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Examining the Effects of Proprioceptive Training on Coincidence Anticipation Timing, Reaction Time and Hand-Eye Coordination

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ABSTRACT This paper is aimed to investigate the effects of proprioceptive training on coinciding anticipation timing (CAT), reaction time and hand-eye coordination. 42 volunteer students participated in the paper. These students were randomly divided into two groups as experiment and control groups. An exercise program was applied to the experiment and control groups for approximately 3 days in 8 weeks, for about 45 to 60 minutes. Additionally, a 20-minute modified proprioceptive balance program was applied to the experiment group only. Paired sample tests were used. As a result, significant differences were found in the CAT performance, reaction time and hand-eye coordination performances of the experiment group, pretest and posttest ($p<0,05$). Significant differences were found in dominant hand visual reaction time and hand-eye coordination performances of the control group, pretest and posttest ($p<0,05$). In conclusion, it is seen that proprioceptive trainings affect CAT performance and reaction time performances in a positive way.

INTRODUCTION

Proprioception is defined as the "sixth sense" to include the classical five senses and the body itself, and involves both peripheral and central systems. Proprioception is an important sensory function for all normal mobility actions including administering the dynamic balance and the skill of moving in the right manner (Batson 2008; Ogard 2011; Hillier et al. 2015), motor control (Hillier et al. 2015). Acquiring a comprehensive understanding of proprioceptive function is important in that it will contribute greatly to the rehabilitation after sports injuries, and will be beneficial in athletic condition and performance (Ogard 2011). Proprioceptive training is defined as the (preventive) 'series of exercises or situations that will produce a reaction in response to an external stimulant by the nerve system' (Cerulli et al. 2001). The purpose of the proprioceptive training is to increase the complex activity of the neurovascular system (Ogard 2011). The important components of the proprioceptive exercises consist of balance training, leg-press and one-leg jumping, back-strengthening and similar kinesthetic chain exercises (Laskowski et al. 1997). Proprioceptive training is directed to develop the proprioceptive sense, which is found in the muscles, joints and ligaments. We obtain information about our body and environment with the help of these senses. There is no doubt that sports performances are based on cognitive and perceptual skills as well as motor and physical abilities (Schwab and Memmert 2012). The effect of exercise on cognitive performance is more likely to be of importance because, in many sports, athletes have to make decisions rapidly and accurately, despite great physical exertion (Delignieres et al.1994).The relation of the physical exercise and the cognitive functioning could be important because of optimizing processes of the good sport performance (Antunes et al. 2006). In literature, there are some studies which indicate that exercise or physical activity improve cognitive and motor function (Bossers et al. 2015; Erickson et al. 2015; Moreau et al.; Zieres and Jansen 2015). Most sports necessitate athletes to have high perceptual abilities that can affect their response accuracy and sports performance. Open skills sports such as soccer, badminton and basketball, which are done in a temporally and spatially changing environment, necessitate an athlete's fast reaction to sensory stimuli before starting the physical action. This is the one aspect of cognitive performance, called anticipation, which is the measurement of accuracy in performance of motor behavior (Meng et al. 2015). Some movements being sensed beforehand and

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being made with correct timing and proper hand-eye coordination prove to be advantageous for the athletes against their opponents. Reaction time means the decision-making process, and the speed to start the movement, and is an important component of many activities. Reaction time, as a criterion of data processing, is a very important parameter, which is influenced by various factors such as age, gender, stimulus, tiredness, and physical activity (Ashnagar et al. 2015). Most sports depend on an excellent eye-hand coordination, which in turn is directly related to the speed of visual reaction time and motor response (Schwab and Memmert 2012). The hand-eye coordination is especially important in individual sports in which the motor-manipulative skills are used much, and in team sports such as handball, basketball, volleyball and the sports in which rackets are used. It has been proven that the manipulative skills are especially important in activities that require sensitivity and rough muscle control (Menevse 2011).

