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Research Article

Effect of Proprioceptive Training on Reaction Time: A Randomized Control Trial

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ABSTRACT

Introduction: Reaction time is an important indicator of good performance. Different types of exercises have been used by researchers to improve the reaction time of an individual. Other types of exercises still need more research to study their effect on simple reaction time, such as proprioceptive training. The purpose of this study is to examine the effect of a proprioceptive training program using the Huber machine on the simple reaction time.

Materials and Methods: Twenty-one participants from the medical staff were assigned to two groups including the experimental group (1) composed of 5 male and 5 female participants and a control group (2) including 5 male and 6 female participants. A simple reaction time (SRT) test was assigned to all participants. Only the experimental group performed a proprioceptive exercise protocol on Huber motion's platform, while the control group was tested at identical periods without exercising before the training (T0), immediately post-exercise (T1), and twenty minutes after exercising (T2). The procedure was repeated for six sessions over two weeks.

Results: The participants of the group (1) show a decrease in the mean of RT (-43 min) immediately after proprioceptive training (T1), but they reveal a little increase (at T2) in SRT after an interval of 20 minutes (-23 min). They still prove a retention effect, while few participants in the control group show improvement at T1 or T2. Paired sample t-test was significant for the group (1) at T1 and T2 (P<0.05) while it was not significant for the control group.

Conclusion: Proprioceptive training may have a positive influence on reaction time with a retention effect. Clinicians can use proprioceptive training to improve the reaction time of their patients.

Keywords:

Proprioception; Reaction time; Performance; Huber; Motor learning

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1. Introduction

Recently, proprioception training has been considered an essential technique in the avoidance of musculoskeletal injuries [1]. Many sports activities are taking into consideration the important effect of proprioception as a core stability training [2]. Unstable platforms can be used as a modality to achieve this goal in addition to strength improvements. In literature, it is argued if there is a substantiated correlation between proprioceptive training and athletic performance improvement [3-6].

Previous research in group sports found that the accomplishment in this sport depends on the level of numerous functioning features. Besides physical characteristics which are of primary importance, recent studies support the importance of perceptual-cognitive functions. They suggested that success relies on the processing function considering the complex and quickly changing environments [3].

A discrepancy can be made between the "lower-level" and "higher-level" cognitive functions. The "higher-level" cognitive executive functions include working memory, inhibitory control, and cognitive flexibility while the "lower-level" cognitive processes are essential for basic information processing, such as reaction time (RT), psychomotor performance, and visuoperceptual abilities [4, 5].

Some studies considered "lower level" cognitive processes as a requirement for all players similarly. The results of previous studies are incongruent when comparing performance levels on these "lower-level" cognitive processes, they suggest no differences related to this level of performance in sports [7].

So far, shorter RT was found to be correlated with better psychomotor responses and a need in novices and sub-elite players [3, 4]. Psychomotor responses are characterized by continuous changes of direction, neuromuscular control, agility, and eccentric/concentric strength [8].

To improve performance, gifted athletes must grow their abilities in this multidimensional performance [7]. Some characteristics, i.e. training quality and frequency, had a direct effect on endurance, mainly, and force in addition to secondary factors like balance, rapidity, rotational perturbation from support surface [9], and RTs [10].

That is why recent approaches consider neuromuscular training crucial in many sports, as it allows athletes to have more motor control over their performance [11]. Moreover, it facilitates the learning of complex movements in a relatively rapid way. Athletic balance and performance were found highly correlated when reviewed by Silfieset et al. (2015) who emphasized the understanding of this correlation between performance and postural control. The role of neuromuscular training has become better known. In such type of training, the central nervous system (CNS) gathers information sent from different stimuli receptors to generate stability, and hence, results in a quick and specific force [1].

This study aims to examine the effect of the proprioceptive training program with an unstable platform type Huber motion lab on the reaction time of healthy subjects using visual simple reaction, one of the most sensitive indices of cognitive performance.

2. Materials and Methods

Design

This is a randomized controlled study. The therapist who performed all the assessments and training was the same in all sessions. When baseline measurements were obtained, the subjects were randomly assigned.

Population

Twenty-one participants were randomly allocated to either the experimental group (i.e. proprioceptive training) or the control group.

