Effects of lower and upper body fatigue in striking response time of amateur karate athletes

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In combat sports, strikes or counter-strikes response time (RT) can be related to performance and sporting success. Moreover, training sessions are usually high fatiguing, which is expected to impair basic skills, such as RT. Thus, this study aimed to investigate the effect of fatigue on punches and kicks RT of amateur karate practitioners. Twelve individuals aged 22±3 years old, with a height of 169.1±6.5 cm and a body mass of 65.5±10 kg took part in the study. Six visits were held with each volunteer. On the first two days, the shorter RT of punches and kicks was measured by a validated smartphone app. For the subsequent visits, a randomized incremental test for the upper or lower body was adopted as fatigue protocol, immediately followed by the RT tests. One-way repeated measures ANOVA was performed, and significance was set at $p \leq 0.05$. Therefore, induced fatigue in the lower body significantly influenced the average kick RT when it comes first than punches ($p=0.002$) and the best kick RT in the same condition ($p=0.001$). Furthermore, induction of lower body fatigue significantly affected RT independent of the test order. In upper body fatigue, the punch RT showed significant impairment ($p=0.045$) only when the punch was applied first. Lower body fatigue also impaired average punch RT ($p=0.008$). Thus, it is concluded that the specificity of fatigue protocols and striking order should be considered while performing RT demanding techniques in karate practice.

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• Recommend expand Abstract, expand Methods and Results sections

Title: Effects of lower and upper body fatigue in striking response time of amateur karate athletes

Running Head: Fatigue effects in striking response time

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Abstract

In combat sports, strikes or counter-strikes response time (RT) can be related to performance and sporting success. Moreover, training sessions are usually high fatiguing, which is expected to impair basic skills, such as RT. Thus, this study aimed to investigate the effect of fatigue on punches and kicks RT of amateur karate practitioners. Twelve individuals aged 22±3 years old, with a height of 169.1±6.5 cm and a body mass of 65.5±10 kg took part in the study. Six visits were held with each volunteer. On the first two days, the shorter RT of punches and kicks was measured by a validated smartphone app. For the subsequent visits, a randomized incremental test for the upper or lower body was adopted as fatigue protocol, immediately followed by the RT tests. One-way repeated measures ANOVA was performed, and significance was set at p:S0.05. Therefore, induced fatigue in the lower body significantly influenced the average kick RT when it comes first than punches (p=0.002) and the best kick RT in the same condition (p=0.001). Furthermore, induction of lower body fatigue significantly affected RT independent of the test order. In upper body fatigue, the punch RT showed significant impairment (p=0.045) only when the punch was applied first. Lower body fatigue also impaired average punch RT (p=0.008). Thus, it is concluded that the specificity of fatigue protocols and striking order should be considered while performing RT demanding techniques in karate practice.

Keywords: Martial arts; Response time; Fatigue; Athletic Performance; Biomedical Technology Assessment; Mobile Apps.

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Introduction

Karate is a striking combat sport in which movements are performed intermittently, with high-intensity actions interspersed by short recovery/low-intensity periods. The scores are mainly achieved through punches and kicks [1,2]. In ~~Kumite~~ kumite matches (i.e. sparring), fast reactions are required due to the high speed of the striking actions and the proximity between opponents. Therefore, it is suggested that experienced karate ~~experienced~~ athletes ~~had~~ would have better response time (RT) and anticipatory skills than novice practitioners [3]. In this context, RT is calculated from the time between the presentation of an initial stimulus and the execution of the motor gesture [4], which, in striking combat sports, would be an external visual or audible stimulus, and the end of a strike reaching a target, respectively [5].

Specifically, the construct of RT seems to be composed of central and peripheral variables, that refer to i) the time between the stimulus and the onset of muscle activation (reaction time) and the full contraction (RT) and; ii) the time between the onset of muscle activation and the full contraction [6]. Thus, RT may be affected differently depending upon the status and characteristics of specific fatigue processes [7], which may reflect an inability to maintain muscle strength and power levels during repeated muscle contractions [8]. Also, essential capacities such as aerobic and anaerobic endurance, and decision-making performance can be altered by fatigue as well [9].

In Taekwondo practitioners, Sant'Ana *et al.*[5] showed that fatigue could induce adverse responses in reaction time and kick's impact. Similarly, upper body successive Wingate tests have also been shown to~~also~~ have induced negative effects on RT of mixed martial artists (MMA), and the results showed a low consistency of responses (i.e., in some moments they were slower and in others, faster) [10].