Coinciding timing anticipation, reaction time to similar bio-motor skills are higher order perceptual abilities (Meng et al. 2015), that have to be developed as it is extremely important in terms of performance and in making use of the strength of the opponent. Poor visual performance in reaction response and anticipation ability may prevent high sports achievement (Meng et al. 2015). Hence, in the literature scan, no studies were found that examined the effects of the proprioceptive training on the coinciding timing anticipation, reaction time, and hand-eye coordination. This situation shows the importance of the present paper in terms of the literature. In this paper, the issue of whether the proprioceptive training, which is a different training method when compared with the other types of trainings and which aims to develop the sense of position in the athletes, affects predicting the movements of the opponent in advance and reacting with a proper coordination, has been studied.

METHODOLOGY

Forty-two volunteer physical education and sport teaching students who having no health problems and sports injuries for doing exercises, participated in the study. These students were randomly divided into two groups—experiment (20) and control (22) (Table 1). An exercise program (included main speed, general endurance training program, flexibility and cooling exercises) was applied to the two groups for approximately 3 days in 8 weeks, for about 45 to 60 minutes. Additionally, 20 minutes of modified proprioceptive balance program (Verhagen et al. 2004; Panics et al. 2008) was applied to the experiment group only. Coinciding anticipation timing, reaction time, hand-eye performance values of experiment and control groups were recorded, pretest and posttest.

Table 1: The values of age and height of control and experiment groups

Variables		*N*	*X*	*S.D.*
Age	Experiment	20	21.30	1.68
(year)	Control	22	22.22	1.97
Height	Experiment	20	1.79	.059
(m)	Control	22	1.77	.049
Weight	Experiment	20	72.87	8.04
(kg)	Control	22	70.83	6.35

Sample Modified Proprioceptive Balance Training (Verhagen et al. 2004; Panics et al. 2008).

1. Movement: Standing on one leg in knee flexion. Taking one step with the other knee flexion, and standing in balance for 5 seconds. Repeated 10 times for each leg.

2. Movement: Standing on one leg in knee and hip flexion. Taking one step with the other knee and hip flexion leg, and standing in balance for 5 seconds. Repeated 10 times for each leg.

3. Movement: With a partner, stand on one leg so that the knees are in flexion. With a 5-meter distance between yourself and your partner, throw the ball to one another 5 times, catch it and ensure balance! Repeated 10 times for both.

4. Movement: With a partner, stand on one leg so that the knees and hips are in flexion with one another. With a 5-meter distance between yourself and your partner, throw the ball to one another 5 times, catch it and ensure balance! Repeated 10 times for both.

5. Movement: Stand on one leg on the balance board for 30 seconds and ensure balance, then change legs. Repeated twice for both legs.

6. Movement: Stand on one leg on the balance board for 30 seconds as the hip and knees are in flexion, and ensure balance. Then change legs. Repeated twice for both legs.

7. Movement: Stand in a position such that one leg is on the balance board, and while doing so continue the balance in the horizontal position. Repeated 10 times for both legs.

8. Movement: Stand on both legs on the balance board. Perform 10 knee flexion activities and maintain balance.

9. Movement: Stand on one leg in balance so that the knee in in flexion. Perform 10 knee flexion activities and maintain the balance. Repeated twice for each leg. ,

10. Movement: Jumping on the soft mat over the small box with both legs in knees flexed position (10 repetitions).

11. Movement: Jumping on the soft mat over the ball with both legs in knees flexed position (10 repetitions).

12. Movement: Jumping on the soft mat over the small box with both legs by twisting the body 90^o (10 repetitions).

13. Movement: Jumping on the soft mat over the ball with both legs by twisting the body 90^o (10 repetitions).

14. Movement: Jumping on the soft mat over the small box with one leg (10 repetitions).

15. Movement: Squats (standing on single leg or on both legs, taking side steps or without taking side steps)

Data Collection Tools

Anthropometric Measurements

Body Weight and Height: The weight was measured with an electronic scale with a sensitivity of 0.1 kg. The height was measured with a digital device with a sensitivity of 0.01 cm (Tamer 2000).