Before starting the experiment, an interview was carried out briefly for choosing our participants. Only healthy subjects were recruited in this study (age 20-30). All participants were hospital staff with digital literacy (i.e. the knowledge and behaviors in using digital devices, such as smartphones, tablets, laptops, and desktop PCs) and with a BMI of 18.5-24.9. For being eligible, participants must be free of any injury (or in the recovery phase) in the hip or ankle within the past six months. They should not be either diagnosed with any chronic diseases. In addition, female participants were not recruited during menstruation. Furthermore, subjects performing proprioceptive training and specific athletic, musical, or other intensive motor skills training were excluded.

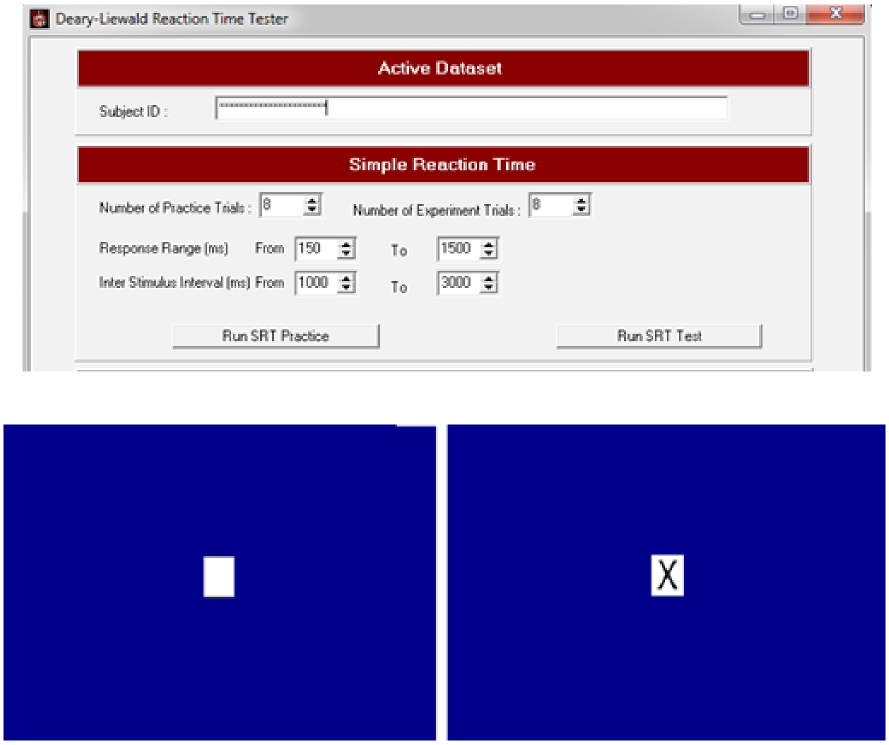

Figure 1. The deary-liewald reaction time test

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Before starting the test, participants were informed about the procedure and the proprioceptive training steps. Also, written informed consent was obtained from each subject signed before the initiation of the experiment, and ethical approval from the Ethics Committee of Tehran University of Medical Sciences (IR.TUMS.VCR.REC.1395.581) was achieved.

Participants were randomly assigned into experimental or control groups using papers with "EG" or "CG" written on each piece and the participants chose a paper that specified their group.

Measurement tools

The anthropometric data, weight, and height of each participant were measured by a mechanical weight and height scale TZ-120. BMI was calculated using Quetelet's index which is weight/(height)^2, weight in kg, and height in meters [12].

The visual reaction time for each participant in both groups was measured at three onsets including before the training (T0), immediately (T1), and after ten minutes (T2) using a personal computer PC (Toshiba laptop, CPU core i3 /1, 7GHZ, RAM 4GB, Window 8.1 pro.) with DLRT software, version 3.10 installed on it. The Deary-Liewald reaction time tester (DLRT) is a freely available program that can be run simply and choose RT tasks [13].

The participants were seated upright half a meter away from a 21 laptop screen in the same comfortable chair with good back support in the same room to ensure a consistent environment. All tests were performed at the same time of day between 3.00 pm and 5.00 pm. The environment was quiet and the temperature was maintained between 22°C and 25°C. The participants were thoroughly informed about the test and were advised to have lunch before 1.00 pm and show up at least two hours after lunch with empty bowels and bladder. The participants were also instructed to avoid alcohol, caffeine, and vigorous exercise during the 12 hours before each session. Subjects must refrain from taking psychotropic drugs (sedatives, hypnotics, and tranquilizers), and antihistamines 48 hours before the study.

