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Research article

The Impact of Eye-closed and Weighted Multi-ball Training on the Improvement of the Stroke Effect of Adolescent Table Tennis Players

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Abstract
This paper investigated the impact of eye-closed and weighted training (EWMT) on the stroke effect of adolescent table tennis players. Forty-eight adolescent table tennis players were randomly selected from the China Table Tennis College and were divided into two groups as 1) the experimental group (EG, n = 24) in which they engaged in multi-ball exercise with eye-closed and weighted swing for 10 weeks, and 2) the control group (CG, n = 24) in which they received a normal training without eye-closed and weighted swing intervention. The stroke effect was assessed by three outcome measures: accuracy, stability, and ball speed. Results showed that 1) both the traditional training method and EWMT can improve the stroke effect of adolescent table tennis players. 2) In terms of accuracy, the number of stroke in the corner area was significantly different between EG and CG after the experiment ($p = 0.022$, $p < 0.001$, respectively). 3) In terms of stroke stability, there was a significant difference in the number of net ball strokes between EG and CG after the experiment ($p = 0.014$). 4) In terms of ball speed, there was no significant difference between EG and CG after the experiment ($p = 0.871$). 5) After EWMT, the stroke stability of backspin had more significant improvement than that of topspin. Thus, compared with the traditional training method, the EWMT method can improve the stroke effect of adolescent table tennis players in terms of accuracy and stability more significantly; the EWMT method can improve the stroke effect of backspin more significantly than that of topspin in terms of stability.

Key words: Weighted; training; table tennis; intervention; accuracy; stability.

Introduction

After the Chinese table tennis association put forward "the third business plan", training methods used for adolescent table tennis players has changed considerably to strengthen international exchanges and cultural dissemination of table tennis (Chen and Huang, 2014). The traditional all-day training method was replaced by a "sports-education combination" training approach, which aims to cultivate student-players to help them become well-rounded for their moral, intellectual, physical, and aesthetic qualities (Hu, 2016; Zhang, 2013). Due to this change in approach, the training time given to adolescent table tennis players has shortened. Therefore, table tennis coaches and researchers face the challenge of improving the training efficiency of adolescent table tennis players. The goal of this study was to examine the effectiveness of new training methods that improve current practices.

Multi-ball table tennis training method has been used for more than three decades among players of all ages and levels. The term ‘multi-ball exercise’ refers to training in which a coach or robot continues to supply a number of balls to a player within a certain period of time. The type, duration, direction, and frequency of ball injection depend on the design of the training process (Katsikadelis et al., 2017). Multi-ball training is one of the common methods used in adolescent table tennis training and it is always used to promote formation and fixation of players’ technical movements, improve their training effects (Jiang, 2005; Katsikadelis et al., 2014; Shen, 2012; Wang and Qiao, 2011). Multi-ball training with different means of spin, power, speed, placement, and arcs can improve training efficiency and help players strengthen a variety of difficult movements, therefore, improving the player’s capabilities. Players can use different placements and different speeds of the ball to improve the combination of different ball techniques (Zheng and Jin, 2016).

The forehand drive shot is fundamental and crucial in table tennis, and the spin is an important key factor in winning table tennis competitions. Table tennis players perform a greater lateral impulse to cause the trunk rotation and accelerate the body movement to implement a forehand drive shot. Players also exert greater ground reaction force on the right foot in receiving backspin than receiving topspin serves (Chen et al., 2012). Players increase the racket tilt angle for a forehand drive and raise the forward trajectory angle to return a backspin serve compared with returning the topspin serve. Table tennis players would increase the upswing path angle to perform the forehand drive in receiving backspin serve (Tsai et al., 2010). The players exert greater muscular activity in the wrist extensors, the biceps and the triceps for the backspin serve forehand drive than when returning the topspin serve forehand drive (Tsai et al., 2012). More rotation of the body and more strength should be exerted for table tennis players to perform forehand drive in returning backspin serve than topspin serve.

Weighted training is a training exercise designed to increase muscle strength and volume. The workout involves using different types of skeletal muscle contraction (concentric or eccentric contraction) to generate power against gravity, usually with respect to the weight of a dumbbell, barbell, etc. or some other form of resistance. Weighted swing training is a form of special physical training in table tennis. After continuous practice, it can improve the strength and coordination of upper limb muscles (Guo and Zhang, 2004; Trzaskoma et al., 2010). Table tennis coaches can utilize weighted training to develop their players’ muscle strength in both upper and lower limbs since its benefits are better than traditional strength training

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(Sofiene et al., 2016).