Measuring the Coinciding Timing Anticipation

In measuring the coinciding timing anticipation performances, the Bassin Anticipation Timer (Lafayette Instrument Company, Model 50575) measurement device was used. The coinciding timing anticipation of the participants at different speeds (3 mph, 5mph and 8 mph) were measured in random order (Duncan et al. 2013). The reason for the choice of stimulus speeds was based on paper conducted by Lyons et al. (2008) that determined a stimulus speed of 5 mph as 'intermediate', where the stimulus speeds of 3mph and 8 mph were considered 'slow' and 'fast' speeds respectively, according to the work by Lobjois et al. (2006). Both participants were given three trial rights before the real measurement started. Five measurements were taken for coinciding timing anticipation performance at three different speeds and the average values were recorded (Sogut et al. 2009 reported from Rudisill and Jackson 1992).

Measuring the Reaction Time

The dominant hand, visual, audio, and mixed reaction times of the participants were determined by using the Newtest 1000 device. In measuring the reaction times, the dominant fingers of the participants were used, and the measurements were taken in a noise-free and well-lit environment. The measurement was repeated 10 times. The lowest 2 scores and the highest 2 scores were not taken into consideration. The average of 6 scores that were close to each other were recorded as the reaction time (Tamer 2000).

Measuring the Hand-Eye Coordination

In measuring the hand-eye coordination performance, the Minnesota Dexterity Test was used. This test was applied to the participants in 2 different styles, as a placing test, and as a turning test. The protocol was introduced to the participants before the measurements and they were asked to practice. The participants fought against time, and their performances were recorded with a chronometer in seconds. This test was applied thrice on the participants, and the best scores were recorded for statistical analyses (Lafayette Instrument 1998).

Statistical Analyses

Statistical measurements were done using the SPSS program (Version 16.0). The paired samples t-test was used in comparing the pre-and posttests of the experiment and the control group. The significance level was accepted as $p<0.05$.

RESULTS

Significant difference was found in coinciding anticipation timing (3mph, 5mph, 8mph) of the experiment group between pretest and posttest value averages at $p<0.05$ level. The percent of mean difference between pretest and posttest values for 3mph was 43.17, for 5mph was 43.15, for 8mph was 46.34 (Table 2).

Table 2: Comparison of the pretest and post test values of coinciding-anticipation timing of experiment group

Variables		N	X	S.D.	Ä%	t	p
Coinciding Anticipation Timing (3 mph) (ms)	Pre-test	20	62.3	34.75	43.17	3.370	.001*
	Post-test	20	35.4	14.16			
Coinciding Anticipation Timing (5 mph) (ms)	Pre-test	20	76.7	60.08	43.15	2.406	.026*
	Post-test	20	43.6	25.30			
Coinciding Anticipation Timing (8 mph) (ms)	Pre-test	20	76.6	45.44	46.34	3.237	.004*

There was significant difference in reaction time performances (visual, audio and mixed) ($p<0.05$). The percent of mean difference between pretest and posttest values for visual was 28.87, for audio 32.26, for mixed reaction time was 21.54 (Table 3).

Significant difference was found in hand-eye coordination (placing and turning test) performances ($p<0.05$). The percent of mean difference between pretest and posttest values for placing and turning test were 12.24 and 13.08, respectively. (Table 4).

No significant difference was found in coinciding anticipation timing (3mph, 5mph, 8mph) performances for the control group between pretest and posttest values averages. The percent of mean difference between pretest and posttest values for 3mph was 22.01, for 5mph was 10.15. A 1.98 decline in the 8 mph performance was observed between the pretest and posttest values ($p>0.05$) (Table 5).