Regarding the effects of lower body fatigue on the upper body punching performance, Dunn *et*

al.[11] showed that lower body intermittent exercises performed at maximum intensity impaired the performance of highly trained boxers, mainly in punches that used hip rotation.

Then, the observed association between RT with performance and competitive level, and the importance of motor actions performed at high speeds [3,12], highlights the need for a better understanding of the effects of specific fatigue protocols on athletes' and practitioners' performance. It is noteworthy that investigations on the effects of specific fatigue in striking combat sports performance are still emerging. For example, the RT of the semicircular kick in response to pace training protocols at different intensities had been described in Taekwondo athletes [5,13]. In karate, a study by Loturco and colleagues described the effects of combat on jump height in a world champion athlete [14], which may be associated with the performance of determining actions and represent an anaerobic characteristic, as observed in previous studies [15]. However, it is not a direct measure of sports-specific skills, such as the RT of kicks and punches.

Therefore, investigating the effects of specific fatigue induction on the RT of punches and kicks of karate fighters could contribute to a better understanding of the effect of specific karate protocols and provide more effective decision-making on physical and technical-tactical training for karate. Thus, the present study aimed to investigate the effect of specific lower body or upper body muscular fatigue on the RT of punches and kicks in karate fighters. The central hypothesis is that the induction of muscular fatigue can negatively affect the RT of punches and kicks according to the specificity principle.

Materials & Methods

EXPERIMENTAL APPROACH TO THE PROBLEM

Six laboratory visits were held with each volunteer, separated by a minimum of 24 hours between ~~them~~visits. Initially, on the first two days, the minimum RT for punches (*Guiako zuki*) and kicks (*Mawashi-geri*) were measured and the mean value was considered as baseline. In the subsequent four sessions, the incremental fatigue tests for the lower body and upper body were applied ~~to aim fatigue induction~~ in a randomized sequence. Immediately ~~after~~ following the lower body and upper body fatigue induction, the punch and kick RT were measured, and the sequence was also randomized. The experimental design is described in figure 1.

PLEASE, INSERT FTGURE 1 HERE

SUBJECTS

This study was approved by the Institute of Health Sciences ethics committee from the Federal University of Para (#5.539.827) and subjects signed the informed consent form prior to participation. The research project was ~~announced~~ advertised at karate gyms in the city. After, 12 individuals of both sexes were selected and included three yellow belts, three red belts, two orange belts, two green belts, one brown belt, and one black belt~~,~~. Participants were aged 22 ± 3 years old, with a height of 169.1 ± 6.5 cm, and body mass of 65.5 ± 10 kg. As inclusion criteria, the athlete should have practiced the sport for at least ~~6~~ six months and regularly trained at least three times per week, practicing ~~1~~one hour and 30 min per training session or longer. The exclusion criteria were musculoskeletal joint problems, muscle and/or joint discomfort during the progressive fatigue tests, or the athlete's absence during the meetings to perform the tests.

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PROCEDURES

RESPONSE TTME

To measure RT, the TReaction® App (ETS4ME, Sao Jose, SC, Brazil) was used, which is calculated from a visual stimulus (flash) emitted by a smartphone. ~~This~~ The visual stimulus ~~is~~ was captured by the individual who performs the strike until it reaches the target (punchbag), and the sound generated by the strike's impact on the target is captured by the smartphone microphone, ending the RT. The app ~~is~~ has been validated to measure the response time of combat sports athletes [16]. In this sense, five direct punching techniques were executed with the opposite hand to the stance (~~*Gyiako*~~ *guiako zuki*). In addition, five semi-circular kicks were landed in a region marked by the evaluator (~~*Mawashi*~~*mawashi-geri*). The interval from the emission of the stimuli to the execution of the five punches attempts varied between 10 to 15s. The distance between the athlete and the punch bag was previously self-selected by each athlete.