In this study, weighted swing training requires players' eyes to be closed. Keeping the eyes closed allows players to engage in motor imagery training. Motor imagery (MI) training is a mindfulness method that involves players recalling and reproducing the correct technical actions they have completed in the past in order to evoke the player's feeling of presence (Tian, 2000). MI has received much attention for its role in athletic performance and is often included in athletes' psychological skills training packages to complement their regular training programs (Beauchamp et al., 1996). Hall (2001) suggested that imagery training should be treated similarly to physical practice since research has suggested that they are functionally equivalent (Gabriele et al., 1989).

Because training constitutes a large part of the daily work of athletes, motor imagery training enables athletes to recall actions accurately (Starkes, 2000). Cumming and Hall (2002) found that the amount of imagery practice that an athlete engages in is monotonically related to their competitive standard. Furthermore, they found that athletes perceive imagery as being highly relevant to improving their performance and thereby require a great deal of concentration (Hall, 2001). Elite athletes can use MI to improve movement efficiency and strength if combined with physical training (Lebon et al., 2010).

In addition, several studies have demonstrated that schoolchildren who use motor imagery effectively learn motor skills. Bohan et al. (1999) found that motor imagery is more beneficial in the early learning stages of a motor task. Imagery is twice as effective in the development of motor skills in young children (Bohan et al., 1999; Doussoulin and Rehbein, 2011).

Previous studies only investigated the effects of eye-closed and weighted training methods on participants respectively (Ducher et al., 2011; Guillot et al., 2015; MacKelvie et al., 2002; Robin et al., 2007). The target population of this study was adolescent table tennis players whose technique was in its formative stage. It aims to explore the stroke effect of eye-closed and weighted training on adolescent player's stroke accuracy and stability through the experiment, which combined the weighted training and training to intervene the adolescents' table tennis skill and offer coaches reference when formulating daily training plans.

We hypothesized that: 1) both the traditional training method and EWMT method can improve the stroke effect of adolescent table tennis players. 2) Compared with the traditional training method, EWMT method can significantly improve the stroke effect of adolescent table tennis players. 3) Compared with the topspin, the EWMT method can significantly improve the backspin's stroke effect.

Methods

Participants

This study was approved by the ethics committee of Shanghai University of Sport. Participants were randomly selected from China Table Tennis College. The inclusion criteria included; table tennis player, 9 to 12 years of age, right-hitting arm, shake-hands grip. Forty-eight adolescent players ($M_{age} = 10.25 \pm 1.12$; $M_{height} = 1.50 \pm 0.06$ m; $M_{weight} = 41.15 \pm 5.84$ kg) who met the inclusion criteria were chosen to attend this study. The average training time for them was 3.85 ± 1.23 years, and the table tennis technical grade (General Administration of Sport of China, 2013) of them has been to the same level. All subjects were informed prior to the experiment about the study procedures, and they provided written informed consent.

The 48 players were randomly divided into two groups: 24 players (12 male and 12 female) were assigned to the experimental group (EG), in which they engaged in eye-closed and weighted swing exercises for 10 weeks; the other 24 players (14 male and 10 female) were assigned to a control group (CG), in which they received normal training without eye-closed and weighted swing intervention. There was no significant difference between EG and CG in age, training year, technical grade, height, weight, and other study variables ($p > 0.05$) (Table 1).

Table 1. Comparison of basic information of the participants.

Variables	EG (n = 24)	CG (n = 24)	*p*-value
Age	10.2 ± .9	10.3 ± 1.0	.969
Training-Year	3.9 ± .9	3.8 ± .9	.724
Height	1.51 ± .04	1.50 ± .04	.363
Weight	41.2 ± 5.6	41.1 ± 5.1	.939

Instrument

(1) The experimental ball was DHS D40+ (3-star) of Double Happiness Company (DHS). The table and rackets used in this experiment were Rainbow table made by DHS, and Timo Boll-ZLCacrbon, separately. The racket was wrapped with red rubber on one side while black on the other side.

(2) Radar speed detector: SPEEDSTER radar produced by BUSHNELL Company (the United States), located approximately 3½ - 4 meters away from the player (directly facing the player).

(3) Dumbbells: 1 kg and 2 kg dumbbells manufactured by Langwei Company, China.

(4) Serving machine: V-989H Serving machine was manufactured by Nittaku Company, Japan. The parameter settings used for the study included the following: when serving topspin, the serving machine's upper wheel speed was level 7 (10 levels in total, the higher level the faster speed), the bottom wheel speed was level 3, and the service frequency was 60 balls per minute; when serving backspin, the serving machine's upper wheel speed was set at level 3, the bottom wheel speed at level 7, and the service frequency was 40 balls per minute.