Significant difference was found in the dominant-hand visual reaction time performances of control group between pretest and posttest val-

Table 3: Comparison of the pretest and post test values of dominant-hand reaction times of experiment group

Variables		N	X	S.D.	Ä%	t	p
Visual Reaction Times (ms)	Pre-test	20	440.5	102.97	28.87	4.388	.000*
	Post-test	20	313.3	91.68			
Audio Reaction Times (ms)	Pre-test	20	419.3	135.23	32.26	4.428	.000*
	Post-test	20	284.0	95.79			
Mixed Reaction Times (ms)	Pre-test	20	436.3	77.77	21.54	3.084	.006*
	Post-test	20	342.3	107.17			

*$p<0.05$

Table 4: Comparison of the pretest and post test values of hand-eye coordination of experiment groups

Variables		N	X	S.D.	Ä%	t	p
Turning Test (sec.)	Pre-test	20	61.67	6.06	12.24	6.705	.000*
	Post-test	20	54.12	6.14			
Placing Test (sec.)	Pre-test	20	56.08	5.67	13.08	7.214	.000*
	Post-test	20	48.74	3.30			

*$p<0.05$

Table 5: Comparison of the pretest and post test values of coinciding-anticipation timing of control group

Variables		N	X	S.D.	Ä%	t	p
Coinciding anticipation timing (3 mph) (ms)	Pre-test	22	52.7	21.70	22.01	1.975	.062
	Post-test	22	41.1	19.29			
Coinciding anticipation timing (5 mph) (ms)	Pre-test	22	51.2	31.81	10.15	.602	.553
	Post-test	22	46.0	21.36			
Coinciding anticipation timing (8 mph) (ms)	Pre-test	22	45.4	18.65	1.98	-.159	.875
	Post-test	22	46.3	20.85			

*$p<0.05$

ues averages ($p<0.05$). No significant difference was found in dominant-hand audio and mixed reaction times performances of the control group between pretest and posttest values averages ($p>0.05$) The percent of mean difference between pretest and posttest values for visual, audio and mixed reaction time were 16.67, 2.21, and 6.9, respectively (Table 6).

It was observed that a significant difference was found in hand-eye coordination (placing and turning test) performances of the control group between pretest and posttest values averages at $p<0.05$ level. The percent of mean difference between pretest and posttest values for the placing and turning test performances were, 13.64, and 9.6, respectively (Table 7).

DISCUSSION

The purpose of the paper is examining the effects of proprioceptive training on coinciding timing anticipation (3mph, 5mph, 8mph), reaction time (visual, audio, mixed) and hand-eye coordination performances(placing and turning test). A proprioceptive training based on the balance and imbalance-training components is an important part of the physical condition training technology. The purpose of the proprioceptive training is to increase the complex activity of the neuromuscular system. Information is transferred from the peripheral receptors, which provide the stability and balance in the body, via the afferent and efferent of the neural system during the static and dynamic activities (Laskowski et al. 1997). In the literature, there are papers conducted on the positive effects of the proprioception trainings (balance exercises, neuromuscular training) affecting the proprioception (Malliou et al. 2004), balance and dynamic postural control (Ljubojevic et al. 2012), joint positions (Panics et al. 2008), muscular force (Heitkamp et al. 2001), and jumping performance (Ziegler et al. 2002; Sanja 2007), improving joint awareness (Asadi et al. 2015). Accurate anticipation of an object with movement is an important determinant of the efficient motor replies (Ramella 1984). An efficient anticipation is not always easy, because it requires that the player have important information on the inclinations of the opponent in various situations. If the player coincides what will happen and when it will happen, s/he will have great advantages (Schmidt 1991). When the results of the paper are considered, a significant difference has been observed between the pre and post values of the coinciding timing anticipation (3mph, 5mph, 8mph) performances of the experiment group (Table 2). No significant differences were determined between the pre and post values of the coinciding timing anticipation (3mph, 5mph, 8mph) performances of the control group (Table 5). Duncan et al. (2015) examined coincidence anticipation timing (CAT) performance at slow and fast stimulus speeds before, during, and after an acute bout of walk on a tread-