~~TNCREMENTAL~~ INCREMENTAL TESTS

For induction of lower and upper body-specific fatigue, the TRsriker App (ETS4ME, Sao Jose, SC, Brazil) was used, which operates by emitting sound signals transmitted by a smartphone or tablet [13] ~~with~~ using a validated incremental kicks and punches protocol [17]. For the lower body test, the participant was asked to stand at a distance where the kicking motion would reach the punching and kicking bag. The athletes were also asked to stay in a stepping movement, simulating a fight. For fatigue induction, the athlete had to respond with a kicking motor action at the opponent's chest height whenever the sound signal from the TRsriker app was triggered. The protocol was progressive, and the time interval between beeps decreased progressively. ~~To~~

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~~determine the end of the protocol~~The protocol terminated when~~,~~ the athlete could no longer follow the frequency of the beeps,

and/or did not reach the height pre-established by the researcher, and/or voluntarily stopped the test (volitional exhaustion). ~~The~~ This procedure ~~adopted~~ was the same as ~~that applied~~reported in previous studies[5,13,17].

For the upper body specific test, the same app was used, which ~~is~~ has also applied to boxers. The upper body fatigue protocol functioned exactly as mentioned above, using the validated incremental punching protocol [18]. The athletes positioned themselves in front of a punching bag and used gloves specific to the karate modalities at a distance favorable to their wingspan, which ~~they~~ was self-selected. For each sound signal, the participant started a sequence of two punches: punch with the front arm of the guard (~~*Kizami*~~ *kizami zuki*) and then punch with the opposite arm (~~*Guiaku*~~*guiaku zuki*). From the total of strikes in the TT, maximal oxygen consumption was estimated by the following equation: Y= 28,187 + 0,6132x.

RATE OF PERCETVED EXERTTON

For measuring the subjective rate of perceived exertion (RPE) the Borg CR-10 scale was used, which ranges from level 0 (no effort) to 10 (maximal effort) ~~levels, ranging from no effort to maximum effort~~. [19]. At the end of each cycle, the participant was asked to answer, "How was your training session?" on ~~an~~ a 0 to 10 scale. [20].

STATTSTTCAL ANALYSTS

After verifying the normality of the data by using the Shapiro-Wilk test, the data are presented by mean, as a measure of centrality, and standard deviation, as a measure of dispersion. Test and retest response times were compared by t-test for paired samples, and reproducibility was tested by intraclass correlation coefficient (ICC). The mean between test and

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re-test was taken as the baseline value and used for comparisons between time points. Comparisons between time points were checked by one-way ANOVA for repeated measures with Bonferroni post hoc test when appropriate and, when sphericity was not reached, the Greenhouse-Geisser correction was considered. All tests were carried out in IBM SPSS Statistics for Windows, version 20.0 (TBM Corp., Armonk, N.Y., USA). Statistical significance was established when $p<0.05$.

Results

Regarding the performance in the incremental test, values are described in Table 1. Despite the ~~obvious~~ significant difference found regarding the total number of strikes (two punches and one kick were performed at each beep), no other differences were observed.

PLEASE, TNSERT TABLE 1 HERE

No significant differences in RT were observed between test and re-test for punches ($p>=0.13$) and kicks ($p>=0.28$). TCC values of 0.76 and 0.70 were found for the average and best values for the punches test, respectively. ICC values of 0.75 and 0.76 were identified for the average and best results for kicks, respectively. The RPE results during incremental test were 9±1 a.u. after kicking efforts and 9.5±1 a.u. after the punching tests.

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Figure 2 (panel A) shows that the best RT is only affected when the subject starts performing the lower body fatigue protocol (incremental kick test) and when the kick RT test comes first than the punch RT. In this sense, it is only when kicks come first than punches RT, compared with the baseline values, that there is a statistical difference of $p=0.002$. Thereafter, the mean values of the kick RT, shown in figure 2 (Panel B), present significant differences in the same sequence as the situations mentioned above (kick's RT first than punches after the

incremental kick test); comparing the baseline values with this abovementioned situation, there was a statistically significant difference of p=0.001.

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For the analyses of the best punch RT, figure 3, shows that the induction of the lower body fatigue significantly affected the RT regardless of the order of the tests. Hence, compared to baseline, punches and kicks RT right after the incremental kick test had a difference of p=0.033, and p=0.015, respectively. On the other hand, in the induction of upper body fatigue, the RT is only affected when punches comes first than kicks, meaning the relationship between the baseline test with situation three (punches RT first than kicks after punch incremental test) had a statistical difference of p=0.045.