Then, to perform the DLRT (Deary-Liewald reaction time), in the middle of the screen, a white square with a colored background appears in front of the participant. When a diagonal cross the square, this is considered the stimulus. Directly, the participant must press the bar key on the keyboard; otherwise, the cross will remain on the square till he responds. This process will be repeated several times. The inter-stimulus interval (the time interval between each response and when the next cross appeared) ranged between 1 min and 3 min and was randomized within this limit (Figure 1).

The simple reaction time (SRT) involved non-recorded eight practice trials and eight test trials. The computer program recorded the response times for each cross and the inter-stimulus interval for each trial [13]. The computer also computed the mean, median, variance, and standard deviation and saved all trials for each subject during the six sessions in an independent excel file.

The SRT was repeated three times per session (8 trials each) for each subject from the experimental group. The first test was done before proprioceptive training T0, and then, it was repeated immediately after training T1. After that, the participant rested for twenty minutes before accomplishing the last test T2. The control group followed the same order of tests without training.

Procedures

After screening the subjects who were eligible to participate in this study, the RT was tested. Then, the experimental group underwent six sessions of proprioception training, while the control group did not receive any intervention.

As preparation for training, participants were asked to wear a comfortable shirt and comfortable sports pants and be barefooted to exclude any effect from clothing or footwear. In all proprioceptive training, the participants were instructed to stand straight in the middle of the platform on one leg stance, knee slightly bent, and to look forward (EO set), as a way to ensure that the judgment was based on proprioceptive information. The accurate application of the procedure was fully explained and supervised by a physiotherapist (Figure 2).

The proprioception training was done using HUBER® MOTION LAB, the mobile platform, variable speed, and amplitude, platform angle: 0° to 10°, oscillation frequency: 0 to 40 round per minute (RPM) maximum, four handlebars. Preset protocols with a free menu option were used to create a personal program.

Six sessions, (three sessions per week) were performed for the experimental group. Each session consists of thirty minutes after performing the initial SRT at T0. A five-minute warm-up running on a treadmill at 2.5 km/h speed was performed followed by proprioception training on the Huber motion lab machine [14] for 10 minutes (free menu: 2 series (sets) with 30-second rest between them, 10 repetitions each set, workout for 15 second and active rest for 15 seconds, maximal speed 40 RPM, platform angle 10°). The participant achieved all the training on one leg stance with five repetitions each,

Figure 2. Photo for exercise JMR

he switched to the other leg, the first set with EO and the second set with EC. The subject was recommended to use the handles to avoid the risk of falling. After that, the participant cooled down for 5 minutes on the treadmill at 2.5 km/h speed. Afterward, the subject repeated the test immediately at T1 and rested for 10 minutes before the last repetition of the SRT at T2. The control group underwent identical reassessments at the same time intervals without intercurrent exercise (Figure 3).

It is noteworthy that the testing and training were done at the same time to minimize variations. All subjects were followed in all steps by one examiner, and the other carried out all tests to eliminate any variability from utilizing separate observers.

Statistical analysis

Descriptive data analysis was conducted to measure the mean (μ), median, variance, and standard deviation to describe the sample data. Analysis of subgroups was tested for gender as previous studies show the difference in RT gender. Paired t-test was applied for comparing RT within both groups as well as for subgroup comparison, and $P<0.05$ was considered statistically significant for assessing hypotheses about the population's means. Scientific support was acquainted, using the reputable German online services of "In-Silico" (in-silico.net) which has been founded in 2006, and IBM SPSS software, version 23, (2015). The trials of the individual recruited in both samples were studied, and adjusted to read a normal