Outcome measures

Stability was the premise of accuracy. Only with higher stability, can a higher accuracy be achieved. Accuracy means the arc of one's batting was moderate, and the location was in place (Liu, 2004). The stroke effect was assessed using the following measures:

(1) Stroke accuracy: whether balls were struck into a large 30 cm by 30 cm corner area or a small 15 cm by 15 cm corner area (also known as the winning area) (Chen, 2000);

(2) Stroke stability: the number of out, net, miss, and racket-edge stroke;

(3) The stroke speed was replaced by the mean value of the ball's average speed.

These outcome measures were used to assess participants' accuracy, stability, and stroke ball speed, as shown in Table 2.

Table 2. Outcome measures of the stroke effect.

Primary index	Secondary index
Accuracy	Large corner area (30 cm*30 cm)
	Small corner area (15 cm*15 cm)
Stability	Out
	Net
	Miss
	Racket-edge stroke
Ball Speed	Ball speed of flying over the net

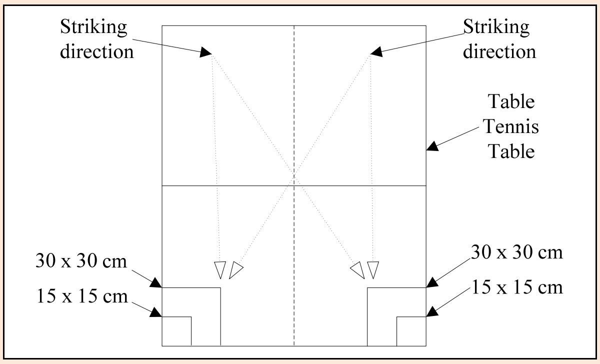

Figure 1. Regional map of bottom corner (large & small).

Corner area

During the test, in order to evaluate the stroke effect of players, a rectangular area of 30 cm by 30 cm was drawn at the two bottom corners of the table tennis table on each side. In order to increase the difficulty of training and improve the accuracy of the player's stroke, a small square area of 15 cm by 15 cm was drawn in the 30 cm by 30 cm rectangular area forming the large and small area at the bottom corner of this experiment, as shown in Figure 1 (Chen, 2000).

Experimental protocol

The experimental intervention period was 10 weeks. Data from all participants were collected before and after the experiment, including the number of strikes in the corner area (including both the large and small corner areas), the number of out, net, miss, and racket-edge stroke, and the speed of the ball.

In the experimental group, the intervention consisted of two sets: players stroke 90 forehand topspin balls followed by a 5 minutes' rest, then stroke 90 forehand backspin balls. Players can strike either the cross-court or the long-line ball targeting at the bottom corner area (including large corner and small corner area, which demands higher accuracy). Both the 90 topspin balls and the 90 backspin balls were in three sets of 30 repetitions (Figure 2).

The specific steps of each set were as follows: the players held the dumbbells of the corresponding weight, closed their eyes, and visualized the specific technical movement in their mind and simultaneously performed the swing exercise for 30 repetitions in accordance with the visualized movement (He, 2016), followed by 30 multi-ball exercise with eyes opened.

In the control group, the subjects performed normal practice with eye-opened and without weighted swing. 90 forehand topspin balls and 90 forehand backspin balls were performed with a 5 minutes break in-between. Both the 90 topspin balls and the 90 backspin balls were done in three sets of 30 repetitions.

The daily training of the experimental group and control group remains consistent except that the weighted swing exercise intervention was performed during training. A serving machine was used to serve topspin and backspin balls for both groups. The number of stroke, net, out, miss, and balls in the bottom corner area (including large corner and small corner area) and ball speed were recorded by four table tennis teachers respectively.