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Figure 3 shows the best (panel A) and mean (panel B) RT of punches. The results suggest that the upper body and lower body incremental tests negatively affected the RT of punches, except when the kick test was performed immediately after the upper body incremental effort.

Discussion

The purpose of the study was to verify the effect of fatigue induction on the RT of amateur, experienced karate practitioners. The main findings indicated that the RT of kicks was only affected ~~upon~~by the specific incremental kick test and when the test was performed immediately after fatigue induction. ~~On the other hand~~Alternatively, it ~~seems~~ appears that the RT of punches is more susceptible to fatigue effects regardless of the motor pattern generating fatigue.

Our results are not without precedent findings. Fatigue induced by kick execution Was shown to negatively affected RT (145 ± 51 ms to 223 ± 133 mws) and impact (43 ± 27 g to 13 ± 10g) of

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kicks in taekwondo athletes after a specific fatigue protocol using roundhouse kick [5]. It is worth highlighting that in this study, in the protocol for fatigue induction, the intensity of maximum strike frequency was applied, being similar to the intensities reached by the participants in our study, which suggests that the volunteers reached the maximum pace and exhaustion in the maximum incremental tests, immediately before the RT tests. In contrast, when the effort ~~is~~ was performed at an intensity relative to the anaerobic threshold, no impairment effect ~~is~~ was observed in any of the variables related to RT and neither on the performance of the vertical jump [13]. Therefore, it ~~seems~~ appears that the increase in the kick RT (i.e., kick execution time) and the maintenance of the movement's technical quality and performance, might be influenced by the intensity demand imposed by the intermittence relation of the high and low-intensity actions that the athlete is submitted to. Thus, the fatigue process (or tolerance to it), the quality of the motor pattern, and the RT result from the modulation or demand required for the intervention or combat to which the subject is submitted [9,13,21].

In the present study, the upper body fatigue protocol negatively affected the RT of punches. Similar results were observed with ~~Mixed Martial Arts (~~MMA~~)~~ athletes who showed worsening RT after performing the Wingate test to induce upper body fatigue [10]. Additionally, the RT of punches was also impaired when the athletes were subjected to lower body fatigue. Similar findings were observed in a study by Dunn et al., that examined the induction of lower body and trunk region fatigue by rowing test that resulted in reduced impact and punching strength of boxers [11]. Collectively, these findings suggest that induction of fatigue in the lower body is more systemic than upper body protocols, which would be expected since lower body efforts move more muscle mass, thus producing higher values of O_2 consumption [22].

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In striking combat sports, the decisive actions are supplied by the anaerobic energy system, particularly the ATP-CP system, noting that these actions require high force production in short time intervals [23]. In addition to being dependent on an increased number of muscle fibers recruitment, especially ~~those of~~ fast-twitch [24]. Thereby, the fact that an increased RT after the lower body incremental test was found, might be related to the contractile function of the involved muscles, thus directly affecting the ability to respond in the same way as they were before the fatigue protocol [25], as well as was verified on boxing fighters that presented reductions on force and power outputs after a rowing test [11].

In general, kick RT scores were impaired independently on the incremental protocol. Tt is suggested that more complex motor gestures may require more cortical areas to be involved in processing tasks, thus considering that kicking is a more complex task than punch, it may explain why kicks were more easily affected [26]. Moreover, the differences observed after the upper body and lower body incremental protocols may be related to mechanisms associated with the fact that both protocols present different motor gestures. Another explanation may rely on the task duration, since RT, but not reaction time seems to be mainly affected by ongoing processes throughout the movement and not by the movement initiation itself (15). Notwithstanding, kicking has -40% higher RT than punching, which would suggest a higher susceptibility of kicks to be affected by other factors, such as feedback and fatigue. However, to establish a conclusion on how the fatigue process occurs physiologically and its effects on RT, ~~more~~ additional studies are needed due to the complexity of the different mechanisms associated with fatigue [27].

Tt is noteworthy that the reproducibility found between the test and re-test of RT measured with the TReaction App was lower (TCC= 0.75) than that ~~evidenced~~ reported previously (TCC= 0.99) [16]. A few factors can be speculated to explain this difference. First, the larger number of

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subjects assessed increases the heterogeneity of the sample, which may incur greater inconsistency and greater inter-situational variation. Second, in this study, the interval between test and retest was 24h, and not in the same session as the baseline study [16], which may also affect the variability of intra-subject conditions. Third, the fact that they were amateur athletes may lead to more technical variability and less inconsistency in the assessed motor pattern. Despite this, the procedure still showed reproducibility considered good.

