hip abduction

The isokinetic hip peak abduction torque of the control and experimental subjects during pre, mid and post training are shown in Figure 4.24. ANOVA for repeated measures indicated that there was no significant main effect of time on isokinetic hip peak abduction torque (F=0.159; df =2, 42; p=0.854) and no significant interaction between time and intervention (F=1.765; df =2, 42; p=0.184) on isokinetic hip peak abduction torque. Isokinetic hip peak abduction torque in the intervention group increased 8% after 12 weeks but this difference was not statistically significant. In contrast, there were no significant differences in isokinetic hip peak abduction torque in the control group after 12 weeks. There were no significant differences between groups at all time points.

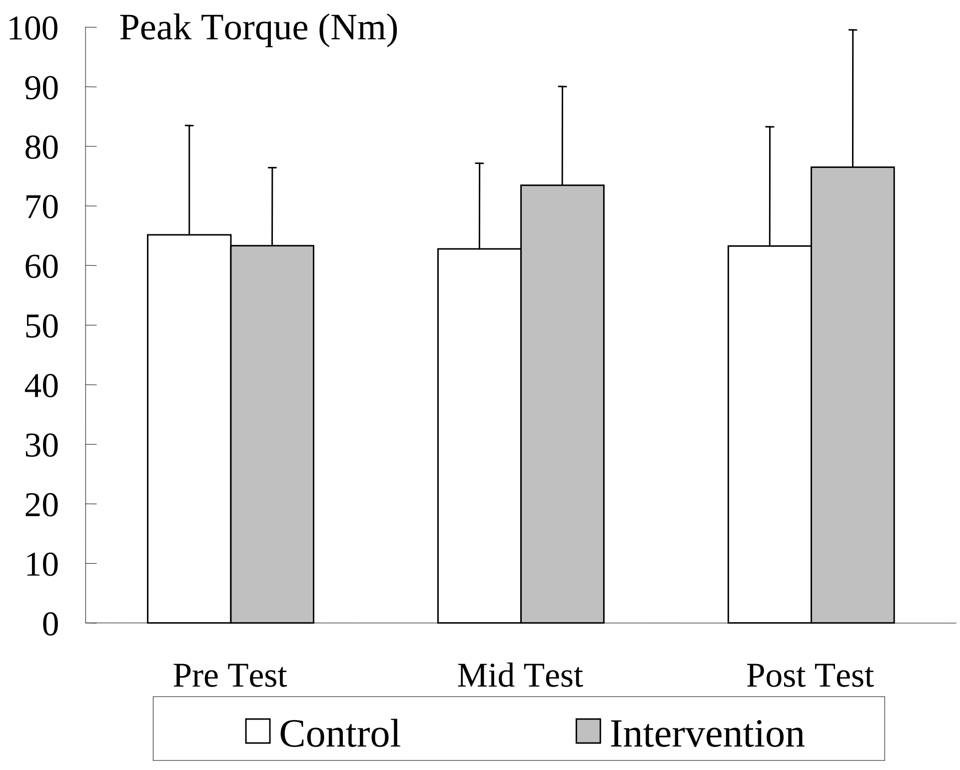

Figure 6. Peak torque during hip abduction at pre, mid and post tests

4. DISCUSSION

Peak anaerobic power reflects short-term anaerobic performance and mean anaerobic power reflects intermediate-term performance (Malina *et al*., 2004). Factors determining the anaerobic performance include morphological (muscle architecture and fiber type), physiological (efficiency of metabolic pathway), biochemical (substrate availability and accumulation of reaction products) and neuromotor (motor skill and motor unit recruitment) variables. The amount of muscle mass, especially the thigh muscle cross-sectional area has a direct consequence on the absolute anaerobic power output that can be generated. In addition, the amount of type II muscle fibers also considered as a factor influencing maximal peak anaerobic power achieved by individual (Sargeant *et al.*, 1984). These factors could have contributed the initial differences between control and intervention groups in peak and mean power although they were age and weight-matched. Present study indicated that 12 weeks of 50% of 1RM resistance training (twice a week) was able to increase peak and mean anaerobic power marginally in the subjects, but not stastiscally significant.

Hetzeler *et al.* (1997) also observed that a 12 week resistance training programme with free weights and machines (3 times a week) did not improve the relative anaerobic power in adolescent male athletes.

Chromiak *et al.* (2004) showed that the relative anaerobic power of physically active adults increased significantly following a 10 weeks of periodised strength training programme consisting of 4 days of training a week, In our study, a 12 week resistance training programme of 2 days a week showed that the relative anaerobic power though not increased significantly but did show a trend of improvement. The values for the relative peak torque for knee flexion and extension in the present study were comparable to the values for the same parameters obtained in other study by Hussey *et al.* (2002).

The decline in isokinetic strength observed in the control group compared with the pre-post test intervention may reflect a lack of functional adaptation and lesser degree of general muscular conditioning in the absence of a resistance training programme. Actually, in our study, the intervention group was having a 2 days per week extra training programme than the control group. Resistance training using elastic bands also did not influence the peak torque significantly. The training load used in the present study was moderately low at 50% of 1RM. However, in previous studies when the load was greater than 50% of 1 RM, significant increase were observed in isokinetic, isotonic and isometric strength of upper and lower body (Weltman *et al.*, 1986, Faigenbaum *et al.*, 1993, Faigenbaum *et al.*, 1996, Treuth *et al.*, 1998).

On the other hand, the prescribed resistance training did not show any significant increase in flexion and extension for the knee and hip joints. Similarly, it has been reported that six weeks of strength and proprioception training had no effect on isokinetic measures of strength on ankle inversion and eversion (Kaminski *et al.*, 2003). This finding could be attributed to the lack of specificity of the exercises and also the different modes in testing. Weltman *et al.* (1986) demonstrated that there was a significant strength increase in the knee and elbow joints when resistance training (3 days per week for 14 weeks) was carried out using hydraulic system.

Thus, the issue in the specificity of training can influence the strength gains. When training and testing are performed using the same type of resistant equipment, a large increase in strength is normally demonstrated. If training and testing are performed on two different types of equipment, the increase in strength normally is substantially less and sometimes non-existent (Fleck and Kraemer, 2004). This specificity of the response to resistance training is understandable because strength improvement is related to the adaptations that occur both in the muscle fiber itself and in the neural organisation and excitability for a particular pattern of voluntary movement (Kovaleski and Heitman, 2001).

5. Conclusion

There are relatively few comparable reports on anaerobic power abilities and isokinetic strength for combat athletes especially after following a resistance training programme. Thus, the comparison of the results in the present study with the previous studies were less. Under the conditions set up for this study, we concluded that prescribed resistance training programme (three sets of 10 repetitions with the intensity of 50% of 1 RM, 2 days per week) did not confer an overall significant increase in isokinetic peak torque and anaerobic power. But a trend was observed in the improvement of these variables. in the intervention group.

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