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The Effect of Different Fatigue Protocols on Choice Reaction Time

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Abstract: The aim of the present study was to investigate the effect of different exercise-induced fatigue on choice reaction time (CRT). Fifteen male (age= 22.68±0.8 y) were asked to attend the laboratory for 9 days. In five sessions, subjects' characteristics by Conconi test on treadmill and variables of different exercises; Aerobic (AE), Anaerobic (ANE), Mixed (ME), Prolonged Intermittent (PIE) and Super Maximal Intermittent (SMIE)) were measured. In four sessions, participants did exercises randomly, also before and after exercises they did CRT and rating of perceived exertion (RPE). Results indicated that the greatest increase in reaction time occurred after ANE, ME and SMIE and the least increase after AE and PIE. Different exercises negatively affected CRT; however, the extent to which reaction time declined depended on the type of exercise.

Key words: Exercises · Mental Fatigue · Performance · Reaction Time

INTRODUCTION

Reaction time (RT) is one of the most important attribute in all sports. RT is the ability to respond quickly to a stimulus. It is the period from the presentation of the stimulus to the initiation of the obvious response [1, 2]. It acts as a reliable indicator of rate of processing of sensory stimuli by central nervous system and its execution in the form of motor response [3, 4]. RT can be fractionated into pre motor time (PMT) and motor time (MT). The pre motor time is the interval between the imperative stimulus and the first discernible electromyography (EMG). The motor time measures the time from the onset of muscle activities (from EMG) to the onset of movement, designating generation of motor responses. PMT and MT have been used to identify the central (cognitive) and peripheral (neuromuscular) processing in human performance research [2, 3]. There are many factors affecting RT, ranging from the nature of the stimulus information to the type of movement being performed [5]. According to Kosinski [1, 4, 6], these factors are such as number of stimulus-response alternatives, stimulus-response compatibility, arousal, age, gender, type of stimulus, exercise, fasting and stimulant drugs.

Fatigue is a multidimensional and unknown phenomenon defined as a reduction in the arbitrary power output (decrease in force or speed of force generation) or work capacity [7-10]. Fittts [11] divided fatigue into local (fatigue of a group of muscles) and general (spinal and super spinal fatigue). Sensory inputs and CNS outputs would be disrupted by fatigue [12-15]. Welford [16] found that reaction time gets slower when the subject is fatigued. Singleton [17] observed that this deterioration due to fatigue is more marked when the reaction time task is complicated than when it is simple. Mental fatigue, especially sleepiness, has the greatest effect. Arcelin [18] found no effect of purely muscular fatigue on reaction time. The results of Davranche [19] showed that moderate-intensity exercise (50% maximal aerobic power) improves cognitive performance and that low-intensity exercise (20% maximal aerobic power) enables participants to compensate the negative dual-task effect.

Accordingly, physical exercise can be divided into aerobic exercise (AE), anaerobic exercise (ANE), mixed aerobic and anaerobic exercise (ME), prolonged intermittent exercise (PIE) and supra maximal intermittent exercise (SMIE) [10, 20, 21]. Most of studies have been done on the topic of fatigue in the form of local and just a few of them covered the general one; nevertheless, unfortunately less emphasis and attention have been placed on using simulated exercise protocols. Hence, the purpose of the present study was to study the effect of AE, ANE, ME, PIE and SMIE fatigue protocols on variation in reaction time.

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MATERIAL AND METHODS

Data Collection: Fifteen healthy male subjects (mean age: 22/1±1/23) voluntarily participated in this experiment. All subjects read and signed informed consent forms.

Procedures: Data collection was performed in 9 sessions for each participant. In the first session, their 10 km record was measured in the athletic track. In the second session, Conconi test [22, 23] was given in order to determine the heart rate at lactate threshold (HRLT) and the speed of this heart rate (HR). Then intensity of AE, ANE, ME and PIE was calculated accordingly. Participants' records were computed in the 60 m straight way athletic track in order to determine average speed (velocity = displacement divided by time) in a 60 m sprint for SMIE on the 3th day. On the 4th day, they learned exercise protocols and choice reaction time task. The RPE was explained to them and while acquainting themselves with the exercise protocols, they practiced RPE as well. Then during five days with at least three day gap between them, after warming up shortly, participants did RPE, CRT, one of the exercise protocols randomly and immediately after exercise protocols, mentioned tests were done again.