As a limitation, karate practitioners of amateur competitive level were part of this study. Consequently, the findings cannot be extrapolated to professional competitive levels, especially for aspects related to technical consistency. A further limitation was the absence of specific measures that could better describe the systemic or neuromuscular fatigue conditions presented by the athletes after the incremental efforts, such as measures of O_2 consumption, electromyography, vertical jump tests, and local RPE, for example. However, the inclusion of different orders of RT tests after fatigue induction helped to improve meaningful inferences that should be considered in future work. Finally, although essential for this experimental design, specific gestures for fatigue induction (punching or kicking) do not reflect the pattern of training and fights (punching and kicking), which may limit inferences related to fatigue derived from more usual daily practices.

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Conclusions

The findings presented here can be useful for coaches, trainers, and athletes while planning and performing ~~Karate~~ karate training sessions. In general, ~~Martial~~ martial arts training is composed of high physically demanding warm-ups and technique repetitions. However, our results suggest

that, when punches and kicks RT are relevant elements of the training session, some combinations should be avoided.

Thus, considering that kick performance may be impaired by previous lower body fatigue, coaches should avoid extenuating and high-volume stimuli or guarantee enough recovery before the main activity, competitions, or evaluations. Regarding punch performance, it seems more sensitive to non-specific fatiguing actions, such as those performed mainly by the lower body segment, and for this reason, coaches should dedicate attention to avoiding excessive demanding efforts with lower and upper body actions. However, if the preceding actions are performed predominantly by the upper body, adequate recovery time may be sufficient to re-establish punches RT.

In summary, our findings ~~become~~ are relevant for the striking combat sports environment. With this, coaches and athletes can adjust the training to improve the technical and tactical performance, avoiding excessive and exhausting use of the lower body in karate training to obtain a better performance of the RT of kicks and punches.

Finally, it is concluded that the specificity of fatigue protocols should be considered while performing RT demanding techniques in karate practice. Therefore, lower body fatigue negatively affects the RT performance of kicks when realized in the same order. Furthermore, it is worth highlighting that regarding upper body RT, the incremental test for the lower body alters the RT independently of the evaluation order, that is, whether punches or kicks RT comes first. Nonetheless, the incremental test of the upper body has just affected the RT of punches when it comes first than kicks.

Acknowledgements

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Figure 1

Experimental design

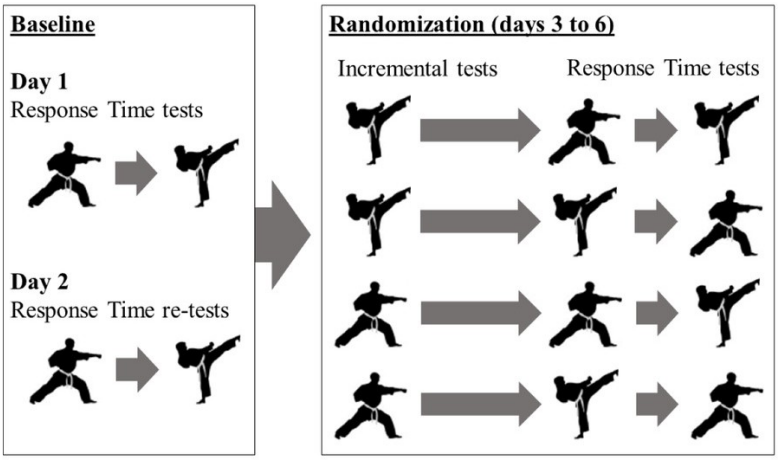
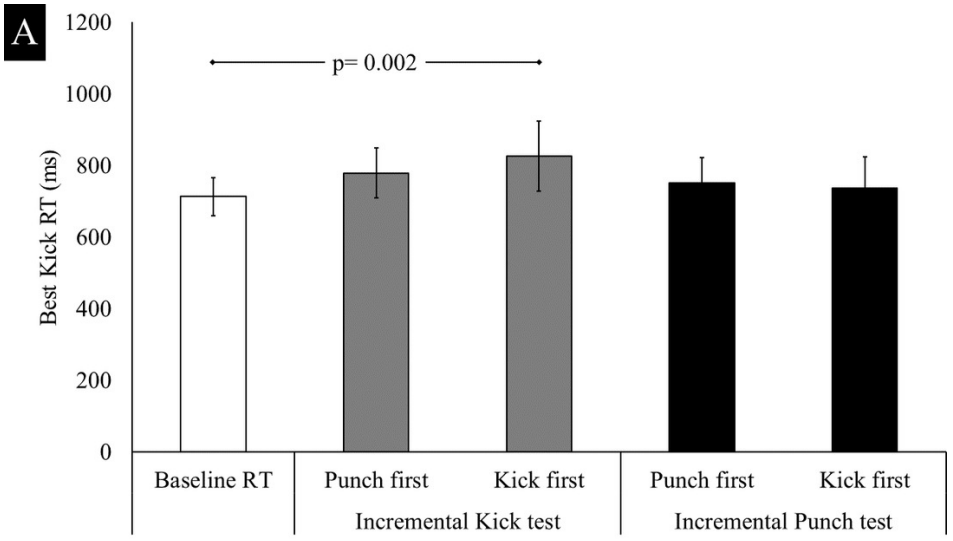