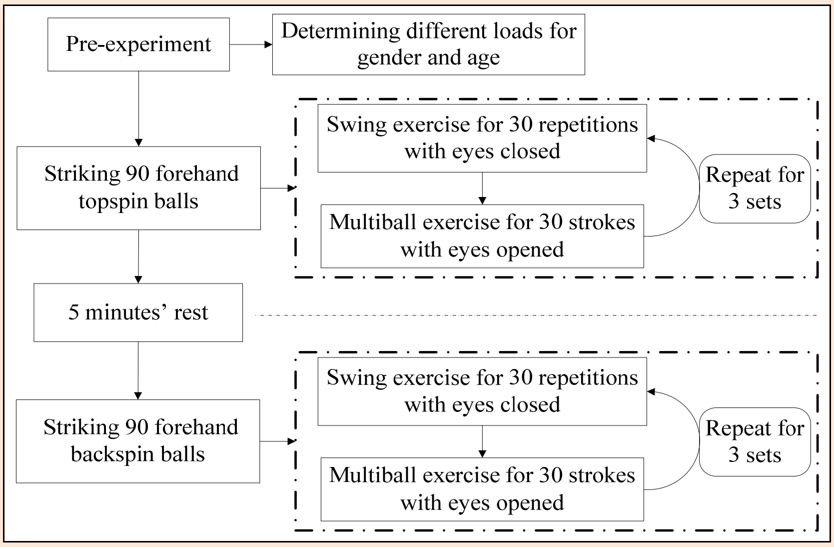

Figure 2. Experimental protocol for EG.

Table 3. Pre- and posttest comparisons of the overall stroke effect by group.

Variables	EG (M±SD, N=24)			CG (M±SD, N=24)		
	Pre-	Post-	*p*-value	Pretest	Posttest	*p*-value
Large area	12.10±5.0	23.10±3.05	0.000**	13.60±4.56	16.40±2.16	0.003**
Small area	0.50±0.13	4.15±1.09	0.000**	0.85±1.14	2.00±0.79	0.001**
Out	15.45±2.51	10.85±1.43	0.000**	14.10±3.16	11.00±1.74	0.001**
Net	2.10±0.52	2.05±0.40	0.840	4.05±3.60	4.20±2.13	0.876
Miss	1.00±1.01	0.35±0.59	0.035*	0.75±1.12	0.50±0.21	0.371
Racket-edge stroke	1.05±1.23	0.25±0.91	0.030*	1.50±1.07	0.40±0.14	0.005**
Ball speed	25.38±2.55	26.86±2.56	0.000**	26.16±2.54	26.90±2.05	0.001**

EG = Experimental group, CG = Control group; * p < 0.05; ** p < 0.01.

Data processing

All statistical analyses were conducted by the Statistical Product and Service Solutions (SPSS 22.0, SPSS Inc.). Data normality was verified by using the Kolmogorov-Smirnov test. Multivariate analysis of variance (MANOVA) with repeated measures was performed to examine the stroke effect between different groups at baseline and after the 10-week intervention. To account for multiple testing, Bonferroni corrections, with adjusted CIs, was performed to investigate the differences between groups. Statistical significance was defined at 5% ($p<0.05$). Effect size (ES) was calculated by using the Cohen's delta (.2 or less was considered to be a small ES, about .5 was considered a moderate ES, and .8 or more was considered a large ES).

Results

Pre- and post-test comparisons of the stroke effect within groups

Repeated measures analysis of variance was performed to analyze the pre- and post-differences of the overall stroke effect within different groups. The result showed that the interaction effect (Time * Group) was not significant (Pillai's Trace =0.030, $F(1, 58) = 1.791$, $p = 0.186$, $p > 0.05$).

Comparison of the overall stroke effect

The pairwise comparison results of the pre- and posttest overall stroke effect within different groups (no matter topspin or backspin) were presented in Table 3.

For the experimental group, the number of balls stroke in the corner area (including large corner area and small corner area) was significantly different between pre- and posttest after the 10-week intervention ($p < 0.001$, ES = 0.799; $p < 0.001$, ES = 0.920) (Table 3). The average number of balls stroke in the large corner area increased from 12.1 to 23.1, and the average number of balls stroke in the small corner area increased from 0.5 to 4.15. In terms of stability, all four indices of stability decreased after the experiment. Three outcome measures (the out, miss, and racket-edge stroke) were significantly decreased ($p < 0.05$) after the experiment. The average ball speed, increased from 25.38 to 26.86, was also significantly different ($p < 0.001$) between the pre- and posttest for EG after the experiment.

For the control group, the number of balls stroke in the corner area (including the large corner area and the small one) was significantly different between pre- and posttest ($p = 0.003$, ES = 0.365; $p = 0.001$, ES = 0.506, respectively) and both were increased after the experiment (Table 3). In terms of stability, after the experiment, the number of out and racket-edge strokes were significantly different ($p = 0.001$, ES = 0.519; $p = 0.005$, ES = 0.585, respectively), while the other two indices were not significantly different between the pre- and post-test for CG ($p = 0.876$, $p = 0.371$, respectively). The average ball speed, increased from 26.16 to 26.90, was significantly different ($p = 0.001$, ES = 0.158) between the pre- and posttest for CG after the experiment.