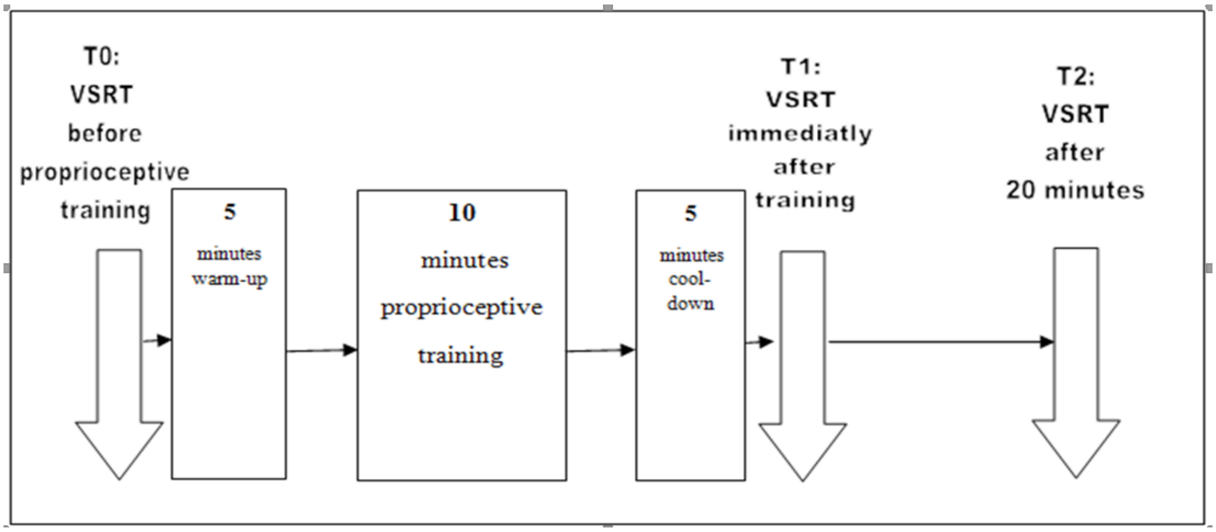

Figure 3. Main sequences of conditions

distribution. Both groups were independent samples; hence the paired t-test is designed to test the equality of the difference between the means of the two samples. The t-score to P transformation was done according to T cumulative distribution function. The paired t-test was measured based on a 95% confidence level, α=0.05.

3. Results

Sixty healthy individuals without visual defects were assigned at the beginning (Table 1). Forty-six subjects were eligible for participating in this study. But, only twenty-one participants completed the study (Figure 4).

In the experimental group (EG), ten participants were assigned including five males (Mean±SD 26.4±2.4 years (age), 178.4±9.6 cm (height), 72.4±7.5 kg (weight), and BMI with Mean±SD 22.7±0.8 kg/m^2) and five females (Mean±SD 22.6±2 years (age), 162±5.8 cm (height), 57.2±5.5 kg (weight), and BMI with Mean±SD 21.72±1.0 kg/m^2). While, in the control group (CG) eleven participants were assigned including six males (Mean±SD 27±2 years (age), 176.4±5.5 cm (height), 73.6±5.7 kg (weight), and BMI with Mean±SD 23.7±0.8 kg/m^2) and five females (Mean±SD 23.8±2.6 years (age); 165.5±4.6 cm (height), weight 59.5±5.9 kg (weight), and with Mean±SD BMI 21.7±1.4 kg/m^2).

All participants are from the medical staff of Dar Al Amal Hospital, the broad range of digital literacy of EG (males 5.8±1.3 hours, females 5.2±1.3 hours) and CG (males 5.2±1.3 hours, females 6.2±1 hours).

In the EG at T1, the time dropped by 43 minutes in comparison with T0, while in CG, the time increased by 9 minutes instead of dropping (Figure 5). The mean of difference (T1-T0) is significant in group P<0.05 while it is not significant for CG (P=0.343) (Table 2). At T2 in EG, the time increases by around 20 seconds comparing it to T1 but still lower than T0 (Figure 5), no significance was shown for the control group at this time (Table 2). The participants of the group (1) were faster immediately after proprioceptive training (T1), but they showed a little increase in SRT after a rest of 20 minutes, while the control group participants did not show any improvement at T1 or T2 (Figure 6).

Table 1. Mean±SD of age group and anthropometric measurements of twenty-one study subjects

Gender	Group	Mean±SD				
		Age (y)	Height (cm)	Weight (kg)	BMI (kg/m²)	Digital Literacy (h)
Male	EG (n=5)	26.4±2.4	178.4±9.6	72.4±7.5	22.7±0.8	5.8±1.3
	CG (n=6)	27±2.0	176.4±5.5	73.6±5.7	23.7±0.8	5.2±1.3
Female	EG (n=5)	22.6±2.7	162±5.8	57.2±5.5	21.7±1.0	5.2±1.3
	CG (n=5)	23.8±2.6	165.5±4.6	59.5±5.9	21.7±1.4	6.2±1

Abbreviations: EG: Experimental group; CG: Control group; BMI: Body mass index; SD: Standard deviation.

