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Simple reaction time and decision making performance after different physical workloads: an examination with elite athletes

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Abstract

The purpose of the present study was to investigate effects of both local and general physical fatigue on visual simple and visual choice reaction time of elite level athletes. 15 male and 3 female national Muay-Thai athletes (M_{age} = 21.55, SD= 3.47) who participated at least 5 training sessions per week volunteered to participate present study. Subjects were asked to perform Wingate anaerobic test on a mechanically braked cycle ergometer (834 E, Monark) to induce general fatigue. Hand grip dynamometer was used for resistance exercises to induce local fatigue. Simple, two-choice and three-choice visual reaction times were measured at resting, after local and general physical fatigue conditions both on right and left hands, respectively. The results of repeated measure ANOVAs yielded that compared to resting conditions simple reaction time significantly increased after inducing the local and general physical fatigue on both hands. On the other hand, although two-choice and three-choice reaction time mean scores increased from resting to both general and local physical fatigue conditions, these increments were not statistically different among measurements. It was concluded that both dynamic and resistance exercise induced fatigue may seems to lengthen only simple reaction time and did not affect decision making processes of elite level Muay-Thai athletes**.**

Keywords: Reaction time; fatigue; exercise; elite athletes

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Introduction

Reaction time (RT) reflects the speed of both cognitive and motor functioning, and is also acknowledged as a good indicator of performance in several sports (Starkes & Allard, 1983; Roosen, Compton, & Szabo, 1999; Williams & Elliott, 1999; Mori, Ohtani, & Imanaka, 2002). Many studies have demonstrated the significance of RT in sport that athletes are superior to non-athletes in response to given stimulus (Layton, 1991; Kim & Petrakis, 1998; Kaur, Paul, & Sandhu, 2006; Cheung, Catley, Mcgregor, & Strutton, 2006). In competitive situations, athletes should not only be able to perform several motor skills effectively, but also maintain these skills under the restriction of several regulations during strenuous exercise conditions (Williams, Davids, & Williams, 1999). Under such competitive and fatiguing conditions, success is often determined by very fast actions that are performed in a few seconds.

Considerable amount of research has been conducted to examine effects of exercise on RT performance (Kruk, Chamura, Krzeminski, Ziemba, Nazar, & Pekkarinan et al. 2001; Arı, Kutlu, Uyanık, Taneli, & Buyukyazı, 2004; Sparrow, Begg & Parker, 2006; Davranche, Burle, Audiffen, & Hasbroucq, 2006; Audiffen, Tomporowski, & Zagrodnik, 2008). Studies in one group, having cross sectional designs, mainly carried out single boat of exercise sessions (Davranche, Audiffen, & Danjean, 2006; Serwah & Marino, 2006). Studies in the other group, having longitudinal designs, used different types of exercise interventions to examine the changes in RT performance (Hascelik, Basgoze, Türker, Narman, & Ozker 1989; Brisswalter, Collardeu, & Arcelin, 2002).

Research concerning the acute effects of exercise on RT mainly applied resistance or dynamic exercise types. The results of these laboratory based research, however, yielded inconsistent findings regardless of the exercise type used (Tomporowski & Ellis, 1986; Tomporowski, 2003). Some of these studies reported improvements in RT (Taskiran, Gunendi, Bolukbasi, & Beyazova, 2008) whereas others revealed unchanged, (Whitehurst, 1991; Duinen, Renken, Maurits, & Zijdewind, 2007) or deteriorated RT performance as a result of heavy exercise (Ando, Kimura, Hamada, Kokubu, Moritani & Oda, 2005).

Taskiran et al. (2008), for example, examined the effect of single bout of aerobic exercise on pre-motor fraction of RT in sedentary healthy individuals. According to their findings, a single bout of cycling exercise significantly improved pre-motor fraction of RT.