Comparison of the stroke effect of topspin and backspin

The pairwise comparison results of the pre- and posttest stroke effect of topspin and backspin for EG and CG were presented in Table 4 and Table 5, respectively.

For EG, there was a significant difference in the number of strokes (both topspin and backspin balls) in the corner area (including the large corner area and the small one) after the eye-closed and weighted practicing ($p < 0.01$) (Table 4).

In terms of stroke stability, the stroke effect of backspin had more significant improvement than that of topspin. For backspin, all outcome measures except for the number of net ball strokes were significantly different after the experiment (the number of the net: $p=1.000$; the number of out: $p = 0.011$, ES = 0.533; the number of miss: $p = 0.040$, ES = 0.521; the number of racket-edge strokes: $p =$

Table 4. Pre- and posttest comparisons of the stroke effect of topspin and backspin for EG.

Variables	Topspin				Backspin			
	Pretest	Posttest	Δ%	*p*-value	Pretest	Posttest	Δ%	*p*-value
Large area	13.30±4.50	19.00±2.06	42.86%	0.008**	10.90±3.46	18.90±2.13	73.39%	0.007**
Small area	0.60±0.97	4.20±0.79	600.00%	0.005**	0.40±0.69	4.10±1.37	925%	0.005**
Out	15.50±3.86	11.10±2.72	-28.39%	0.033*	15.40±3.42	10.60±4.17	-31.17%	0.011*
Net	1.90±1.08	2.10±0.96	10.53%	0.798	2.30±1.45	2.00±1.03	-13.04%	1.000
Miss	0.60±0.70	0.40±0.69	-33.33%	0.527	1.40±1.26	0.30±0.18	-78.57%	0.040*
Racket-edge stroke	0.70±0.48	0.40±1.26	-42.86%	0.206	1.40±1.64	0.10±0.12	-92.86%	0.043*
Ball speed	26.27±3.12	27.33±2.54	4.04%	0.005**	24.50±1.52	26.40±1.18	7.76%	0.005**

EG = Experimental group;* p< 0.05; ** p< 0.01.

Table 5. Pre- and posttest comparisons of the stroke effect of topspin and backspin for CG.

Variables	Topspin				Backspin			
	Pretest	Posttest	Δ%	*p*-value	Pretest	Posttest	Δ%	*p*-value
Large area	12.90±4.89	15.40±2.78	19.38%	0.035*	14.30±4.21	17.40±3.31	21.68%	0.037*
Small area	0.80±1.13	2.30±0.82	187.5%	0.004**	0.90±1.19	1.70±0.67	88.89%	0.099
Out	15.70±4.27	11.80±2.67	-24.84%	0.011*	12.50±3.76	10.20±2.73	-18.40%	0.065
Net	2.60±1.27	3.81±0.89	46.54%	0.058	5.50±2.47	3.80±1.78	-30.91%	0.106
Miss	0.80±0.73	0.70±0.37	-12.50%	0.914	0.70±1.06	0.30±0.48	-57.14%	0.234
Racket-edge stroke	0.80±0.59	0.30±0.28	-62.50%	0.096	2.20±1.64	0.50±0.36	-77.27%	0.203
Ball speed	26.83±2.11	27.26±1.80	1.60%	0.047*	25.50±1.85	26.54±2.31	4.08%	0.005**

CG = Control group;* p< 0.05; ** p< 0.01.

0.043, ES = 0.488). However, the average number of net ball strokes was decreased from 2.30 to 2.00. For topspin, all outcome measures except for the number of out were not significantly different after the experiment (the number of out: p = 0.033, ES = 0.550; the number of the net: p = 0.798; the number of miss: p = 0.527; the number of rocket-edge strokes: p=0.206), and the average number of net ball strokes was increased from 1.90 to 2.10. In terms of ball speed, there were significant improvements both in topspin and backspin after the experiment (p = 0.005, p=0.005, respectively) (Table 4).

For CG, the number of topspin ball stroke in the corner area (including the large corner area and the small one) improved significantly after the experiment (p = 0.035, ES = 0.300; p = 0.004, ES = 0.605, respectively) (Table 5). For backspin, there was a significant difference in the number of balls stroke in the large corner area (p = 0.037, ES = 0.379). In terms of stability, the number of the out of topspin decreased significantly after the experiment (p = 0.011, ES=0.480), while there was no significant difference in backspin between pre- and posttest for CG (p > 0.05). In terms of ball speed, backspin had more significant improvement (p = 0.005, ES = 0.241; p = 0.04, ES = 0.219, respectively) rather than topspin even though both ball speeds of topspin and backspin were increased (Table 5).