Figure 2

Kick Response Time (*Mawashi geri*) in different experimental situations. Panel A: Best response time; Panel B: Average response time.


A
1200
1000
800
600
400
200
0
Best Kick RT (ms)
p= 0.002
Baseline RT
Punch first
Kick first
Incremental Kick test
Punch first
Kick first
Incremental Punch test

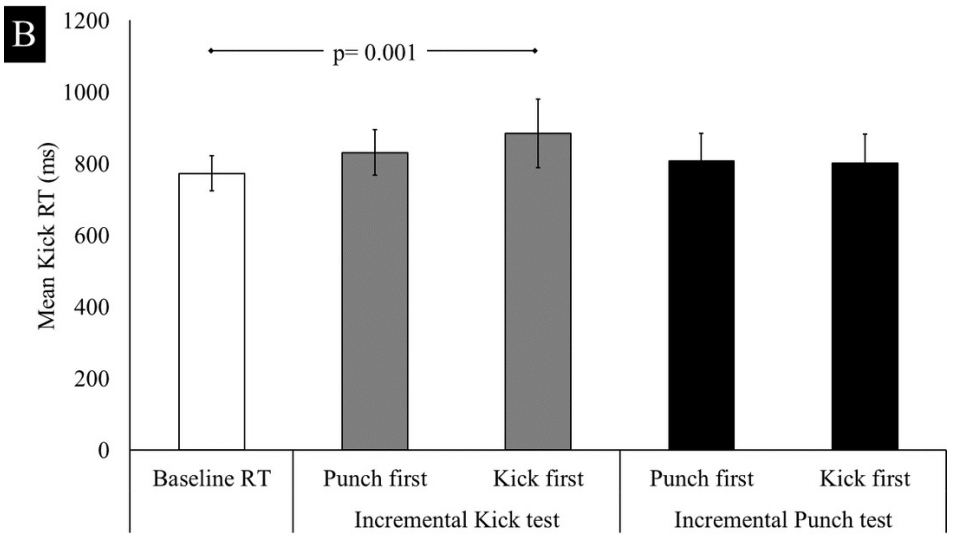
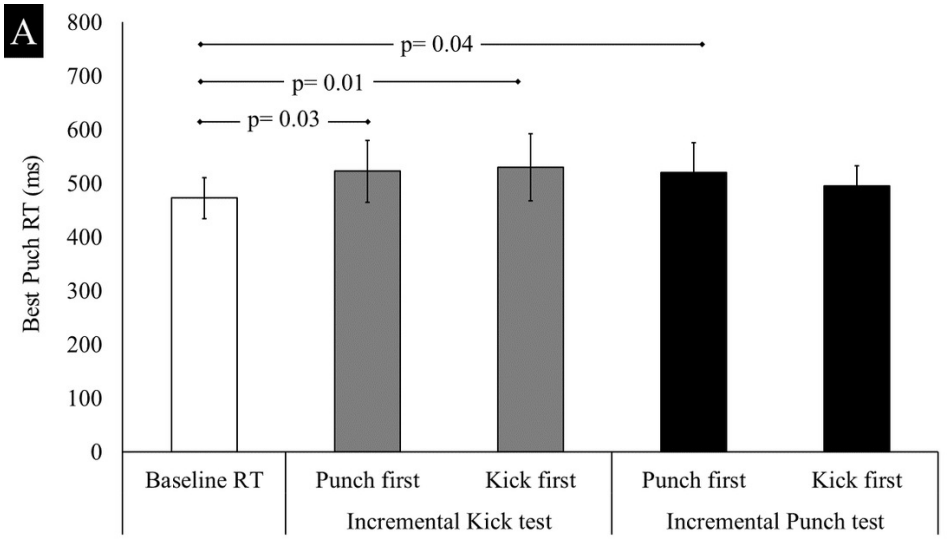