Collardeu, Brisswalter and Audiffren (2001), on the other hand, observed non-significant changes in well trained athletes' simple RT performances after prolonged running exercises. Contrary to these findings, Mcmorris and Keen (1994) showed that although there is no significant difference in RT scores while resting and during 70% of maximum workload, simple RT during maximal exercise conditions was significantly slower than both in resting and 70% workload conditions. Regarding this contradictory findings, a number of alternative explanations have been proposed for both beneficial and detrimental effects of exercise on RT (Ando, Yamaka, Tanaka, Oda, & Kokubu, 2009). Particularly, beneficial effects of exercise on RT are attributed to increased arousal level and metabolic activity during exercise (Brisswalter, Collardeu, & Arcelin, 2002). In contrast, physical exhaustion and fatigue, which is the consequence of heavy exercise, are considered as possible reasons for the detrimental effects of exercise on RT. Although the underlying physiological and psychological mechanisms are not very well known, fatigue was shown to impair both cognitive (Hanson & Lofthus, 1978; Wood, 1979) and motor performance (Ivoilov, Smirnov, & Chikalow, 1981; Forestier and Nougier 1998; Kellis, Katis, & Vrabas. 2006; Lyons, Al-Nakeeb, & Nevil, 2006).

As can be inferred from the existing literature, there is still no clear picture regarding the consequences of different exercise modes on RT performance. Besides, notable limitations have been identified in the literature. First; nearly all of the studies include either resistance or dynamic type of exercises and none of them compared the effect of different physical workloads on RT performance in a single study, simultaneously (Hanson & Lofthus, 1978; Wood, 1979; Arcelin, Delignier s, & Brisswalter, 1998; Davranche, Burle, Audiffen & Hasbroucq, 2006; Audiffen, Tomporowski, & Zagrodnik, 2008). Accordingly, Tomporowski and Ellis (1986) have suggested that exercise parameters are important because different physical workloads produce basically different physiological and psychological states. In accordance with these suggestions, they stressed that studies investigating the effects of fatigue states brought about by maximal anaerobic (resistance type) physical workloads must be regarded differently from those utilizing aerobic exercise (dynamic type) interventions. Therefore, examining the different exercise modes and their effects on RT performance may have potential to provide us preliminary insights to further understand underlying physiological mechanisms of possible changes in RT performance.

Second; most of the previous studies (Hanson & Lofthus, 1978; Wood, 1979; Davranche et al. 2006: Burton, Leddy, Wilding, & Horwath, 2008; Taskiran et al. 2008) only measured simple RT (sRT) performance and neglected the choice RT (cRT). Actually, sRT requires single response to one type of stimuli and does not include decision making processes. Choice RT, on the other hand, refers situations in which there are two (2cRT) or more possible stimuli requiring different responses and is considered as an useful parameter to infer the speed of decision making processes including stimulus identification and response selection components (Schmidt & Wrisberg, 2000). Basically, RT performance in cRT condition is slower than RT performance in sRT condition, and performance differences between cRT and sRT are attributed to decision making processes involved in cRT. Since, these decision making processes are shown to influence athletic performance remarkably in competitive situations (Abernethy, Wood, & Parks, 1999; McPherson, 2000; McMorris & Beazeley, 1997), it is worth to examine how different types of exhaustive activities effect decision making processes.

Moreover, moderate or sub-maximal exercise intensities were frequently utilized by previous studies (Arı et al., 2004; Taskiran et al., 2008). In most of the sport settings, however, competitive situations require heavy exhaustive activities. In this regard, investigating the possible changes in RT performance under exhaustive conditions may shed light on deteriorations in perceptual abilities in competitive sports settings.

Finally, most of the research concerning effects of exercise on RT performance has used recreational athletes or university students as subjects (McMorris & Keen, 1994), and relatively very few studies have examined the effects of exercise induced fatigue on RT performance in elite level athletic population. Tomporowski and Ellis (1986) have indicated that studies including strenuous exercise sessions reported both beneficial and detrimental effects of exercise on RT performance. It is assumed that differences among these studies could be attributable to the physical fitness level of the subjects. A number of investigations **(**Sjoberg, Ohlsson, & Dornic, 1975; Sjoberg, 1980; Etnier, Salazar, Landers, Petruzzello, Han, & Nowell, 1997) argued that physically fit individuals are superior to sedentary people on compensating the negative effects of strenuous exercise and they may perform better than the sedentary people on cognitive tasks under fatiguing conditions. In accordance with these arguments, it is necessary to examine elite level subjects' decision making performances under different fatiguing conditions in order to clarify whether their physical fitness level can compensate negative effects of heavy exercise, and help them to perform better.