Table 6: Comparison of the pretest and post test values of dominant-hand reaction times of control group

Variables		*N*	*X*	*S.D.*	*Ä%*	*t*	*p*
Visual Reaction Times (ms)	Pre-test	22	329.8	57.39	16.67	3.906	.001*
	Post-test	22	274.8	42.05			
Audio Reaction Times (ms)	Pre-test	22	257.1	48.86	2.21	.623	.540
	Post-test	22	251.4	28.96			
Mixed Reaction Times (ms)	Pre-test	22	341.7	54.66	6.90	1.215	.238
	Post-test	22	318.1	69.72			

*$p<0.05$

Table 7: Comparison of the pretest and post test values of hand-eye coordination of control group

Variables		*N*	*X*	*S.D.*	*Ä%*	*t*	*p*
Turning Test (sec.)	Pre-test	22	62.39	6.16	13.64	5.313	.000*
	Post-test	22	53.88	4.55			
Placing Test (sec.)	Pre-test	22	55.39	4.81	9.60	4.613	.000*
	Post-test	22	50.07	3.97			

*$p<0.05$

mill (20 minutes at an intensity of 50% of HRR) in adults aged 60 to 76 years. They indicated that stimulus speeds play an important role; specifically walking (exercise) enhances CAT performance at slow stimulus speeds but reduces CAT performance at fast stimulus speeds. In our paper, proprioceptive training improved CAT performance at stimulus speeds of 3mph, 5mph, and 8mph. In the paper conducted by Smith and Mitroff (2012), it was reported that the stroboscopic training affects the coinciding timing anticipation in a positive way. In another paper conducted on elderly adults by Lobjois et al. (2006),it was reported that playing tennis affected the coinciding timing anticipation performance in a positive way. The results of the present paper show parallelism with the results of the abovementioned papers. The exercises performed with ninety percent exercise intensity are interrelated with the coinciding timing anticipation depending on weak coincidence (Duncan et al. 2013). There are various papers in literature showing that the exercise intensity does not affect coinciding timing anticipation performance, and the coinciding timing anticipation performance was determined only in mild exercises (70% exercise intensity) (Lyons et al. 2008). Akpinar et al. (2012) compared the coinciding timing anticipation performances of the players in different racket sports at various stimulus speeds. As a result, they reported that the coinciding timing anticipation performances of the players of tennis were good at low stimulus speeds, the coinciding timing anticipation performances of the players of badminton were good at medium-level stimulus speeds, and the coinciding timing anticipation performances of the players of table tennis players were good in high speed stimulus. The positive effect in the coinciding timing anticipation performances may be related with the development in the agreement between the neural and muscle systems.

The time of the reaction is extremely important in sports in which the movements of the athletes are conditioned with the signals or with the movements of the ball or with the actions of the opponent. In many fast movements, the success depends on the speed of the athlete for deciding on the counter-movements and on the speed of the reaction (Schmidt 1991). When the results of the paper are considered, it is observed that a significant difference has been determined between the pre and post values of the visual, audio and mixed reaction time performances of the experiment group (Table 3). In the control group, on the other hand, a significant difference has been determined between the visual reaction time performances; however, no significant differences were found between the pre and post values of the audio and mixed reaction time performances (Table 6). In a paper, which was conducted to test the effects of the aerobic exercises on the reaction time, it was reported that the premotor fraction of the reaction time in the exercise group decreased substantially after the exercise, and that the exercise developed the premotor fraction of the reaction time (Ozyemisci-Taskiran et al. 2008).

