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Acute neuromuscular responses to short and long roundhouse kick striking paces in professional Muay Thai fighters

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Abstract

BACKGROUND: Muay Thai fighters strongly rely on the use of the roundhouse kick due to its effectiveness (i.e. power) and implications on the final score. Therefore, different striking tempos at full power are used during training as a method to enhance kicking power. However, the neuromuscular responses are unknown. Thus, the goal of this study was to investigate neuromuscular responses to a single bout of shorter (every second = H1) and longer (every 3s = H3) kick striking time intervals, measured with the countermovement jump (CMJ).

METHODS: Nine professional Muay Thai fighters participated in this randomized, cross-over trial. CMJs were measured on force plates before and after (post 0min, post 5min, post 10min, post 20min and post 30min) two striking (1set x 20reps) conditions (H1; H3).

RESULTS: Although no difference was observed between H1 and H3 values, neuromuscular fatigue parameters displayed different patterns over time. CMJ height decreased immediately after H3 striking ($P<0.05$), whereas for H1 condition CMJ height decreased from post20 as compared to baseline ($P<0.05$). Peak force in H3 condition was significantly lower at post10, post20 and post30 as compared to baseline. For H1, peak force values were lower than baseline only at post30. Peak power was significantly lower than baseline for both middle kick procedures. A slight but significant increase was observed at post5 for H3 condition, but decreased further post10 and remained constant during subsequent tests. In contrast, for H1 condition peak power remained unaffected after post10, whereas it decreased post20 and post30 minutes only when compared to post0.

CONCLUSIONS: Results showed that both kick striking modes provoke comparable neuromuscular fatigue but H3 condition showed the potential to induce post activation potentiation. Muay Thai and conditioning coaches should focus on hard striking with both long and slow pacing during specific heavy bag or pad work.

Keywords: Thai-boxing - Middle kick - Countermovement jump - Neuromuscular fatigue

Introduction

Muay Thai is a martial art requiring complex skills and tactical abilities[1] Fights are based on both stand-up actions and clinching phases.[2,3] Striking includes punches, elbow-strike, knee-strokes and a variety of kicks.[1–3] The most commonly used, middle kick, is a powerful kicking technique,[1] as such it strongly influences the fight outcome and final score according to the official rules.[1,4] Hence, Muay Thai coaches seek to develop middle kick power output via specific training methods. However, studies on fatiguing effects induced by Muay Thai kick-striking training that reflect training stressors are non-existent, limiting power training to suboptimal or inappropriate strategies.

Two traditional strategies are currently employed: (a) striking the pads/heavy bag as hard as possible with a few seconds (long) rest between strikes; (b) striking as hard as possible with a shorter rest between strikes within the same set.[5] As a result, specific power training prescriptions (i.e. kick power output) are based on empirical experience potentially leading to excessive neuromuscular fatigue and/or poor improvements.

Therefore, the objective of this study was to examine the effect of one bout of middle kick striking on neuromuscular fatigue under two conditions: the hardest possible middle kick every 3 seconds (H3); and the hardest possible middle kick every second (H1). We expected that H3 condition would allow more time for kicking preparation, leading to higher force generation at impact. Therefore, we hypothesized that neuromuscular fatigue -related changes were more pronounced for H3 (longer rest) compared with H1 (shorter rest) conditions. Results from this study will inform Muay Thai and strength and conditioning coaches of good practice in middle kick optimal power training.

Materials and methods

Experimental Approach to the Problem

In a randomized cross-over trial, two middle kick testing conditions (H3 and H1) were completed in an indoor Muay Thai gym, within an evening (19:00-23:00). Each condition was separated by 2h deemed sufficient to prevent carryover effects because participants were professional athletes accustomed to high training workloads. Each fighter acted as their own control, and familiarization with experimental protocols was completed a half day prior to testing (Figure 1). Computer generated random number IDs were assigned to either H3 or H1 condition (Microsoft, Excel 2011 v. 14.4, USA). Pieces of papers with participants' names and IDs where placed in two separate boxes and drawn blindly to associate individuals to IDs. The countermovement jump (CMJ) is generally used to estimate lower limb muscle power and neuromuscular fatigue.[6] Indeed, although the CMJ may be influenced by the sport-specific training background,[7,8] it was previously used to assess neuromuscular fatigue in other similar combat sports such as taekwondo.[9,10] Therefore, before and after each condition acute neuromuscular fatigue indicators; jump height, peak power and peak force derived from CMJ ground reaction forces where measured.[11,12]