Thus, the main purpose of the present study was to examine the effects of resistance and dynamic type of exhaustive exercises on simple visual RT performances of elite level Muay Thai athletes. The Thailand boxing Muay-Thai is a good example of competitive sports which requires very rapid and accurate actions through the extensive use of hands, shins, elbows and knees with high level of endurance, speed and strength. Due to the intense nature of Muay-Thai, fatigue can be claimed as an indispensible part of the competition and it is essential for Muay-Thai athletes to maintain basic psychomotor skills under fatiguing conditions.

Generally, there exist two different ways of inducing fatigue in the literature. Specifically, resistance type of exercises can be used to induce the fatigue locally (Fleck & Kraemer, 1997) on the selected limb that would be dominantly used in the execution of selected movement (e.g. locally induced wrist flexors muscle fatigue during continuous gripping) (Hägg &Milerad, 1997). Dynamic types of activities, on the other hand, are extensively used to induce the whole body fatigue (general fatigue) (Fulco, Lewis, Frykman, Boushel, Smith, & Harman et al., 1996). Based on the previous studies that applied exhaustive exercises, it was expected that both resistance and dynamic type of physical workloads would induce local and general fatigue, respectively, and would also lead to retardations in visual RT performance.

The secondary purpose of the present study was to examine the effects of exhaustive exercises on decision making component of the RT performances. Since the choice RT performance include decision making processes, we hypothesized that exhaustive exercises would impair decision making component of choice RT, and increments from simple to choice RT performances would be greater in local fatigue and general fatigue conditions when compared to increments from simple to choice RT in the resting condition.

Methods

Subjects

Fifteen male and three female national Muay-Thai athletes (M_{age} =21.55, SD=3.47) who participated at least 5 training sessions per week volunteered to attend present study. The mean height, weight and sport age were 176.14 ± 7.2 cm, 73.8 ± 6.0 kg and 4.77 ± 2.36

years, respectively (Table 1). All subjects were considered as healthy males and females and were not familiar with RT measurements. All subjects were also informed to avoid from drinking alcohol, smoking or consuming products that contain caffeine during the 24hr preceding the test.

Measurements

A portable reaction time device (Sport Expert MPS-501, Tümer Engineering CO.) was used to assess both simple and choice reaction time performance of subjects. The device had three parts including central unit with LCD display screen, a stimulus generator and a junction box with piezo switches. For visual reaction time, subjects were instructed to press the switches whenever they detect the light on the stimulus generator. Five trials for simple visual, two choices visual, and three choices visual reaction time were taken from both right and left hands, respectively. Measurements were taken at the beginning of the study when subjects were rested, thirty seconds after the anaerobic work load (wingate anaerobic test) and thirty seconds after the resistance work load (maximal hand gripping).

For the purposes of this study reaction time was determined as the time interval in milliseconds (ms) between the onset of stimulus and the key-press response. Trials with reaction time recordings lower than 160 ms were regarded as anticipation errors and excluded from the study. This criterion is consistent with the current standards of RT (Schmidt & Lee, 1999) which indicated that RT was rarely found to be shorter than 160 ms for visual stimuli. Trials with RT recordings higher than 1000 ms were regarded as omission errors and also excluded from the study. Using those criterions 11 (0.7%) trials lower than 160 ms were excluded from the analyses. No values were recorded exceeding the upper bound of 1000 ms.

Heart rate levels of the subjects by using Polar Vantage NV instrument (Polar Electro, Kempele, Finland) were also measured at resting, local fatigue, and after general fatigue conditions.