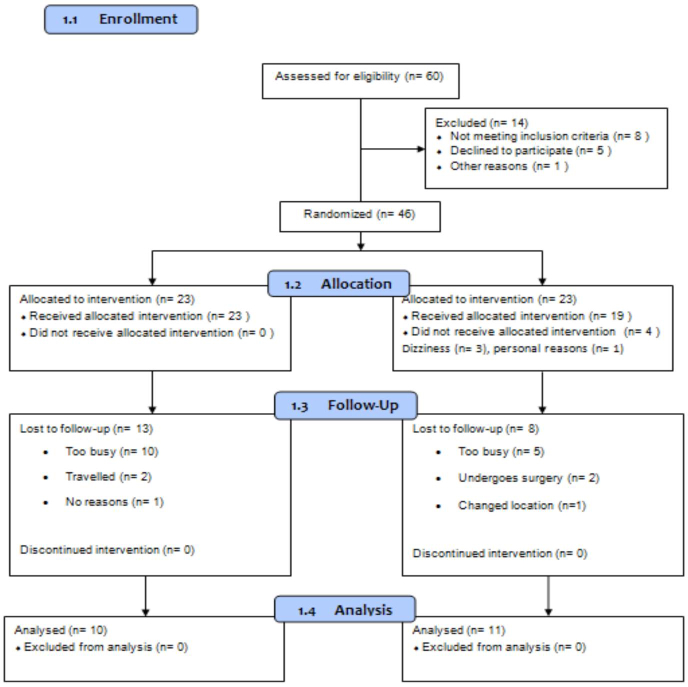

Figure 4. Flow chart of outcome measure testing CONSORT

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If we compare the reaction time between the two genders regardless of group division, the males were faster than females (Figure 7) even after training (Figure 7) and this difference is statistically significant.

The results (Figure 8A) showed a continuous drop in the SRT in EG at different times T0, T1, and T2 through all sessions. While in CG, the means of SRT from S1 to S6 was unstable (Figure 8B).

The results showed that the SRT before test T0, for all the experimental group's participants, was more than T1, which is in turn, more than T2 (Figure 8C) which indicates all participants who underwent PT became faster when performing the SRT. The performance of SRT by the control group's participants was inconstant and unstable for all participants at T1 and T2 (Figure 8D), few of them (P6, P8, P10) have SRT at T1 or T2 faster than T0 (Table 3).

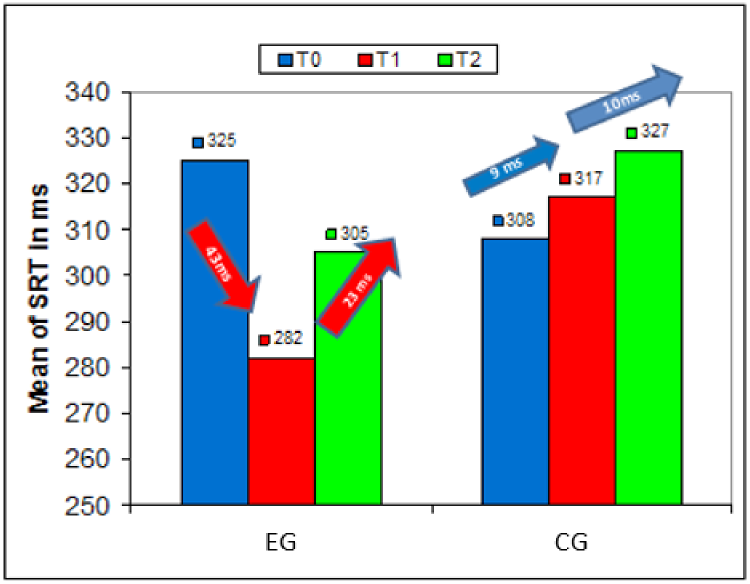

Figure 5. Comparison of mean of simple reaction time overall in both groups from T0 to T2.

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Abbreviations: EG: Experimental group; CG: Control group; T0: Time 0; T1: Time 1; T2: Time 2.

Table 2. Paired t-test results of T1-T0, T2-T0, and T2-T1 Mean±SD

Group	Δ T1-T0		Δ T2-T0		Δ T2-T1	
	Mean±SD	Effect Size	Mean±SD	Effect Size	Mean±SD	Effect Size
EG	-42.6±37.2	-1.14	-19.9±18.2	-1.09	22.7±30	0.75
CG	8.8±29.3	0.3	19.3±42.6	0.45	10.4±45.9	0.22

Abbreviations: EG: Experimental group; CG: Control group.

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Table 3. Pared t-test of mean of ΔT1-T0 and ΔT2-T1.