Pre- and post-test comparisons of overall stroke effect between groups

To compare the stroke effect between EG and CG before and after the experiment, a MANOVA with repeated measures was performed. The results were shown in Table 6.

In terms of stroke accuracy, neither the large corner area (30 cm by 30 cm) (p = 0.635) nor the small corner area (15 cm by 15 cm) (p = 0.353) had a significant difference between EG and CG before the experiment (Table 6). In terms of stability, there was no significant difference between the pre- and posttest results of the number of out, net, miss and racket-edge stroke (all p values were over 0.05). There was also no significant difference in the mean value of ball speed. Therefore, there was no significant difference in the stroke effects between EG and CG before the experiment.

After the experiment, the number of balls stroke in the corner area (including the large corner area and the small one) was significantly different between EG and CG (p = 0.022, ES = 0.785; p < 0.001, ES = 0.749, respectively) in terms of stroke accuracy (Table 6). The stroke effect of EG was significantly improved compared to CG after the experiment. In terms of stroke stability, there was a significant difference only in the number ofnet ball strokes between EG and CG after the experiment (p = 0.014, ES = 0.574), while the other three outcome measures (out, miss, and rocket-edge strokes) were not significantly different (p > 0.05). In addition, the better stroke effect of EG can be supported by EG's lower proportion of the number of net ball strokes compared to CG. In terms of ball speed, there was no significant difference between EG and CG after the experiment.

With regard to the stroke effect of topspin and backspin, there was no significant difference between EG and CG before the experiment, and no significant difference between EG and CG after the experiment in terms of stability.

Comparison of the basic information between male and female participants within different groups

In EG, there was no significant difference in age, height, weight, and training year between male and female participants (all p > 0.05). In CG, the result was the same as EG (all p > 0.05) (Table 7).

Pre- and post-test comparisons of the stroke effect between male and female participants within different groups

The pre- and posttest comparisons of the stroke effect between male and female within EG and CG were shown in Table 8.

Table 6. Pre- and posttest comparisons of the stroke effect between EG and CG.

Variables	Pre-			Post-		
	EG	CG	*p*-value	EG	CG	*p*-value
Large area	12.10±5.0	13.60±4.56	0.635	23.10±3.05	16.40±2.16	0.022*
Small area	0.50±0.13	0.85±1.14	0.353	4.15±1.09	2.00±0.79	0.000**
Out	15.45±2.51	14.10±2.16	0.371	10.85±2.43	11.00±1.74	0.615
Net	2.10±0.52	4.05±1.60	0.090	2.05±0.40	4.20±2.13	0.014*
Miss	1.00±1.01	0.75±0.52	0.308	0.35±0.59	0.50±0.21	0.364
Racket-edge stroke	1.05±1.23	1.50±0.47	0.808	0.25±0.91	0.40±0.14	0.243
Ball speed	25.38±2.55	26.16±2.54	0.289	26.86±2.56	26.90±2.05	0.871

EG = Experimental group, CG = Control group;* *p< 0.05; ** p< 0.01.*

Table 7. Comparison of basic information between male and female participants in EG and in CG.

Variables	EG			CG		
	Male	Female	p-value	Male	Female	p-value
Age (yrs)	10.39±1.09	10.21±1.14	0.634	10.28±1.23	10.12±1.02	0.658
Height (m)	1.51±0.06	1.49±0.06	0.263	1.51±0.06	1.49±0.06	0.294
Weight (kg)	42.14±6.30	40.27±5.93	0.675	42.12±5.82	40.07±5.32	0.628
Training-year	3.76±1.26	3.89±1.23	0.926	3.92±1.25	3.83±1.18	1.082

EG = Experimental group, CG = Control group

Table 8. Comparison of the stroke effect of pre- and posttest between male and female participants within different groups.

