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TABLE TENNIS PRACTICE REDUCES GENDER GAP IN EYE–HAND RESPONSE TIME: A CROSS-SECTIONAL STUDY

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ABSTRACT

Gender difference in response time (RT) is well known, however, whether table tennis (TT) practice is capable of reducing the gap in RT between men and women is unknown. This study aimed to evaluate the eye–hand RT among collegiate TT athletes (n=62) and non-athletes (n=108) of both gender. The FITLIGHT Trainer™ System was used to measure static eye–hand RT of both hands in five conditions: simple RT at zero distance; simple RT at shoulder distance; choice RT at zero distance; choice RT at shoulder distance; and choice RT at random distance. Results showed that RTs increased from simple to choice trials and from zero to random and then to shoulder-distance trials. There was no significant gender difference in all RTs among TT athletes ($p>0.05$). Female TT athletes responded significantly faster than did female non-athletes in choice at zero and at shoulder distance for both hands ($p<0.05$). No significant difference in RT was observed among male TT athletes and non-athletes. In conclusion, male and female TT athletes have similar eye–hand RT, suggesting that TT practice reduces gender difference in eye–hand RT. The better RT in athletes than non-athletes was only seen among women, but not among men.

Keywords: Table tennis; Response time; Gender difference; Athletes; FITLIGHT Trainer™ System.

INTRODUCTION

Response time (RT) is the time interval required for an individual to react and physically respond to a signal. It involves sensory skills, decision-making processes, and motor performance (Spierer *et al.*, 2011; Heitz, 2014). Sensory RT involves identification of signals under simple or choice conditions. Simple reaction involves only one stimulus and one outcome, whereas choice reaction consists of more than one stimulus and outcome. Motor RT is the interval from identification of an external stimulus to completion of the corresponding action. Hence, eye–hand RT is the duration from seeing the signal to responding with the upper extremities.

In sports, visual RT is usually the decisive factor in winning a contest (Williams & Elliott, 1999). Table tennis (TT) is one of the fastest ball games and an extremely popular sport worldwide. In TT, players often have little time to react because of the high speed of the ball and limited distance between players; 140-kilometres per hour serves are common (Lees, 2003). RT is one of the essential skills for good performance of TT. Athletes need excellent RT in order to react consistently in a fraction of a second during a game. Athletes with short RTs react faster to an opponent's shot and can better execute shots (Ak & Koçak, 2010). Visual RT, or more specifically eye–hand RT in TT, determines a player's ability to accurately return the serve of an opponent. In TT, this ability is particularly important because the 40-mm ball is smaller than that used in other ball games and the distance between opponents is short. Thus, it is essential to visually identify the ball and respond with an accurate shot.

Research on visual reaction time in athletes began a few decades ago. Many studies compared athletes with non-athletes and reported that RTs were faster in athletes than in non-athletes of the same age and body mass index (Ando *et al.*, 2001; Nakamoto & Mori, 2008; Akarsu *et al.*, 2009; Moscatelli *et al.*, 2016). Later research examined RTs in different sports (such as racquet vs combat sports) or in two similar sports (Guizani *et al.*, 2006; Ak & Koçak, 2010). The results showed differences in RT between sports and confirmed that visual RT is a critical factor in the performance of athletes in racquet sports (Ak & Koçak, 2010, Kolman *et al.*, 2018). Visual RT of TT athletes was also widely studied and findings revealed the importance to sports performance (Bhabhor *et al.*, 2013; Vimal *et al.*, 2018; Castellar *et al.*, 2019).

A significant gender difference in visual RT is well known (Adam, 1999; Bamne *et al.*, 2011; Woods *et al.*, 2015). Adam (1999) reported that men have faster RT than women because they use a specific information processing strategy that differs from the strategy used by women. Although physical differences may limit the development of sports skills among female athletes, studies have shown promising improvements in females who have undergone specific training (Kudryashov, 2015; Biernat *et al.*, 2018). Whether table tennis is capable of reducing the gap in eye–hand RT between men and women is unknown.

PURPOSE OF THE STUDY

This study aimed to evaluate the simple and choice eye–hand RT among TT athletes and non-athletes of both genders. It was hypothesised that (1) male and female TT athletes have similar eye–hand RT and (2) TT athletes have better eye–hand RT than non-athletes.