Resistance and Dynamic Exercises

Hand grip dynamometer was used for resistance exercises to induce local fatigue. Hand grip size was adjusted to a position that is comfortable for the individual. During the work load period subjects were asked to stand up with straight arm away from the body. To obtain maximal voluntary contraction (MVC) values subjects were instructed to squeeze the dynamometer as strongly as possible for 4 seconds. Two trials were taken with one minute rest intervals and the mean score was considered as the maximal strength score of the subject. Once the MVC was measured, subjects were encouraged to squeeze dynamometer in a maximal manner for ten seconds periods with 2 seconds resting intervals. This continuous protocol was terminated when the local fatigue was assumed to occur at the point that subjects were unable to perform 50% of the MVC that he or she performed at the beginning of measurement, at least 10 s.

To induce general fatigue, subjects were asked to perform Wingate anaerobic test on a mechanically braked cycle ergometer (834 E, Monark). The testing session started with a warming up five minute cycling 0.5 w/kg body mass including two sprints lasting three seconds performed at the end of the third and fourth minute, respectively, to prepare the subjects for the sprint like Wingate anaerobic test. After a subsequent three minute active resting, the subjects were instructed to accelerate pedaling rate maximally. A resistance corresponding to 7.5% of the individual body mass was applied after acceleration phase of three seconds. Subjects were verbally encouraged to maintain as high pedaling rate as possible throughout thirty seconds pedaling period, and after completion of the 30-second maximal pedaling period, a 30 second cool-down period with no resistance was performed. Seat height was adjusted individually and kept constant during the measurements.

Procedure

Present study was conducted in two consecutive days. In the first day, RT measurements were taken at rest, local fatigue and general fatigue conditions. Specifically, treatment measurements were taken while subjects were rested, 30 seconds (s) after the maximal resistance training protocol with handgrip (local fatigue), and 30 s after maximal anaerobic performance (general fatigue). 15 min resting period was given between two exercise interventions to provide subjects enough time to become fully rested (Fox, 1989). In the second day, control measurements were also taken 3 times with similar intervals (15 min period) in order to control time effects. During simple and choice RT measurements, random intervals, ranging from 2 to 5 s, were given among trials to prevent subjects from anticipation.

Heart rate measurements were also collected at resting (1), right after the local (2), and right after the general fatigue (3) protocols in the first day.

All measurements were performed at the Human Performance Laboratory as suggested by the American College of Sports Medicine (ACSM, 1993), by a well trained exercise physiologist and all participants were assessed individually in a quite environment. The experimental protocol was approved by local ethics committee. All subjects signed a consent form after being fully informed of the study's purpose and the possible side effects.

Descriptive statistics and repeated measure ANOVAs were used to analyze demographic characteristics and heart rate differences among 3 different (time1=resting, time2=local fatigue and, time3= after general fatigue) conditions, respectively. A series of repeated measure ANOVAs were performed separately to examine simple RT differences among 3 different time periods (for both treatment and control measurements). Finally, increments in RT performances (mean differences) from simple to 2 choices and 3 choices RT measurements were calculated to infer decision making performances in resting, local fatigue and general fatigue conditions, respectively. Repeated measure ANOVAs then performed on these mean difference scores in three different conditions (mean differences among RT measurements in resting, local fatigue and general fatigue conditions) in order to examine the effects of different exhaustive exercises on decision making processes.

Results

Descriptive characteristics of the participants such as age, sport year, weight and height were given below (Table 1). Mean heart rates were 66.3 beats/min, 94.4 beats/min and 161.1 beats/min for resting, local, and general fatigue conditions, respectively. Repeated measure Anova on heart rate values collected three different time points revealed significant time effect (Wilks' Lambda=.24, $F_{(2, 34)} = 21.55$, $p < 0.05$). Sheffe test was conducted with adjusted alpha levels (α=.018) for pairwise comparisions. Resuls showed that local fatigue (p<.01) and general fatigue (p<.01) heart rate values were significantly higher than the resting heart rate values. Analyses also showed that general fatigue heart rate (p<.01) values were significantly higher than the local fatigue heart rate values.

Simple, 2 choices and 3 choices reaction time performances in treatment (resting, after local fatigue, general fatigue) and control measurements were presented at Figure 1 and figure 2, respectively. All participants completed both control and testing measurements. Significant time effects were found on simple reaction time performances for both right

(Wilks' Lambda=.55, $F_{(2, 34)} = 6.70$, $p < 0.05$) and left (Wilks' Lambda=1.34, $F_{(2, 34)} = 10.79$, $p < 0.05$) hands in treatment measurements.