B
1200
1000
800
600
400
200
0
Mean Kick RT (ms)
p= 0.001
Baseline RT
Punch first
Kick first
Incremental Kick test
Punch first
Kick first
Incremental Punch test

Figure 3

Punch Response time (*Guiako zuki*) in different experimental situations. Panel A: best response time; Panel B: average response time.


A
800
700
600
500
400
300
200
100
0
Best Puch RT (ms)
p= 0.04
p= 0.01
p= 0.03
Baseline RT
Punch first
Kick first
Incremental Kick test
Punch first
Kick first
Incremental Punch test

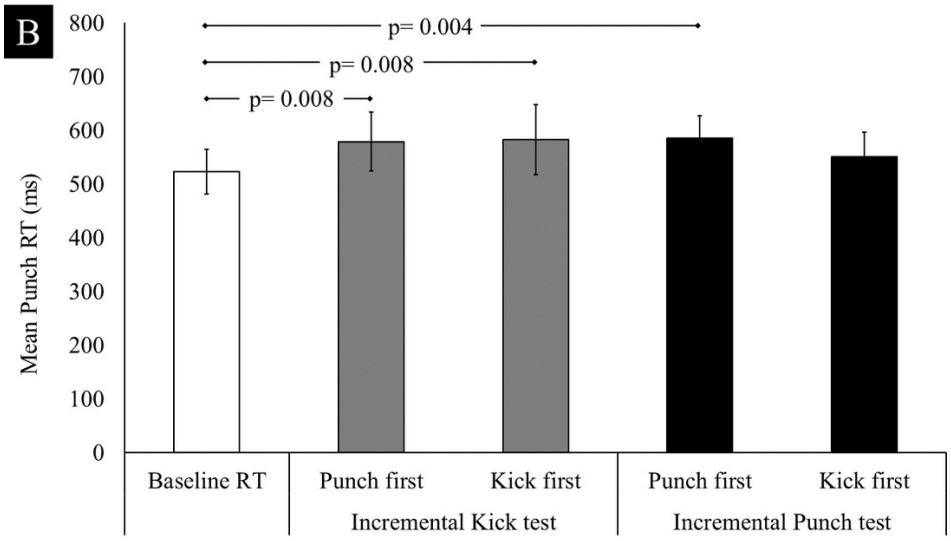

B
800
700
600
500
400
300
200
100
0
Mean Punch RT (ms)
p= 0.004
p= 0.008
p= 0.008
Baseline RT
Punch first
Kick first
Incremental Kick test
Punch first
Kick first
Incremental Punch test

Table 1 (on next page)

Performance in kick and punches during the incremental test and re-test.

1 Table 1. Performance in kick and punches during the incremental test and re-test.

	Kicks		Punches			
	Test	Re-test	Test	Re-test	F	p-value
a . strinking fre uenc (n)	29.9 ± 1.9	29.4 ± 2	31.9 ± 5.6	33.2 ± 4.4	2.91	0.07
Total number of strikes (n)	126.8 ± 15.3	122.7 ±15.9	290.7 ± 101.9	310.8 ± 75.7	31.61	0.00
Total test time (min)	8.7 ± 0.6	8.5 ± 0.6	9.4 ± 1.5	9.6 ± 1.3	2.69	0.09
PVO$_2$max (ml kg^{-1} min^{-1})	46.9 ± 0.9	46.2 ± 1.2	47.7 ± 3.4	48.5 ± 2.7	2.32	1.12

2

3

Commented [R36]: Where is peak HR, peak lactate levels, REP or any other measures of fatigue? This is important to include.

Commented [R37]: Duration of time?

Commented [R38]: The "P" indicates predicted value rather than measured

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