Instrumentation

Conconi Test Using Treadmill: First, participants' 10 km record was measured in an athletic track and based on this measurement; starting speed of the Conconi test was calculated. Then in the next session, they warmed up for 10 minutes and started to run on treadmill with calculated speed. After each 200m, they increased their speed 0.5 km/h and at the end of each 200m, their HR and speed were recorded. Test was continued until they stopped or couldn´t increase their speed. Finally, speed-HR graph in each 200m was drawn by excel software. The graph increased linearly as far as it reached flat; Afterwards, it increased non-linearly. Where the HR reaches the flat, is the lactate threshold (LT), so the speed and HRLT can be obtained from speed-HR graph [23]. Various exercise protocols were designed by using HRLT and running speed in this HR.

Exercise Protocols

Aerobic Exercise: First, speed was determined at 15 beats lower than HRLT according to the speed-HR graph for each participant. After warm up, during 3 minutes they reached at the speed of 15 beats lower than HRLT and continued it until they got exhausted [24].

Anaerobic Exercise: Speed was measured at 110 percent of HRLT. After warm up, they did some running trials with arbitrary speed and then participants ran at the measured speed until they could not keep the pace.

Mixed Exercise: First, distance covered in 30 seconds was measured at the speed which was calculated in ANE (velocity = displacement divided by time). Then the period of time passes to cover that distance with calculated speed in AE was computed (time = displacement divided by velocity). Finally, after 10 minute warm up, participants did an AE with calculated speed and time (nearly 42 sec), plus a 30-second bout with ANE speed without resting (distance was equal in both aerobic and anaerobic bouts, so the work done was the same). 72-second bout activities were repeated continuously without a rest until they could not continue. On average, participants did 12 to 16, 72- second bouts.

Prolonged Intermittent Exercise: Speed was calculated at 103 percent of RLT. After warm up, participants performed 20 second activity at computed speed and had passive recovery for 20 seconds repeatedly and regularly during 30 minutes.

Super Maximal Intermittent Exercise: After warm up, participants ran at the measured average speed of 60 m sprint for 6 seconds; then had 40 seconds active recovery with speed lower than six km/h. In the last 10 seconds of each resting period, speed was increased gradually in order to prepare them to run at the average speed. This activity continued until they could not run at their average speed. On average participants got exhausted after 9 to 13 bouts.

Rating of Perceived Exertion: The Borg 15-point (6 to 20) category rating scale was employed to gauge each participant's RPE so as to make sure that exertion was adequate to induce fatigue. According to previous studies, we assumed that if participants reached 15 or more than it, they would exercise with 80% of VO2max. Before and immediately after all exercise protocols, PRE was assessed [13].

Choice Reaction Time Task: The Vienna software was used to measure choice reaction time. The reaction time test was conducted in a quiet room without visual or auditory distractions. Participants were positioned in a comfortable, seated position in front of the computer screen. They were instructed to rest their wrist on the keyboard table and place the index finger of their dominant hand on the space bar of the keyboard. Before starting, the subjects were familiarized with the procedure and allowed to practice the reaction time task. The choice reaction time task was presented for 60 seconds on identical display equally positioned in front of the participant. The stimulus appeared in the center of screen and was separated by an irregular fore period varying from 3 to 5 sec [18, 19, 25-27]. The program flashed an arrow on a screen; the participant was required to respond to the arrow depending on the direction it was presented, either up, down, left or right. The size of the arrow on the screen was large enough to ensure that participants could see the arrow clearly. Response times less than 160 milli second were considered as anticipated responses and counted as errors.

Data Processing: Data were analyzed in 5 (five exercise protocols or groups) × 2 (time or pre-post) analysis of variance (ANOVA), with repeated measure were conducted for RPE and CRT. We posted hoc analysis (Tokey) to determine the differences between groups at posttest. We use SPSS software version 16 and set our alpha level at 0.05.