Table 1. General Characteristics of Muay-Thai Athletes.

	M	*SD*
Age	21.5	3.4
Sport year	4.7	2.3
Weight	73.8	12.8
Height	176.1	7.2
Right hand Strength	42.9	10.6
Left hand Strength	42.00	10.9

According to results, simple reaction time performances of athletes significantly increased from resting to local and general fatigue conditions. Although RT performances at local fatigue condition, on the other hand, were slower (figure 1) than the RT performances at general fatigue conditions, these differences were not enough to reach statistical significance (p> .05).

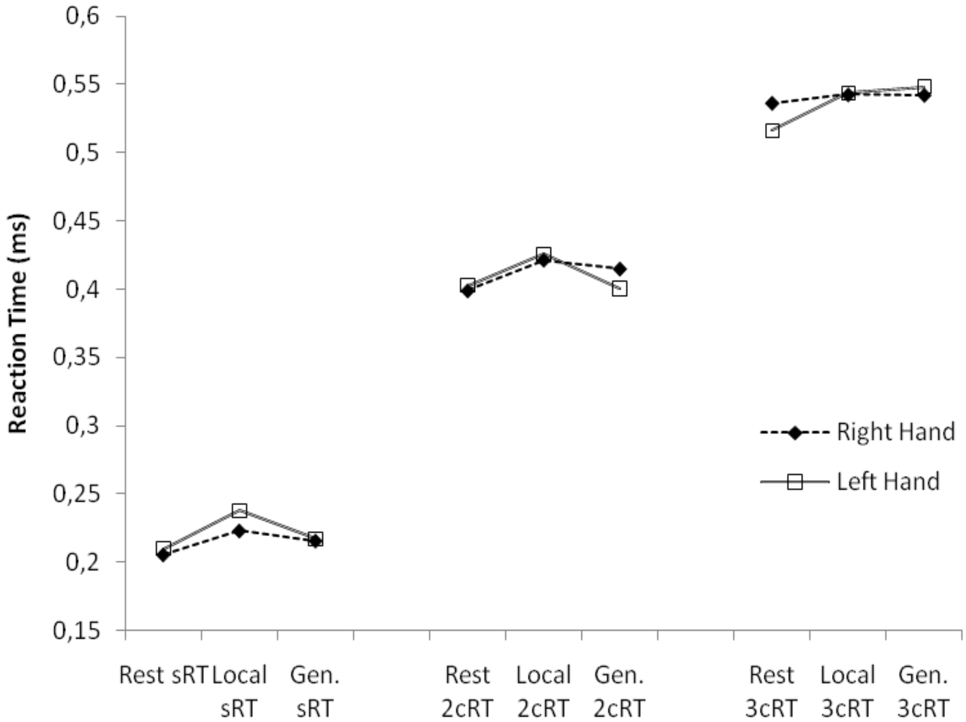

Figure 1. sRT, 2cRT and 3cRT performances of subjects under resting, local fatigue and general fatigue conditions.

Repeated measure Anova results for control measurements, on the other hand, indicated that there are no significant time effects for simple RT (p>.05), 2 choice RT (p>.05) and 3 choice RT (p>.05) performance among 3 different time intervals for both right and left hands (figure 2). Finally, repeated measure Anova results for decision making analyses showed that there is no significant time effect both for right (p>.05) and left hands (p>.05) (Table 2). These results indicated that increments in RT performances from sRT to 2cRT and 3cRT in resting condition were same as the increments in RT performances observed in local fatigue and general fatigue conditions.