METHODS AND MATERIALS

Study design

This was a cross-sectional study design comparing the RT of TT athletes with non-athletes. The study was conducted in a sports university and a non-sport university. Inclusion criteria were at least 18 years old with no major medical conditions. Those with impaired vision, depth perception or illnesses that could affect the study results, such as recent injury or cardiovascular disease, were excluded. The assessment was done in a well-lit room by two consistent research assistants for each university.

This study was approved by the Institutional Review Board of Chang Gung Memorial Hospital, Taiwan (no. 201600729A3 and 201601220B0). Written informed consent was obtained from all participants, and parental consent was obtained for participants younger than 20 years.

Participants

TT athletes from TT club in a sport university were recruited and students not involved in sports. The demographic characteristics of the participants are shown in Table 1. There were 30 male non-athletes (mean age: 20.55±0.71 years), 45 male TT athletes (mean age: 21.35±2.06 years), 78 female non-athletes (mean age: 20.24±0.80 years), and 17 female TT athletes (mean age: 20.25±1.28 years). Male TT athletes were statistically older than the other groups ($p<0.001$), although on average there was less than a year difference. Most participants were right-handed, and there was no significant difference in handedness among the four groups ($p=0.7310$). Notably, hours playing computer games were significantly different among the four study groups ($p=0.0002$). The male non-athletes spent significantly more hours (13.8 hours per week) than the other three groups. The male TT athletes spent 7.8 hours per week in playing computer games that was significantly different from the two female groups. The female non-athletes and female TT athletes spent 2.8 hours per week and 0.9 hours per week in playing computer games, respectively, but no difference was seen among the two female groups. TT athletes had 8.85±2.77 and 9.53±2.92 years of practising TT for males and females, respectively ($p=0.4957$).

Table 1. **DEMOGRAPHIC CHARACTERISTICS OF TABLE TENNIS ATHLETES AND NON-ATHLETES** (n=170)

Variables	Males		Females		p-value
	Non-athletes (n=30)	Table tennis (n=45)	Non-athletes (n=78)	Table tennis (n=17)	
Age, mean±SD (years)	20.55±0.71 [a]	21.35±2.06 [b]	20.24±0.80 [a]	20.25±1.28 [a]	<0.0010
Right-handedness, n (%)	27 (90.00)	40 (88.89)	73 (93.59)	15 (88.24)	0.7310
Computer games playing, mean±SD (hours/week)	13.77±15.05 [a]	7.81±7.79 [b]	2.84±8.46 [c]	0.88±2.47 [c]	0.0002
Table tennis experience, mean±SD (years)	–	8.59±2.70	–	9.53±2.92	0.4957

a, b, c: Similar symbols indicate significant statistical difference

Measurement

FITLIGHT Trainer[TM] System (FTS) is a wireless light system comprised of eight RGB LED powered lights operated by a tablet controller (Figure 1). The controller enables routines, collects and stores data, edits drills and creates various programmes. Data stored in the controller can also be used to download data to the user's computer for further analysis. The lights served as visual stimuli and were used as targets for the user to deactivate. Time taken to deactivate the lights enables the measuring of RT abilities, while the number, colour and position of the lights allows for a variety of conditions.

Figure 1. **FITLIGHT TRAINER™ SYSTEM (FTS)**

The device was equipped with a series of selections for programming routines, including distance and impact sensitivity of impact to the lights, light colour selection, sequence of the flashing lights, delay between lights and runtime of the light-on. Immediate feedback of user's performance was captured in milliseconds (ms) and recorded in real-time in the controller.

Simple RT measures were programmed with green light (Go task), while choice RT measures consisted of green and red lights (Go-NoGo task). Distance from the beginning position of tested hand to the lights were designed to zero distance, shoulder distance and random distance. For zero distance, one light disc was placed immediately next to the participant's tested hand on the wall; while for shoulder distance, the light disc was placed shoulder-width away from the participant's tested hand. For random distance, eight light discs were positioned around the tested hand. Using zero distance as a baseline, shoulder distance was implemented as indicator for motor response, while random distance implied an unknown position of the light to increase the complexity of choice RT.