****Figure 1 near here****

Participants

Nine professional male Muay Thai fighters (age 20 ± 4 y, height 176 ± 6 cm, body mass 68 ± 7 kg) were recruited from two combat sports clubs in Italy. All were experienced (training 13 ± 1 h/week, practice time 6 y ± 2, previous (professional) fights (15 ± 12) and lower-limb injury free in the past two months. The participants were instructed to avoid consumption of caffeine and abstain from strenuous exercise in the 48 h before testing. The study was conducted according to the Declaration of Helsinki and approved by the Institutional Ethics Board. Participants confirmed informed consent prior to study commencement.

Procedures

Initially, all participants performed a 20-minute standardized dynamic warm-up (Table 1). Five minutes after the warm-up, a baseline of five maximal CMJs with 30-second rest between trials was performed. Participants stood with their left and right lower limbs on separate adjacent force plates. They performed a fast downward movement by flexing at the knees and hips (~90deg), then immediately extended their knees and hips to jump vertically as high as possible.[13] Vertical ground reaction forces were recorded using two force platforms (PS-2141, PASCO, USA) at a sampling rate of 1,000 Hz (Capstone, PASCO, USA) and stored on an MacBook Pro (2.6 GHz Intel Core i5, Apple, USA). The signal of each platform was synchronized via an interface (SPARKlinkAir, PASCO, USA). Two middle kick-training conditions (H3, H1) were performed in an indoor Muay Thai gym using a 60kg heavy bag kept steady by the coach to minimize variation in striking technique. Before testing, participants performed submaximal middle kicks (50% of the perceived maximal effort) against the bag to locate and mark with tape their comfortable striking area (i.e. actual middle kick target in real conditions). The first protocol (H3) consisted of striking the bag a total of 20 times as hard as possible every 3s alternating right and left leg, while the second protocol (H1) reduced the interval between strikes to 1s. Twenty strikes approximately represents the common amount of kicks thrown within a set in Muay Thai kick training. An electronic metronome was used to indicate the impact tempo. For both conditions, the coach constantly encouraged participants to strike as hard as possible to promote repeated maximal efforts. Three CMJ trials with a rest of 30s between them were conducted immediately, 5min, 10min, 20min and 30min after the intervention (post, post5, post10, post20, post30, respectively) enabling recovery observations. We used three trials instead of five (baseline trials) to minimize the neuromuscular fatigue induced by the test itself. For all CMJ tests (i.e. baseline-post), participants were verbally encouraged to produce the highest jump possible, and rest in a seated position between phases. All testing and protocols were performed barefoot because of the nature of Muay Thai practice. Force data were filtered using a 2nd order zero-lag Butterworth low-pass filter with a cut-off frequency of 15Hz.[14] The signals of the right and left force plates were summed to obtain a single trace. The flight phase was defined as the data (vertical force) below a threshold set to ≤20N.[14] Vertical jump height (cm), peak force (N.kg-1) and peak power (W.kg-1) were averaged between trials and calculated using the impulse–momentum method [15] using a custom Matlab script (The MathWorks Inc., USA).

****Table 1****

Statistical Analyses

Statistical analyses were performed using STATISTICA v.7.0 software (StatSoft Inc., Tulsa, USA). Shapiro–Wilk tests revealed that data were not normally distributed. Mann-Whitney and Wilcoxon tests were used to compare differences with conditions (H3 vs. H1) and time (baseline, vs. post, post5, post10, post20 and post30), respectively. Significance was set at $P \leq 0.05$ (95%CI) and effect size (ES) calculated using Cohen's d (value ranges of 0.2-0.5, 0.51-1.19 and >1.20 considered small, medium and large effects, respectively).[16] Coefficients of variation and intra-class correlation coefficients were calculated for each dependent variable to evaluate measurements reliability.