Groups		P	
		EG	CG
Paired t-test result (P<0.05)	ΔT1-T0	0.014*	0.271
	ΔT2-T1	0.006*	0.093

Abbreviations: EG: Experimental group; CG: Control group. *Signification

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4. Discussion

Reaction Time (RT) is a reliable indicator of sensory stimuli processing speed by the CNS and its implementation as a response thrusting. Information processing and peripheral coordination can be studied by analyzing the RT of the individual. The complex responses are supposed to require further information processing time. RT testing is a frequently used method to test psychomotor ability. SRT is one of several types of RT that means responding as fast as possible in response to a simple stimulus [13, 15, 16].

This study was designed to explore the effect of proprioceptive training on SRT on male and female subjects. Sensory and motor functions, the processing function of CNS, and coordination were tested by visual RT. We observed that RT was significantly shorter in subjects who performed proprioceptive training, compared to a control group who had not undergone any exercise, irrespective of the gender of the sub-groups (Table 2).

Several published studies have assessed RT improvement by testing short-term effects on it [17–20]. However, there have been fewer studies that have looked at the specific effects of proprioception as a sensorimotor

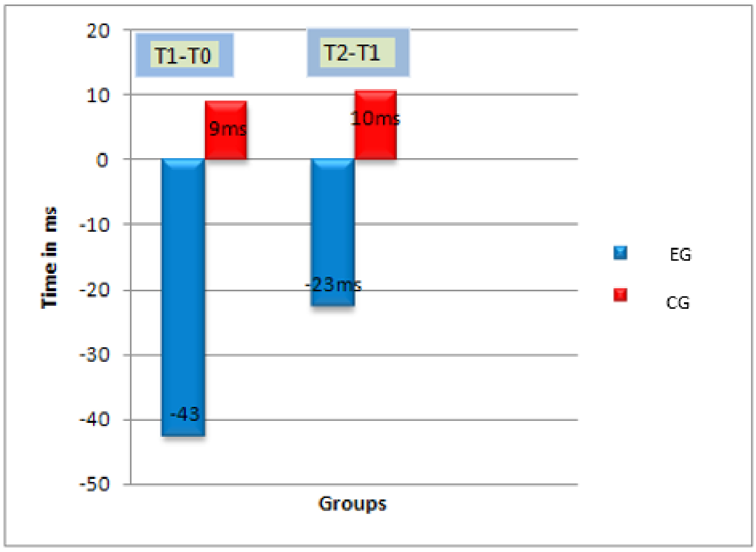

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Figure 6. Mean of difference of simple reaction time before training, immediately post-exercise, and after 20 minutes of rest for both groups

Abbreviations: EG: Experimental group; CG: Control group; T0: Time 0; T1: Time 1; T2: Time 2.

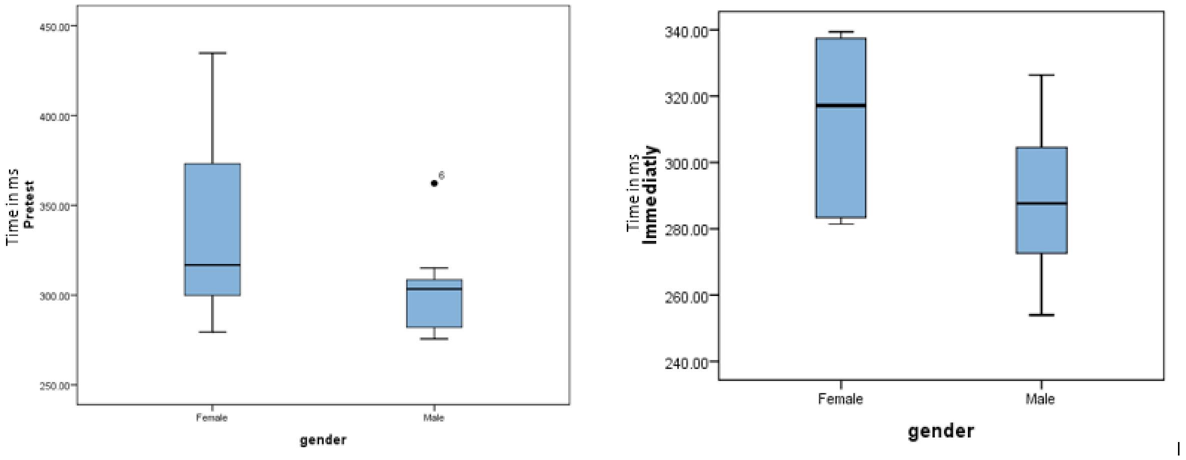

Figure 7. Bar plot for pretest and immediately simple reaction time (T0, T1 respectively) for both genders

training that connects cognitive and motor functions [20, 21], and no studies have highlighted the effect of proprioception on performance by measuring the RT. In the present study, the relationship between proprioceptive training and the decrease of RT is well established (Figure 5).