Eye–hand RT measurements using FTS is highly reliable. In a previous study (Liu *et al.*, 2018) measured the test-retest reliability and known-groups validity for the simple and choice eye–hand RT measurements using FTS. Result showed good reliability (ICC= 0.68-0.90 for non-athletes, ICC= 0.70-0.95 for karate athletes) and valid known-groups validity between karate athletes and non-athletes.

Measurement tool

The measurement tool for eye–hand RT in our study is the commercially available FTS. The FTS is currently widely used in training (Zwierko *et al.*, 2014). It has also gained attention as an assessment tool for RT (Carazo-Vargas & Moncada-Jiménez, 2017, Van Ness *et al.*, 2017). Current measurement tools for RT in research include computer software with clicking on mouse or keyboard (Vimal *et al.*, 2018; Hülsdünker *et al.*, 2019), video-based methods (Mori *et al.*, 2002; Nedeljkovic *et al.*, 2017), self-developed devices (Nuri *et al.*, 2013; Liu *et al.*, 2017), mobile technologies (Burke *et al.*, 2016) or medical diagnostic devices such as electro-encephalography (EEG) and electromyography (EMG) (Endo *et al.*, 2006). The RT measured in the current study using FTS produced similar result to the previous studies. Use of a standard measuring instrument increases comparability of results among similar studies. FTS is considered suitable for this purpose because its results are reliable and because it is user-friendly, commercially available and reasonably priced.

Procedure

Research assistants were trained with the FTS operation and the study flow before the assessment. Standard instruction was given and no verbal cue was allowed during the test. Participants were all in best corrected vision, wearing either glasses or contact lenses for those with myopia or anisometropia. All participants were requested to wear comfortable clothing and not to consume heavy meals an hour before the assessment. Five measuring conditions of simple and choice RT were measured at zero and shoulder distance (SRT_zero, SRT_shoulder, CRT_zero, CRT_shoulder and CRT_random) (Figure 2). Participants stood facing the wall at one arm's-length distance from the wall and positioned the tested arm to eye-level at the front chest with palm gently touching the wall. The participants were instructed to deactivate the lights as fast as possible by placing the tested hand in close proximity to the activated light.

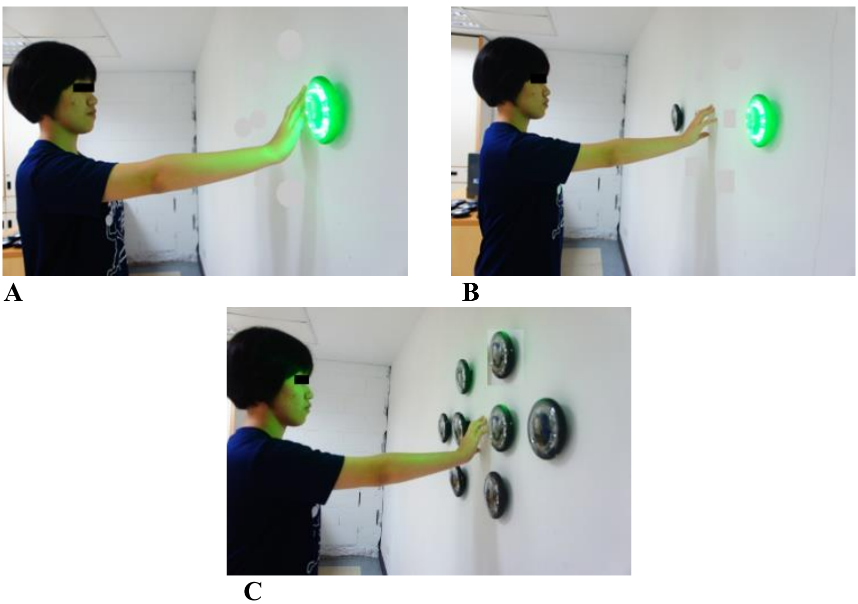

Figure 2. **MEASURING A) SIMPLE/CHOICE RESPONSE TIME AT ZERO DISTANCE; B) SIMPLE/CHOICE RESPONSE TIME AT SHOULDER DISTANCE AND C) SIMPLE/CHOICE RESPONSE TIME AT RANDOM DISTANCE**

The measurement protocol was configured by the tablet controller, and 30s of rest was given between each bout. Five bouts were given for SRT_zero and SRT_shoulder; ten bouts for CRT_zero and CRT_shoulder; and 30 bouts for CRT_random, in consideration of the higher variation of RT in more difficult conditions. Both dominant and non-dominant hands were tested for all conditions. The highest and lowest values of the trial were eliminated and kept one mean for each measurement because the mean is easily distorted by extreme values.