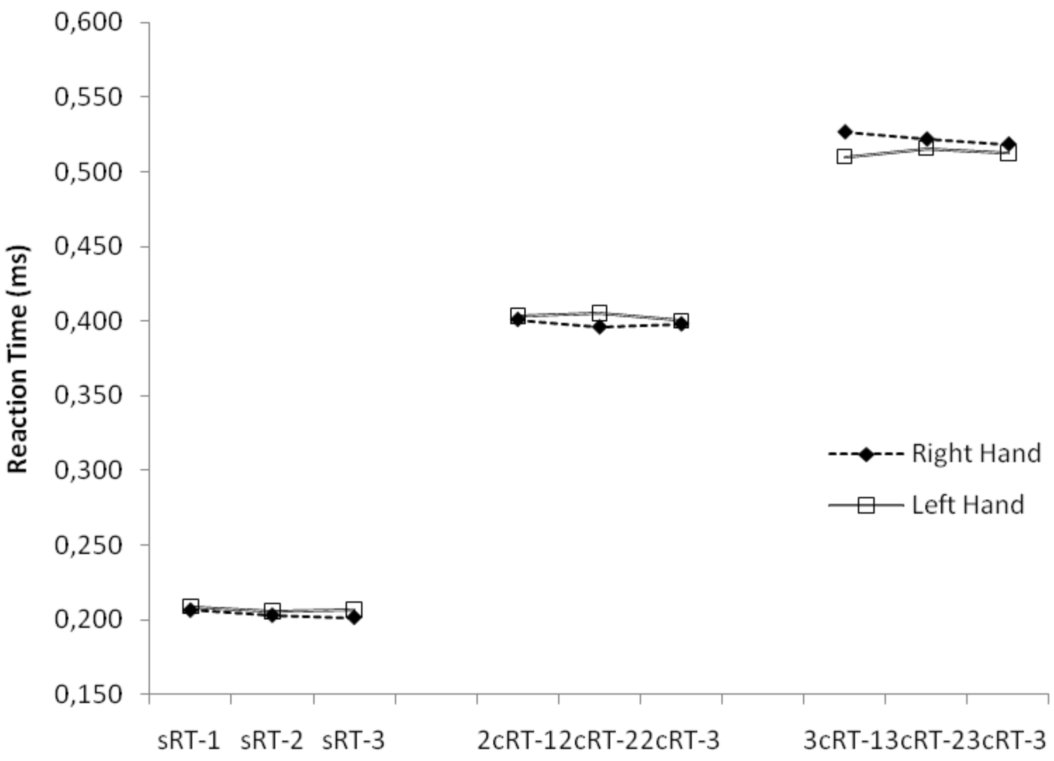

Figure 2. Control measurements of sRT, 2cRT and 3cRT performances of subjects.

Table 2. Increments in RT values from Simple to 2 Choice and 3 Choice in Resting, Local and General Fatigue Conditions.

	From sRT to 2cRT		From sRT to 3cRT	
	Right	Left	Right	Left
Resting	.193 ± .02	.192 ± .06	.331 ± .05	.306 ± .07
Local Fatigue	.198 ± .05	.187 ± .07	.319 ± .06	.305 ± .06
General Fatigue*	.199 ± .04	.184 ± .07	.327 ± .07	.331 ± .08

*millisecond.

Discussion

The present study was designed to investigate consequences of different exhaustive physical workloads on simple RT performance of elite level Muay-Thai athletes. The study also aimed to investigate the differential effects of both resistance and dynamic exercises on decision making performances of elite level Muay-Thai athletes.

Results indicated that simple RT performances significantly slowed down from resting to local and general fatigue conditions which supported the hypothesis that both resistance and dynamic type of physical workloads would induce fatigue and lead retardations in simple RT performance. Control measurements also confirmed that changes in RT performances were not due to time effect. The obtained results are also in line with previous research (Hanson & Lofthus, 1978; Wood, 1979; Mcmorris & Keen, 1994). The causes of prolonged simple RT performance in these investigations, however, were attributed to different physiological mechanisms. Specifically, studies inducing local fatigue with resistance type of exercises suggested that intra-muscular mechanisms such as decrements in acetylcholine, potassium, adenosine triphosphate, phosphocreatine levels and increments in lactate levels may be responsible for impairments in muscle contractility (Wood, 1979) and are thought to lengthen motor component of simple RT negatively. Studies applying dynamic type of exercises, on the other hand, claimed that decrements in the cerebral blood flow during intense exercise induce central fatigue and deteriorate cognitive component of the simple RT (Taskiran et al. 2008).