Hamer et al. (2016) proposed that, indirectly, exercise training decreases RT as an effect of the increase in blood flow and oxygen in the skeletal muscles and the brain [22]. The findings of our study (Figure 8A) indicate that, when exercising, healthy medical staff had faster RT than the control group and the difference between the two groups was statistically significant (Table 2). Similarly, Nakamoto et al. (2008) suggested that physical activity might improve RT. Nakamoto et al. (2008) suggested that the reduced RT of athletes when compared to non-athletes was credited to the function of the CNS to process information and produce more rapid contractions [23].

Several factors might be the cause of the short RT including amelioration in concentration and level of alertness, improved coordination between muscles, and task-performance accuracy and speed. In the literature, we found logical evidence to explain these results suggesting that individuals who exercise have a better motor response and RT due to multiple causes. For example, athletes who train with high or moderate intensities will show enhancement in cognitive functioning as a result of increased blood flow and hence, more nutrients (oxygen and glucose) in the cerebral area [24, 25].

In our findings, several lines can indicate that proprioceptive training can influence the RT and therefore the overall performance; the VSRT was decreasing immedi-

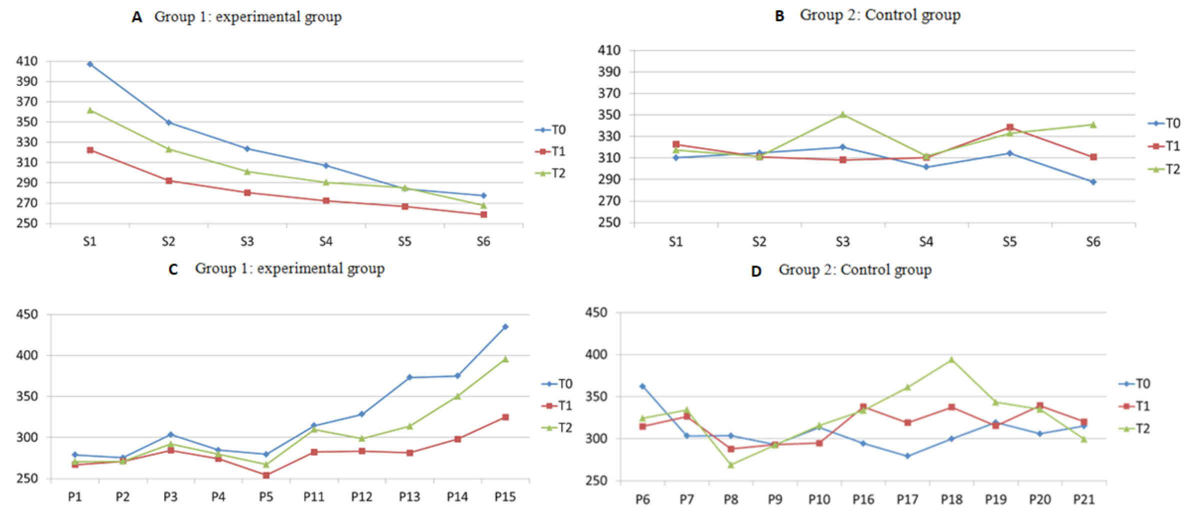

Figure 8. The variation of means of simple reaction time from s1 (the first session) to s6 (the sixth session)

ately in the experimental group (1) by an average of 42 minutes compared to the increased VSRT in the control group by 9 minutes. In addition, the difference between T2 and T1 was statistically significant. Even if there was a little increase in SRT after a rest of 20 minutes, the participants still preserved a retention effect (Figure 6). Nevertheless, all participants of the experimental group showed a decrease in RT from one session to another (T1 or T2). In contrast, few participants showed improvement in the control group (Figure 8D).