Statistical analysis

The interaction between genders (male vs. female) and sport group (TT athlete vs. non-athlete) were examined first for significance in RT using two-way ANOVA. The interactions for 10 RTs were statistically significant for 7 RTs (p-values in the range between 0.0018 and 0.0458). Because of the uneven gender distribution between the athlete and non-athlete group, and the complicated interpretation of two-way interaction, the study groups were categorised as 1=male non-athletes, 2=male TT athletes, 3=female non-athletes, and 4=female TT athletes and analysed by using one-way ANOVA. The Scheffe multiple comparisons test was used to analyse differences among groups. The significance level was set at 0.05.

RESULTS

Table 2 and Figure 3a-3b show the eye–hand RT for dominant hands and non-dominant hands under the five measurement conditions for male and female TT athletes and non-athletes. The RTs of all participants increased from simple to choice trials and from zero to random and then to shoulder-distance trials. Male non-athletes required 317.36±79.46ms to complete the task for SRT_zero, 328.59±57.88ms for SRT_shoulder and 383.70±62.67ms, 409.76±66.34ms and 456.76±75.65ms for CRT_zero, CRT_random, and CRT_shoulder, respectively. Similar patterns were observed for female non-athletes and for all TT athletes. Results of non-dominant hands showed the same increase in RTs with the increased difficulty of the measurement conditions in all groups. Furthermore, RTs were faster in trials of dominant hands than in those of non-dominant hands.

Table 2. **MEAN RESPONSE TIME (ms) FOR TABLE TENNIS ATHLETES AND NON-ATHLETES** (n=170)

Response time	Males: Non-athletes (n=30)	Males: Table tennis (n=45)	Females: Non-athletes (n=78)	Females: Table tennis (n=17)	p-Value
Dominant hands					
SRT_zero	317.36±79.46	318.58±62.95	342.40±69.78	323.10±43.89	0.4347
SRT_shoulder	328.59±57.88^{A}	357.11±67.08	370.22±55.75^{B}	353.00±37.44	0.0424
CRT_zero	383.70±62.67^{A}	393.46±56.16^{A}	439.13±57.75^{B}	379.50±37.94^{A}	0.0018
CRT_random	409.76±66.34^{A}	440.34±69.68^{A}	478.92±70.31^{B}	440.73±45.28	0.0091
CRT_shoulder	456.76±75.65^{A}	446.05±60.03^{A}	514.51±81.05^{B}	454.36±46.94^{A}	0.0122
Non-dominant hands					
SRT_zero	339.75±67.71^{A}	343.66±63.45^{A}	389.11±70.50^{B}	341.00±35.23	0.0458
SRT_shoulder	354.96±60.60	360.84±61.12	403.97±53.38	369.10±40.85	0.1799
CRT_zero	388.04±61.72^{A}	390.50±59.62^{A}	442.61±59.91^{B}	390.54±25.10^{A}	0.0157
CRT_random	424.07±68.14^{A}	456.75±78.89	488.30±66.05^{B}	457.66±50.49	0.0182
CRT_shoulder	482.04±99.02^{A}	443.42±65.28^{A}	539.56±98.37^{B}	455.75±68.59^{A}	0.0005

$^{A, B}$ Presence of different letters indicates a significant statistical difference;
SRT_zero=Simple response time zero distance SRT_shoulder:=Simple response time shoulder distance;
CRT_zero=Choice response time zero distance; CRT_shoulder=Choice response time shoulder distance;
CRT_random=Choice response time random distance