Although present study did not directly attempt to fractionize RT into its motor and cognitive components, analyses on mean differences among sRT, 2cRT and 3cRT under resting, local fatigue and general fatigue conditions may provide us preliminary insights for the effects of strenuous exercises on cognitive components of RT. It has long been known that sRT has shorter response duration and includes minimum amount of cognitive component compared to 2cRT and 3cRT. Thus, increments in RT performance from sRT to 2cRT and 3cRT can be attributed to presence of higher order cognitive processes such as decision making component of choice RT. In this regard, it is plausible to assume that if exhaustive exercises have negative effects on decision making processes, increments from sRT to 2cRT and 3cRT would be greater under fatiguing conditions than in resting condition. Results, however, indicated that compared to resting condition there is no significant difference among increments from sRT to 2cRT and 3 cRT under fatiguing conditions. Combining the results of aforementioned sRT analyses with these findings indicated that rather decision making processes, exhaustive exercises possibly impair motor components of sRT. Checking the changes in performance (Table 2) from sRT to 2cRT and 3cRT under resting, local fatigue and general fatigue conditions revealed that increments were very similar in nature regardless of the condition type. Similar increment patterns under fatiguing and resting conditions, therefore, seem to support the notion that exhaustive exercises mostly affect peripheral mechanisms included in sRT rather than central mechanisms included in 2cRT and 3cRT conditions.

These conclusions, however, should be interpreted with caution and at least two essential points should be taken into account. First, previous research (Kida, Oda, Matsumura, 2005) has pointed out that pre-motor components of choice RT including decision making processes may be shortened with high amount of practice (Parkin, Kerr, & Hindmarch, 1997). Athletes, especially experts in martial arts, have many decisions to make as they compete. In this regard, elite level Muay-Thai athletes' practice history may impede deteriorations in their choice RT performance during fatiguing conditions. Second, as Tomporowski (2003) indicated, research evidence suggested that improvements in physical fitness level followed by prolonged exercise participation may have potential to reveal benefits in cognitive performance. Therefore, non-significant changes in Muay-Thai

Athletes' choice RT performances in fatiguing conditions should also be attributed to their physical fitness level. Further experimental designs with different athletic populations including control subjects are needed to clarify continuing debate on the effects of heavy exercise on RT performance.

Additional research with larger sample size are needed in order to evaluate whether the effects of acute bouts of heavy exercise are related to participants practice history and level of fitness. Lack of objective physiological indicators of physical fatigue can also be considered as a limitation. In the present study, local fatigue was assumed to be induced when subjects, for a given trial, were unable to maintain the 50% MVC for at least 10s and general fatigue was monitored with the heart rate levels of the subjects following completion of general fatigue protocol. Although monitoring decrements in MVC and increments in heart rate levels during exercise were claimed to be agreeable ways of measuring the intensity of resistance (Martin, Millet, Martin, Deley & G. Lattier, 2004**)** and dynamic exercises (Boulay, Simoneau, Lortie, & Bouchard, 1997), respectively, objective indicators of both local and general fatigue such as blood lactate level should also be collected to demonstrate precise effects of induced fatigue on RT performance. Nevertheless, heart rate and MVC values collected after the completion of exhaustive exercises can be speculated to be similar with the ones that can be seen in fatigue situations.

The results of the present study are also limited with visual RT measurements and cannot be generalized to different modes of RT. Simultaneous examination of the different modes of RT, such as auditory, visual and tactile, in a single study may provide us better understanding on the effects of exercise on various modes of RT performances. The absence of the follow up measurements do not enable us to determine how much time is needed to recover from detrimental effects of exhaustive exercise on RT. Repeated measurements with certain time intervals following exercise may also be useful in determining whether recovery time needed for RT improvements differ as a function of physical fitness level of subjects. Apart from these considerations, longitudinal experimental designs including sedentary population are also necessary to clearly define the role of practice and physical fitness level on various modes of RT performance. Within the scope of present study, it can be concluded that exercise induced fatigue seemed to lengthen only simple reaction time, and did not significantly affect decision making processes of elite level Muay-Thai athletes.

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