However, one essential question remains unanswered: Is the decrease in SRT due to that exercise, which can constantly produce the same phenomenon as the one cited above or proprioception training can have an additive effect? We cannot rule out a contribution of congruency between the effects of the two regimens, especially at T1, since many previous studies have shown the positive effect of exercising on RT. This effect has been demonstrated under specific conditions; the RT decreases during - not after- the exercise [26, 27] and the intensity of exercise must be moderate to intensive [18]. These conditions were not applicable in our protocol since we based our proprioceptive training on speed without any resistance force, on an acceptable duration of time (20 minutes), and the test we repeated after a rest time. To wrap this up, we compared the SRT at T2 versus T0 where the difference was statistically significant (Table 2). No such results were obtained by Shailesh (2014) who studied the relationship between acute exercising and RT. They reported no difference between pre and post-exercise results [19].

We can conclude that the immediate improvement of VSRT may be produced in part by the same effects of conventional exercises as cited by many studies, [19, 24, 25] as well as the PT but it is tempting to speculate that the retention effect (T2) might be caused by the proprioceptive training intervention methods which improved sensorimotor performance compared to conventional exercises which have low levels of neuromuscular activation [27].

Our study considered intraindividual and interindividual differences. Population bias is a constant concern [27]. Attributed to behavioral adaptation differences, the capability of healthy subjects to gain new motor skills is of a significant difference when tested inter-individually. The performance of many tasks improves throughout life with repetition and practice [28].

Otherwise, our results suggest that processes related to individual differences in behavioral adaptation can influence motor learning since few participants from the control group (Figure 8D) who did only the test without any intervention showed an improvement in RT due to repetitions. It could be because the improvement of a given activity with repetition would take much longer to cause and show any variability in brain structure and function as well as neurophysiological and psychological effects which can explain the difference in learning outcomes [27]. In contrast, all participants in the experimental group show a significant decrease in RT (Figure 8C). This study tends to consider proprioceptive training an effective method of motor learning. Aman et al. (2015) suggest that no one can argue that any form of proprioceptive processing is associated with motor learning [8].

When compared with females, the literature shows that males have shorter RT within all groups approximately. Studies done by Nikam LH et al. (2012) stated that females' responses were slower than males when responding to a specific stimulus [29]. Also, the findings of Jain et al. (2015) showed females to be slower than males when testing RT between both genders [30]. The results of our study (Figure 7) confirmed these findings and indicated that male medical staff had shorter RTs when compared to female medical staff for visual stimuli. When we compared the performance of male and female medical staff, RTs of male medical staff were faster even after training (Figure 8), in line with the presenting evidence in the literature.

This difference between the two genders' RT might be a result of the time between stimulation and contraction of the muscle. The faster SRT in males, regardless of the type of stimuli (auditory or visual) [31], might be due to the stronger motor response in males when compared with females despite the similar muscle contraction time [32].

There are no studies that accurately determined the effects of proprioceptive training on reaction time. We underlined an important limitation related to the lack of evidence in the literature concerning the effect of proprioceptive training on RT. Only one study was done on Huber motion lab and it was for coronary heart disease; so, we could not adopt the same protocol. In this study, it is highly established that proprioceptive sensory imputes are fundamental to increase alertness and vigilance. We recommend future studies include different modes of exercising to examine the specific effects on RT. Therefore, proprioceptive training may be recommended for improvement of performance, especially in the athletes' population.

5. Conclusion

In summary, we have provided strong evidence supporting the hypothesis that proprioceptive training has a strong influence on RT with a retention effect. Our study showed that the male VSRT is faster than that of the female in medical staff. This study offers a novel approach that may guide the development and implementation of future sport-related programs aiming at optimizing the role of proprioception and will also provide new information about the efficacy of speed proprioceptive training on performance.

Ethical Considerations

Compliance with ethical guidelines

We obtained written informed consent from each subject before the initiation of the experiment and Ethical Approval from the Public Health Faculty in the Lebanese University Ethics Committee of Medicine of Tehran University of Medical Sciences (Code: IR.TUMS.VCR.REC.1395.581) was also achieved.

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Authors' contributions

Supervision: Azadeh Shadmehr; Conceptualization: Rami Kassem Mazbouh, Hussein Ziab; Data collection: Rami Kassem Mazbouh and Hussein Ziab; Methodology: All authors; Writing the original draft and data analysis: Rami Kassem Mazbouh, Hussein Ziab and Itab Farha; Investigation: Rami Kassem Mazbouh, Hussein Ziab, Itab Farhat. Review & editing: Azadeh Shadmehr.

Conflict of interest

All authors declare no conflict of interest.

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