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PREVENTION & REHABILITATION: ORIGINAL RESEARCH STUDY

The effects of strengthening exercises for wrist flexors and extensors on muscle strength and counter-stroke performance in amateur table tennis players

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ABSTRACT

This study aims to evaluate the effects of strengthening exercises on wrist flexor and extensor strength, hand grip strength, and counter-stroke performance. Thirty amateur table tennis players were recruited and randomly allocated into two groups: the control and the training group (n = 15/group). Pre- and post-data were collected. The training group performed home exercises for six weeks using a bucket filled with water, while the controls were asked to keep their lifestyle as usual. The general characteristics were no significant differences. The training group showed significantly higher levels of wrist flexor and extensor strength than the control group ($p < 0.05$). However, the difference in hand grip strength was not statistically significant. Both groups showed significant improvement in counter-stroke performance ($p < 0.05$), however, there was no difference between the groups. In conclusion, specific strengthening exercises increase wrist flexor and extensor strength, but they have no effect on either hand grip strength or counter-stroke performance.

1. Introduction

Muscle strength plays a crucial role in determining speed and power in athletic performance. Although an individual's performance is primarily determined by the specific skills, greater strength leads to a higher potential for athletic performance, especially for untrained individuals. Table tennis is a sport that requires rapid movements, and stroke speed is one of the keys to success (The International Table Tennis Federation Handbook, 2014–2015). Exercises that strengthen wrist muscles can improve the stroke performance of table tennis players by increasing speed and power. A previous study shows hand grip strength is greater in the dominant hand versus the non-dominant hand in young top-level table tennis players (Carrasco et al., 2010). However, another study shows contradicting results in top-level female athletes (Ivanovic and Dopsaj, 2012). These opposite results may suggest the functional complexity of wrist and forearm muscles. A number of studies have been conducted on table tennis players' performance, including stroke performance. However, there are no reports about the effect of wrist-strengthening exercises on hand grip strength and counter-stoke performance. Strengthening exercises for table tennis players should be selected based on the specific movements involved, such as strokes. Therefore, this study aimed to evaluate the effect of strengthening exercises on wrist flexor and extensor

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strength, hand grip strength, and counter-stroke performance of amateur table tennis players.

2. Methods

2.1. Subjects

Thirty amateur table tennis players between the ages of 19 and 28 were recruited through an information poster at the university table tennis gymnasium. The subjects were randomly allocated into two groups: the control group (n = 15, CON) and the training group (n = 15, TR). A self-administered questionnaire was used to collect personal and medical history. All subjects were healthy and had no exclusionary criteria (hypertension, syncope, history of hand or forearm fracture, or previous surgery in the hand or forearm < 6 months). The study was approved by the Khon Kaen University Ethical Committee (HE582136), and written informed consent was obtained from each subject.

2.2. Experimental procedures

The subjects were randomly assigned using computer generated random numbers. Then a block randomization was employed to random the subjects into the TR and the CON groups. Wrist flexor and extensor strength, hand grip strength, and counter-stroke performance was measured for each subject before and after the six-week program using the alternate counter test. Subjects in the TR group were given a booklet in which the details inside explained wrist flexor and extensor strengthening exercise protocol at home and included the diary for recording the exercise session they performed. The subjects who had exercised adherence less than 90% were withdrawn from the study. Subjects in the CON group were asked to keep their lifestyle as usual during the six-week experiment. The protocol of this study shows in Fig. 1.

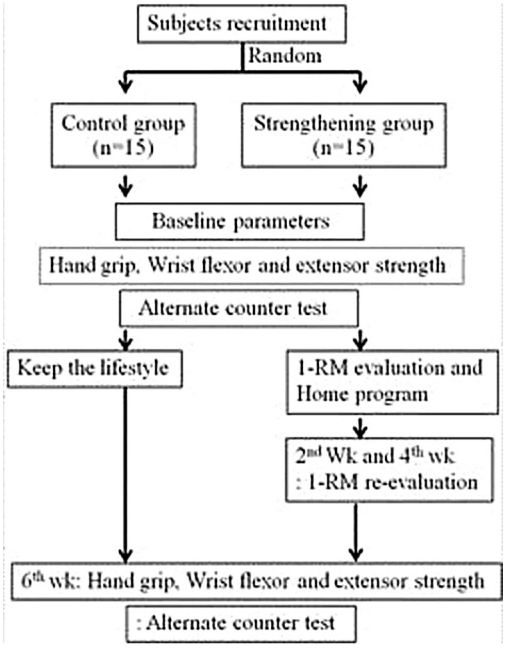

Fig. 1. The flow diagram of this study.

2.3. Measurements

2.3.1. Wrist flexor strength (WFS) and wrist extensor strength (WES)

WFS and WES were evaluated with a push-pull dynamometer (Baseline evaluation instruments® 250#). After 2–3 min of independent warm-up, the subjects were instructed to sit on a chair with forearm resting on a table and wrist and hand over the edge. The forearm position was pronated for wrist extensor and supinated for wrist flexor evaluation. Then, subjects were asked to extend or flex against the push pads as hard as possible when given the appropriate command. The procedure was performed two times; each contraction was held for 6 s and rest between trials was 2 min. The subjects were encouraged to breathe normally to avoid any increase in blood pressure. Then, the higher of the two force measurements was recorded.