There are papers suggesting that the chronic effect of the training is positive on the reaction time performance (Collardeau and Alter 2001; Davranche et al. 2006; Fragala et al. 2014; Dogra 2015). Many researches show that a sports activity reduces reaction time, which is a reliable indicator of rate of processing of sensory stimuli by the central nervous system (Dube et al. 2015). Leon et al. (2015) reported that the aerobic training cognitive exercise program performed for 12 weeks led to a development in the performance of the simple and selective reaction time performance. Dube et al. (2015) indicated that badminton training for 2 to 3 hours per day for a minimum of 2 years is beneficial in improving eye–hand reaction time, muscle coordination, cognitive functions, concentration, and alertness. Abu-Saleh (2010) reported that the volleyball-training program, which is conducted for 5 months, three times a week, and for 2 hours, developed the reaction time. Gavkare et al. (2013) reported that the aerobic exercises performed for a minimum of 2 years and, for 2 to 3 hours a day developed the reaction time (audio, visual, and whole body time) of a group. In addition, Whitehurst (1991) reported that the aerobic trainings which lasted for 8 weeks, 3 days a week and for 35 to 40 minutes a day, did not have any effects on the reaction times of the elderly women. The improvement in the reaction time may be associated with the development in the process skills of the sensory-motor performance and central neural system due to the trainings (Madan 1992), and the effect of the exercises on the reaction time may be associated with the increased stimulation level during the exercises and the metabolic activity (Brisswalter et al. 2002).

The hand-eye coordination means the integrated use of the eyes, arms, hands and fingers to perform hand movements directed towards the purpose (Tsang 2014). The hand-eye coordination is especially important in individual sports as well as in team sports in which the motor-hand skills are used together. It has been proven that the hand skills are important in jobs, which require sensitivity and rough-muscle strength (Menevse 2011).

Two different tests for the purpose of measuring the hand-eye coordination have been used in this paper. When the findings on the hand-eye coordination are considered, it becomes clear that there is a significant difference between the pre- and posttests of the experiment and the control group in terms of placing and turning performances (Tables 4 and 7). This improvement which is considered apart from the modified neural connections in both the experiment and control group may be explained with the hypothesis claiming that the motor reaction depends on the visual information, and with the eye and hand spatial and temporal connection hypothesis (Sailer et al. 2000).

In a study by Menevse in 2011, it was reported that the participants of the study who had the Palmaris Longus muscle, one of the important muscles in the arms in terms of the flexion force of the hand, in their arms, had better reaction time results than those who did not have this muscle. Good eye-hand coordination increases the skills of the player to perform the complex movement, and to reply to the external stimuli in an efficient way (Paul et al. 2011). The papers that examine the effects of training on hand-eye coordination are very few (Kayapinar et al. 2006), and no studies, which examined the effects of the proprioceptive trainings on hand-eye coordination, were observed in the literature.

CONCLUSION

As a consequence, it has been observed that the proprioceptive trainings influenced the coinciding timing anticipation (3mph, 5mph, 8mph) and the reaction time (audio and mixed) performances in a positive way. It is being considered that the positive effects of the proprioceptive trainings on the coinciding timing anticipation and the reaction time performances influence neuromuscular processing skills, improving concentration power and mind-body awareness in a positive way.

RECOMMENDATIONS

Subsequent studies should be conducted on different sports branches (tennis, table tennis, badminton, judo, karate, taekwondo) and with people from different age groups, and also from different genders (women, men). The training program duration and the number of the participants should be increased and examined with athletes at an elite level in a more comprehensive manner. Subsequent studies should be conducted to examine the effects of two different training programs on coinciding timing anticipation, reaction time, and hand-eye coordination with a control group. In addition to the variables like, coinciding timing anticipation and reaction time, the effects of the proprioceptive trainings on different variables (the relation with balance, speed, agility, and sports injuries) should be examined. The trainers should include the proprioceptive training activities, which have positive effects on cognitive functions, in their training programs while they are planning them.

LIMITATIONS

The study is limited to forty-two volunteering physical education and sport teaching students who have no health problems and sports injuries from doing exercises, don't practice regularly, aren't active athletes. The paper is limited to examining the effects of proprioceptive training on coinciding anticipation timing (CAT), reaction time and hand-eye coordination

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