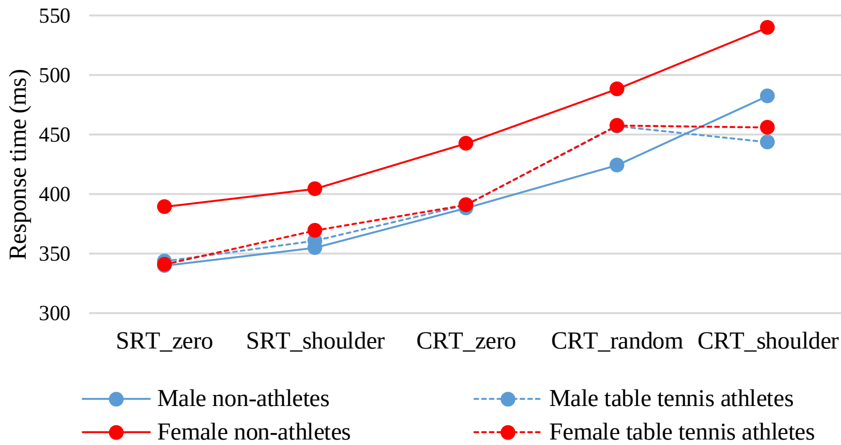

Figure 3a. **MEAN RESPONSE TIME (MS) FOR DOMINANT HANDS AMONG NON-ATHLETES AND TABLE TENNIS ATHLETES** (N=170)

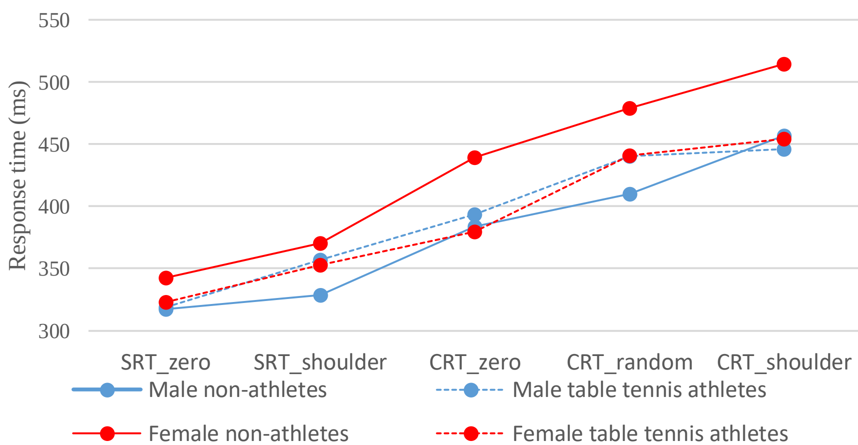

Figure 3b. **MEAN RESPONSE TIME (MS) FOR NON-DOMINANT HANDS AMONG NON-ATHLETES AND TABLE TENNIS ATHLETES** (N=170)

No gender difference in all RTs was observed in TT athletes. Female TT athletes responded significantly faster than did female non-athletes in CRT_zero and CRT_shoulder for both hands ($p<0.05$). This difference was not observed in the comparison of male athletes and non-athletes. The RTs for CRT_shoulder of female TT athletes and female non-athletes were 514.51±81.05ms and 454.36±46.94ms respectively, for the dominant hand and 539.56±98.37ms and 455.75±68.59ms for the non-dominant hand. The RTs for female TT athletes were approximately 60ms and 80ms faster than those for female non-athletes in the dominant hand and non-dominant hands, respectively.

DISCUSSION

The results supported the first hypothesis where male and female TT athletes have similar eye–hand RT, suggesting that TT practice reduces gender difference in eye–hand RT. The better RT in athletes than non-athletes was only seen among women, but not among men.

TT athletes: Similar eye–hand RT between males and females

Although gender difference in RT is well known, studies of RT in athletes reported controversial findings. Studies, which recruited adolescent or collegiate athletes, reported no gender difference between athletes (Lum *et al*., 2002, Notarnicola *et al*., 2014). Lum *et al*. (2002) studied RT in college athletes of swimming, track, soccer and volleyball, while Notarnicola *et al*. (2014) studied adolescent athletes of volleyball and tennis. On the contrary, some researchers (Doğan, 2009; Heirani *et al*., 2012) studied college athletes of varied individual and team sports (but not racquet sports), and reported male athletes have better RT than female athletes. The present findings of TT athletes were in accordance with Lum *et al*. (2002) and Notarnicola *et al*., (2014), but were in contrast to Doğan (2009) and Heirani *et al*. (2012). Gender difference in RT among athletes could be attributed to the type of sports. To date, no comparable studies that reported gender difference in RT among TT athletes have been encountered.