2.3.2. Hand grip strength (HGS)

HGS was evaluated with a hand grip dynamometer (T.K.K. 5001 grip-a®). The subjects stood in an upright position with both arms resting in a natural posture alongside the body. The test hand held the dynamometer with the probe approximately 10 cm away from the body. The procedure was performed two times; rest between trials was 2 min. Then, the higher force was recorded.

2.3.3. Alternate counter test (ACT)

ACT was used to evaluate the counter-stroke performance of the table tennis players (Purashwani et al., 2010). After 5–10 min of warm-up and practice, the subjects were instructed to perform the alternate counter test. They were asked to make the number of rallies of alternate counter (one forehand and one backhand) with the controller for a period of 30 s. The number of balls returned to the controller was counted by an observer. The procedure was performed two times; rest between trials was 5 min. The higher of the two numbers was recorded.

2.4. Exercise training intervention

The TR group was shown how to perform wrist flexor and extensor exercises at home with a bucket of water (Söderberg et al., 2012). The bucket weight for each subject was 60% of the 1-RM (Repetition Maximum: the maximum weight with which exactly one repetition of an exercise can be safely executed) of wrist flexor strength individually. In addition, the 1-RM was re-evaluated at the second and fourth week respectively. A scale with load capacity of up to 50 kg with graduation to 100 g precisely (SOEHNLE®, Germany) was used to weight a bucket of water. After that, the water level was marked with a permanent marker to ensure the same water level for home exercise. Before exercise, subjects were instructed to warm-up for wrist flexor and extensor for 2 min. Then, they were instructed to perform the exercise in the same position used to evaluate wrist flexor and extensor strength. All subjects performed 8 times/set, 3 sets/day and 3 days/week. The resting period between the set was 2 min (Franklin and Balady, 2006). In addition, they were instructed to keep their diary to monitor their exercise adherence and received weekly phone calls to encourage the exercise.

2.5. Data analysis

Data analysis was performed using STATA-10.1. The Shapiro-Wilk test was used to evaluate the data normality. Then all parameters were analyzed with parametric statistics, using paired *t*-test for comparison within each group and ANCOVA for comparison between the groups, expressed as mean ± SD. A value of $p < 0.05$ was considered to be statistically significant.

3. Results

There were no significant differences in general characteristics

Table 1
General characteristic of the subjects.

	CON (n = 15)	TR (n = 15)
Age (yr)	23 ± 5	21 ± 2
Gender (Male:Female)	14:1	13:2
Body weight (kg)	65 ± 17	63 ± 17
Waist circumference (cm)	77.2 ± 13.1	76.6 ± 13.1
Hip circumference (cm)	94.0 ± 12.2	94.3 ± 13.4
WHR	0.82 ± 0.07	0.81 ± 0.07
Medical history (Yes:No)$^{\beta}$	1:14	2:13
Experience (yr)	7 ± 4	8 ± 3
Practice		
Duration (hr/time)	3 ± 1	2 ± 1
Frequency (times/wk)	4 ± 2	3 ± 2

Data are presented as mean ± SD. WHR: waist to hip circumference ratio; CON: the control group; TR: the training group. $^{\beta}$: the control group; asthma = 1, the training group; Allergy = 2.

between the groups, as shown in Table 1. The information gathered from the self-administered questionnaire indicated that one player in the CON group had asthma, and two players in the TR group had a history of allergies. All subjects were right-handed. After the exercise training period, The TR showed significantly increased WFS and WES strength compared to the CON ($p < 0.05$, Table 2). However, HGS was not significantly different between the groups (Table 2). It should be noted that relative improvement of WFS and WES in the TR was 11% and 19%, respectively. In the ACT, both groups showed significant improvement in counter-stroke performance at the end of the study ($p < 0.05$), but there was no difference between the groups (Table 2).

4. Discussion

This study shows that the wrist flexor and extensor strengthening exercises 8 times/set, 3 sets/day and 3 days/week for 6-week with a bucket of water increase WFS and WES, but they have no significant effect on HGS or counter-stroke performance. No advanced exercise equipment was required for the study. The weight of the bucket of water used in training was 60% of the 1-RM for each subject, which was re-evaluated every two weeks. TR performed exercises at home in which adherence to guidelines was acceptable, and no adverse effects were reported.

Lifting the bucket of water requires both gripping force to grip the handle and co-contraction movement of the wrist flexor and extensor. Analyzing the exercise task as a concentric wrist flexor exercise, the flexor muscles (such as flexor carpi ulnaris and flexor digitorum superficialis) work as an agonist, while the extensor muscles (such as extensor carpi radialis and extensor carpi ulnaris) work as an antagonist (Shimose et al., 2011). Then, both muscle groups work vice-versa for eccentric wrist flexor exercises. In addition, similar co-contraction patterns between flexor and extensor were found during the wrist extensor exercises.