Variables	Pretest						Posttest					
	EG			CG			EG			CG		
	Male	Female	*p*	Male	Female	*p*	Male	Female	*p*	Male	Female	*p*
Large area	10.57±3.77	13.63±4.93	0.066	14.63±5.01	11.36±4.37	0.070	18.21±2.80	18.94±3.45	0.538	18.19±2.17	17.80±2.48	0.069
Small area	0.57±0.93	0.69±0.87	0.730	0.81±1.32	1.00±1.17	0.687	3.64±1.01	3.69±1.35	0.920	2.25±0.77	2.71±1.43	0.294
Out	14.86±4.41	15.94±7.04	0.638	13.69±3.98	14.43±4.01	0.618	11.64±2.49	12.00±2.76	0.832	12.63±4.48	10.57±3.15	0.164
Net	3.29±2.23	2.25±3.55	0.355	4.00±5.31	4.07±3.46	0.996	2.79±2.45	1.69±2.15	0.207	3.8±2.68	3.21±3.55	0.892
Miss	0.71±0.82	1.50±2.12	0.206	1.31±1.35	1.21±0.89	0.819	0.64±0.74	0.69±0.79	0.875	0.50±0.51	0.57±0.75	0.762
Racket-edge stroke	1.00±1.41	0.94±1.06	0.894	1.44±2.92	0.64±1.08	0.345	0.57±0.64	0.50±0.63	0.763	0.63±0.61	0.43±0.64	0.404
Ball speed	25.91±2.11	25.11±2.90	0.398	25.64±2.77	25.14±2.14	0.583	27.39±1.75	26.63±2.37	0.331	26.66±2.15	26.39±1.74	0.716

EG = Experimental group, CG = Control group

Pre- comparisons of the stroke effect between male and female participants in EG and CG

In EG, before the experiment, neither the large corner area (p = 0.066) nor the small corner area (p = 0.73) had a significant difference between male and female (Table 8). There were no significant difference between male and female in the number of out, net, miss, and racket-edge stroke (all p values were over 0.05); there was also no significant difference in the mean value of ball speed (p = 0.398). Therefore, for EG, there was no significant difference in the stroke effect between male and female before the experiment.

In CG, before the experiment, there were no significant difference between male and female in the number of the large corner area (p = 0.070) and the small corner area (p = 0.687). There were no significant difference between male and female in the number of out, net, miss, and racket-edge stroke (all p values were over 0.05). There was also no significant difference in the mean value of ball speed (p = 0.583) (Table 8). Therefore, there was no significant difference in the stroke effect between male and female before the experiment.

Post- comparisons of the stroke effect between male and female participants in EG and CG

In EG, after the experiment, neither the large corner area (p = 0.538) nor the small corner area (p = 0.92) had a significant difference between male and female (Table 8). There was no significant difference between male and female in the number of out, net, miss, and racket-edge stroke (all p values were over 0.05). There was also no significant difference in the mean value of ball speed (p = 0.331). Therefore, there was no significant difference in the stroke effect between male and female after the experiment.

In CG, after the experiment, neither the large corner area (p = 0.069) nor the small corner area (p = 0.294) had a significant difference between male and female (Table 8). There was no significant difference between the male and female in the number of out, net, miss, and racket-edge stroke (all p values were over 0.05). There was also no significant difference in the mean value of ball speed (p = 0.716). Therefore, there was no significant difference in the stroke effect between male and female after the experiment.

Discussion

For table tennis players, the nearer the ball's place to the bottom corner of the table, the more difficult for the opponent to return. After a 10-week EWMT, players' stroke accuracies were significantly improved, which verified hypothesis 1. The mean number of balls stroke in the large corner area increased from 12.1 to 23.1. The mean number of balls stroke in the small area improved from 0.5 to 4.15. This showed that the practice of EWMT could improve the accuracy of stroke. In terms of stability, the number of out and racket-edge stroke dropped significantly, and these results suggested that eye-closed and weighted training can improve the stability of strokes. At the same time, the EWMT can reduce the number of net ball strokes, which indicated that EWMT can also help to improve stroke trajectory. Furthermore, the average ball speed increased from 25.38 to 26.86. According to the individual information of participants, there was no significant difference in weight and height. There was no significant difference regarding the stroke effect between male and female participants. Therefore, the differences in average ball speed, which may result from gender and power differences, could be ignored in this paper.

Spin is a key influencing factor in table tennis. The technique of stroke backspin is more difficult than that of topspin. Regarding the technical action, backspin is more complex than topspin due to it requires a shift of spin direction. For a novice, the topspin is the basis while the backspin technique requires further exercise (Liu, 2004). By pulling the forehand loop, the backspin ball will transform into a topspin ball. At that point, players should pay more attention to controlling the arc of stroke backspin ball. After the 10-week EWMT intervention, it was found that the stability of stroke backspin balls improved more significantly than that of topspin balls, with an exception of the number of net ball strokes (which also showed a downward trend), which verified hypothesis 3. The other three stability outcome measures were significantly reduced compared with the pretest. Nevertheless, for the topspin ball, only the number of out had a significant reduction, which indicated that EWMT intervention can improve the stroke trajectory and the height of the ball passing over the net, and reduce the number of net ball strokes, thereby enhancing the stability of players' strokes.