This study and previous studies (Lum *et al*., 2002; Notarnicola *et al*., 2014) implied the importance of practising the sport because the results suggested that TT could close the gap of disparity in RT between males and females. Female TT athletes practiced TT for years and the nature of the sport attributed to the higher ability in their eye–hand RT. In this study, the TT practice year was similar between male (8.6 years) and female TT athletes (9.5 years). It is suggested that TT practice can increase eye–hand RTs of women to a level similar to that of men. Previous studies showed absolute benefits among school students practising TT (Guérin *et al*., 2005; Zou *et al*., 2012) and the current study showed an advantage in eye–hand RT among college students who participated in TT. However, there were challenges in recruiting and retaining girls to participate in TT (Rowe *et al*., 2018). Therefore, one can advocate more sports sessions in schools and universities to enhance students' physical health. This study may not be the first to disclose the advantage of sports, but the importance of women to be trained in sports for higher performance in visual RT was shown.

Women: Faster eye–hand RT in TT athletes than non-athletes

Faster RTs in TT athletes than in non-athletes has been reported in previous studies (Akarsu *et al*., 2009; Bhabhor *et al*., 2013; Vimal *et al*., 2018). In this study, such discrepancy was only seen in female athletes and in female non-athletes. The female participants did not spend as many hours in playing computer games as the male participants. Although female non-athletes played computer games for more hours (2.8 hours/week) than female athletes (0.9 hours/week), the difference was not significant. TT sport required consistently fast reaction during a game because the ball travels fast over short distances between two players. Due to years of practise, eye–hand RT among TT athletes was trained and surpassed that of non-athletes.

Men: Similar eye–hand RT between TT athletes and non-athletes

The male non-athletes in the study reflected an eye–hand RT to the level of TT athletes. This observation was not reported in previous studies. There were few studies comparing the differences of RT of athletes with non-athletes of the same gender. A few studies evaluated gender differences and sport ability in RT, but the analysis did not consider both factors at the same time (Lum *et al.*, 2002; Notarnicola *et al.*, 2014). It was speculated that computer games play a role in the similar visual RT between male TT athletes and non-athletes. Male non-athletes in this study spent significantly more hours in playing computer games in a week (13.8 hours/week) as compared to male TT athletes (7.8 hours/week). Video game playing modifies the visual attention (Green & Bavelier, 2003) and recent research focused on improving the visual-related abilities among children in need (Yatim & Samsudin, 2006; Nejad *et al.*, 2019). Further investigation is needed to examine the influence of playing video games on visual RT among male collegiate non-athletes.

LIMITATIONS AND FUTURE DIRECTION

This study has a few limitations. Firstly, no analysis was made between elite and novice TT athletes in the athlete group because the TT athletes were recruited from two colleges, which differed in their definitions of TT ability. Secondly, the RT movements in the five experimental conditions do not correspond to TT movements. Hence, it is unclear whether the RT test results are applicable to real-life TT performance. Sport-specific testing is needed in order to determine the nature of information processing and response selection in a particular sport (Guizani *et al.*, 2006). Future studies should compare TT with other racquet sports that require years of practise and design movements resembling those performed in the sport. Thirdly, no detailed information on the type of computer games played by the participants were collected. Fourthly, this was a cross-sectional study and not a training study. The present findings require confirmation in future studies. Furthermore, most of the current studies in visual RT focused on young athletes. Future studies could investigate the life-long age effect of visual RT in athletes.

CONCLUSION

Among college TT athletes, males and females had similar eye–hand RT, suggesting that TT practice reduces gender difference in eye–hand RT. Among college female students, TT athletes have better eye–hand RT than non-athletes. Among college male students, TT athletes and non-athletes had similar eye–hand RT. Spending a lot of hours on computer games in male non-athletes may explain the similarity.

Ethical clearance

This study was approved by Institutional Review Board from Chang Gung Medical Foundation, Taiwan (no. 201600729A3 and 201601220B0).

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