RESULTS

Effect of Each Exercise on RPE: The two-way ANOVA elicited only a main effect of time ($F_{1,95} = 118.74$, $P < 0.05$, $\eta^2=0.64$). Neither the main effect of group, nor the Group × time interaction was significant.

Effect of Each Exercise on CRT: The two-way ANOVA yielded a main effect of group, ($F_{1,95} =121.44$, $p<0.05$, $\eta^2=0.75$) and time. There was no significant group × time interaction ($p>0.05$).

Descriptive and post hoc analyses (Tukey) have been shown in Table 1. Generally, our findings showed an increase in choice reaction time after exertion of different exercises. The order of groups based on the increase in choice reaction time was ANE > SMIE > ME > PIE > AE. ANE protocol had the most profound effect rather than other protocols and the lowest effect was for AE protocol. Means and standard deviations for the interaction and main effect were presented in Table 1.

DISCUSSION

The purpose of this study was to examine effect of different intensity and duration of exercises on choice reaction time performance. In general, results demonstrated that regardless of the type of exercise, after-exercise CRT was disrupted by fatigue. However, the greatest increase in reaction time occurred after ANE, ME and SMIE and the least increase after AE and PIE. Nonetheless, the extent to which reaction time declined depended on the type of exercise.

These results are in line with previous findings by Welford [5, 16] and Arcelin *et al*. [28]. Welford [5, 16] found that reaction time gets slower when the subject is fatigued. Arcelin *et al*. [28] showed that with exercise duration, mean RT presents higher decrease at the end of the exercise testing. Our finding is incompatible with Davranche *et al*. [19] and McMorris and Keen [29]. McMorris and Keen [29] demonstrated that performance speed should increase from rest to maximal exercise but should not differ between heavy and maximal exercise levels. Results of Chang *et al*. [30] demonstrated that exercise-induced arousal has a positive influence on the peripheral components of response time tasks; however, it has a limited impact on the central components of these tasks (reaction time). Their explanation for why exercise-induced arousal had an impact on the peripheral task components but did not affect the central task components might rely on the mechanisms underlying the relationship. McMorris and Keen [29] suggested that increase in epinephrine and nor epinephrine is responsible for the relationship between exercise-induced arousal and performance. However, McMorris and graydon [31] pointed out that the changes in peripheral levels of epinephrine and nor epinephrine do not necessarily indicate changes in their levels in the central nervous system.

Table 1: Descriptive Data (Mean ± SD) of fatigue protocols for choice reaction time

	Fatigue Protocols				
Time	AE	ANE	ME	PIE	SMIE
pre	517.65±12.33	517.65±12.33	517.65±12.33	517.65±12.33	517.65±12.33
post	542.22±21.52	690.65±46.1	603.08±32.11	573.15±17.4	638.42±13

Our results demonstrated that type of exercise can disrupt the choice reaction time performance. This finding suggests that exercise has an impact on musculature functioning speed. Thus, our explanation for this result is the generation of increasing force levels; the central nervous system has to increase its drive to the relevant motor neuron pools. In hand muscles, almost all motor units are activated at relatively low force levels (30% MVC) [32]. Thus increasing the force above 30% MVC is only possible by a further increase in motor unit firing frequency. In sustained contractions at levels of 30% MVC or higher, motor units become fatigued and produce less force. To overcome these effects of fatigue, subjects have to increase the central drive to the relevant motor neuron pools. As most motor units are activated during contractions at 30% MVC [32] the only way to increase the central drive is to increase the motor unit firing frequency. Thus, mental fatigue may affect all stages of information processing that receive modulator top-down input, from stimulus processing to response execution. It is these top-down modulations that potentially are vulnerable to mental fatigue. This notion is supported by studies that examined the effects of mental fatigue on preparatory processes in different cognitive tasks. Lorist [7] showed that the facilitation of performance by response-related advance information diminishes with increasing mental fatigue. We interpret these and our findings as indicating that it was not the timing under temporal uncertainty produced by variable FPs but rather the efficiency of processing stimulus information and initiating the motor response that was affected by mental fatigue.

Our results suggest that exercise-induced fatigue can disrupt choice reaction time. Athletics should improve physical fitness for better performance.

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