The results showed that after a 10-week training, some outcome measures of CG were improved to varying degrees, which verified hypothesis 1. The average number of balls stroke in the large corner area increased from 13.60 to 16.40 (an increase of 2.8). The average number of balls stroke in the small area increased from 0.85 to 2.00 (an increase of 1.15). The study also showed that without weighted intervention, the traditional training method could improve the stroke accuracy for adolescent table tennis players. However, by comparing the mean value of EG and CG, the stroke effect of the traditional training method was found not better than that of EWMT, which verified hypothesis 2. In terms of stability, the number of out and racket-edge stroke was significantly decreased, but no significant difference was found among other indexes. The number of net ball strokes was increased compared with the pretest, which means that players in CG lack stability when they strike. Besides, the mean value of ball speed in CG was increased significantly than that of the pretest, but there was no significant difference between EG and CG. This may be because adolescent table tennis players are still in the period of growth, and their overall muscular strength is still developing. Therefore, weighted swing training may not obviously improve the ball speed of their strokes (Manno, 2008; Silva and Martins, 2017).

In conclusion, the outcomes resulting from EG were better than that for CG. This may be because weighted practice with closed eyes can increase players' arc when they strike the ball and can improve the height of the ball passing over the net, which increases the number of balls stroke in the corner area. Apart from enhancing the strike accuracy, it can also play a role in image training, thus improving the strokes' stability (Robin et al., 2007). Long-time EWMT can establish memory and reoccurrence of the strike movement in a player's mind. This improves the ability for a visualization based on memory, brings the player's concentration to the correct technical movement and enhances mastery of the specific movements. Some researchers (Baeck et al., 2012; Kibler et al., 2006; Petersen and Nittinger, 2008; Zhang et al., 2011) also found out that visualized training enables the brain to recall the process of the best movement. Through concentrated, high-intensity training, the correct movements that the body performs can transfer to the pallium-related motor sensory center and leave a deep impression in the brain, which leads to the enhancement of stroke effect.

Weighted dumbbell training is an effective way to improve explosive power in teenage physical training. The instantaneous contraction of the forearm accelerates the speed of the ball. The weighted swing exercise can improve the power of strokes (Trzaskoma et al., 2010). New developments in table tennis materials have led to lower friction, slower speed, and lower elasticity (Li, 2015; Zhang, 2010), which requires players to exert more strength when stroke balls (Inaba et al., 2017; Iino and Kojima, 2016). In this paper, the weighted swing training was found to increase the arc of strokes, improve the height of ball flying over the net, reduce the number of net ball strokes, improve the number of strokes in the small corner area, and improve the accuracy of stroke. Eye-closed and weighted swing exercise is believed to work through imagery training. The imagery training can allow individuals to practice the subtle feelings of the wrist and fingers, which can help improve the stability of the stroke. The combination of traditional training and weighted training methods can improve the accuracy and stability of table tennis players' stroke movements, thereby improving the overall stroke effect and training efficiency.

Implication

This study combined traditional training and weighted training to provide a new training method (EWMT method) for adolescent table tennis players whose techniques are informative stage. The findings showed that EWMT can better improve the stroke effect of adolescent table tennis players than the traditional training method in terms of accuracy and stability, which can offer coaches references when formulating daily training plans.

Limitation

This study mainly compared the differences in adolescent table tennis players' stroke effect between EWMT and traditional training, there was no comparison between the stroke effect of weighted multi-ball trainings with eye-closed and eye-opened groups. The following study should add one more experimental group (eye-opened and weighted multi-ball training group) to investigate the impact of eye-closed training and weighted training on the adolescent table tennis players' stroke effect separately.

Future research may set different load levels, training frequency, and duration of weight training for players of different age and gender to improve the generalizability of this training method.

Conclusion

After the 10-week intervention, EWMT can improve the overall stroke effect of adolescent table tennis players in term of accuracy, stability, and average ball speed. Compared with the traditional training method, the EWMT method can improve the stroke effect of adolescent table tennis players in terms of accuracy and stability more significantly. With regard to spin, the EWMT method can improve the stroke effect for backspin balls more significantly than that for topspin balls. Both the EWMT method and the traditional training method can improve the ball speed, but there was no significant difference between them.

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Key points

- Eye-closed and Weighted Multi-ball Training (EWMT) method can improve the stroke effect of adolescent table tennis players in term of accuracy, stability, and ball speed.
- Compared with traditional multi-ball training method, EWMT method can improve the stroke effect of adolescent table tennis players in terms of accuracy and stability more significantly.
- With regard to spin, EWMT method can improve the stroke effect for backspin balls more significantly than the striking effect for topspin balls.

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