After six weeks of exercise, this study found both WFS and WES increased, while HGS was not significantly changed. This finding indicates that the exercises were effective in increasing wrist flexor and extensor strength among the players. However, the grip strength might be affected by a different mechanism. Previous studies suggest that gripping force is produced not only by wrist flexor activation, but also by simultaneous activation of the extensor as a synergist for stabilizing the wrist (Snijders et al., 1987). Thus, during the flexor and extensor strength tests, the prime mover muscles in each test were activated to produce maximum force. However, during the grip test, both wrist flexor and wrist extensor were activated. Therefore, under this mechanism, the counter-balancing force from agonist and antagonist might explain why WFS and WES significantly increased but the HGS showed no difference.

Based on results from this study, the right hand tends to generate greater grip strength. However, there was no statistical difference between the dominant and non-dominant hand in both groups. One previous study reported maximum strength is greater in the dominant hand versus the non-dominant hand for both left-handed and right-handed young top-level table tennis players (Carrasco et al., 2010). However, another study reported no difference between the force of dominant and non-dominant hands (Ivanovic and Dopsaj, 2012). In fact, table tennis players use the dominant hand for different styles of rocket holding and stroking. Although, the International Table Tennis Federation indicated that the racket may be of any size, shape or weight, however a lightweight racket is preferred among the players (The International Table Tennis Federation Handbook, 2014–2015). Because of the light weight, players do not use all their strength while holding the racket. This could be the reason no significant difference in hand grip force was found among the players in this study.

In this study, counter-stroke performance was determined by the ACT. Previous study categorized performance into five levels:

Table 2
Pre-intervention and post-intervention outcomes for both groups.

Parameter	Hand side	Group	Before	After	Comparison between groups (Adjusted for baseline using ANCOVA)		*P*-value
					Adjusted after	Mean difference	
WFS (kg/kgBW)	Rt	TR	0.28 ± 0.05	0.30 ± 0.05$^{\alpha*}$	0.29 $^{\alpha*}$	0.04 $^{\alpha*}$	0.0037
		CON	0.24 ± 0.05	0.24 ± 0.04	0.26		
	Lt	TR	0.26 ± 0.05	0.29 ± 0.05$^{\alpha*}$	0.28$^{\alpha*}$	0.04 $^{\alpha*}$	0.0029
		CON	0.23 ± 0.05	0.23 ± 0.04	0.24		
WES (kg/kgBW)	Rt	TR	0.28 ± 0.05	0.32 ± 0.05	0.32 $^{\alpha*}$	0.06 $^{\alpha*}$	0.0013
		CON	0.25 ± 0.05	0.25 ± 0.04	0.26		
	Lt	TR	0.25 ± 0.05	0.28 ± 0.05	0.28$^{\alpha*}$	0.04 $^{\alpha*}$	0.0106
		CON	0.22 ± 0.04	0.22 ± 0.04	0.24		
HGS (kg/kgBW)	Rt	TR	0.69 ± 0.16	0.74 ± 0.17	0.73	0.03	0.1352
		CON	0.67 ± 0.13	0.69 ± 0.14	0.70		
	Lt	TR	0.62 ± 0.15	0.66 ± 0.16	0.64	0.02	0.4147
		CON	0.59 ± 0.11	0.61 ± 0.11	0.62		
ACT (number)		TR	32.26 ± 8.84	37.46 ± 7.22	37.12	0.966	0.735
		CON	28.14 ± 8.16	37.74 ± 7.74	38.08		

Data are presented as mean ± SD. WFS: wrist flexor strength; WES: wrist extensor strength; HGS: hand grip strength; ACT: alternate counter test; CON: the control group; TR: the training group; Rt: right hand; Lt: left hand. $^{\alpha}$ significant different within the group ($P < 0.05$) compared with before value; * significant different compared between the groups ($P < 0.05$).

very poor (<15.08), poor (15.08–24.62), average (24.62–33.41), good (33.41–42.21) and very good (>42.21) (Purashwani et al., 2010). This study found that the TR categorized as "average" improved to a "good" performance level after completing the training program. The progression pattern was also found among the CON. The reason might be that all of them were continuing to practice regularly during participate the study.

5. Study limitation

There were a few limitations in the present study that should be considered. First, this study was limited by small numbers of participants. Second, due to table tennis demands great speed in a very short distance, therefore, the velocity of ball stroke might be affected by a strength training program. Unfortunately, a high speed motion capture system was not available in this study. Third, this study did not evaluate forearm girth, which might help indicate how strengthening exercise correlates to muscular hypertrophy. Thus, larger sample size and more research are needed in this area.

6. Conclusion

Specific strengthening exercises with 60% of 1-RM, three days per week for six weeks using a bucket of water were shown to increase wrist flexor and extensor strength, but had no significant effect on hand grip strength or counter-stroke performance.

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