Results

No difference was observed between conditions (H1 vs. H3) for CMJ height, peak force and peak power. However, vertical jump performance was affected by repeated middle kicks (Table 2). CMJ height significantly decreased after H3 condition (-3.8±3.5%; ES=0.42) and remained significantly lower than baseline after 30 minutes rest ($P<0.05$). After H1, vertical jump height significantly decreased at post20 and post30 as compared to baseline. Peak force in H3 condition was significantly lower at post10, post20 and post30 as compared to baseline ($P<0.05$), whereas for H1 peak force values were lower than baseline at post20 and post30. Peak power was significantly lower than baseline after both middle kick modalities at post (-4.5±3.1%; ES=0.52 [H1] and 4.6±3.5%; ES= 0.57 [H3]). A small but significant increase was observed at post5 as compared to post for H3 (+3.3±3.0%; ES=0.36), but decreased further post10 and remained constant during subsequent tests. In contrast, for H1 condition peak power remained unaffected after the first 10min, whereas it decreased after 20min and 30min only. The coefficient of variation (CV) for CMJ height was 3.0%, for peak force was 4.2%, and 2.5% for peak power. Intraclass correlation coefficients (ICCs; 2.1) showed high agreement for the height (ICC = 0.95, 95 % CI = 0.84-0.98), peak force (ICC = 0.95, 95 % CI = 0.87-0.99), and peak power (ICC = 0.98, 95 % CI = 0.94-0.99) variables, respectively.

****Table 2****

Discussion

This is the first study quantifying neuromuscular fatigue (i.e. CMJ variables) of two common Muay Thai kick-striking training modes. Our results first indicate no difference between conditions (i.e. H1 and H3). However, individually (H1, H3) recovery patterns observed over time indicate that: (i) qualitatively H3 condition elicits greater perturbations as compared to H1; (ii) H3 showed the potential to induce post activation potentiation 5 min after the end of the drill.

Participants kicked as hard as possible at a self-selected distance that ensure high acceleration rates meaning greater impact force.[17] The fact that no difference between modes was found suggests that neuromuscular fatigue was equivalent. However, when striking modes were analyzed independently, it was clearer that time intervals between kicks (1-3s) impacted on striking intensity since CMJ height reduced (indicating fatigue) immediately after H3 but not H1. Because in the H1 condition less time was available to strike the target, participants may have emphasized execution speed to respect the metronome pace supposedly reducing impact force. In fact, according to the force velocity relationship, one would expect that at greater striking speed, force produced was lower diminishing repeated kicking efficacy.[1,18,19] Therefore, lower intensity meant as reduced impact force could modulate the magnitude of neuromuscular fatigue,[18,20] ceteris paribus (i.e. kick volume = 20). Nonetheless, because impact force was not measured, this hypothesis should be explicitly addressed in the future.

Moreover, because CMJ height reduced immediately after H3, neuromuscular fatigue induced by slow (every 3s) and hard kicking probably alters vertical jump coordination[21] more than fast (every second) and hard kicking. No similar studies are available for direct comparison, making the interpretation of our data between conditions difficult. Nevertheless, it is known that neuromuscular fatigue provokes kinematic and kinetic alterations leading to CMJ height impairment [21] probably due to neuromuscular fatigue multifactorial reasons (i.e. central, peripheral). In fact, it is likely that striking hard at longer time intervals strongly relied on both neural drive efficiency and anaerobic sources, supposedly provoking neural impairment and an accumulation of other metabolic byproducts such as Pi that could play a major role in muscle neuromuscular fatigue.[22] As a result CMJ height could be affected via impaired inter-muscular coordination.[21]

In future, investigating how training striking modalities affect muscle activation and net torque production at hip, knee and ankle joints would clarify striking fatigue origins. Yet, the sport-specific training background may influence CMJ performance, meaning the absolute results should be carefully considered when comparing different sports populations.[7,8] However, in this study CMJ variables were used to estimate neuromuscular fatigue rather than comparing performance between participants or different populations, and a familiarisation session was performed before testing. Therefore, we deemed the use of CMJ appropriate and valid as a tool to estimate neuromuscular fatigue.[11]

Peak power was observed to decrease after both conditions. However, a significant increase at post5 for H3 suggests a possible postactivation potentiation (PAP) effect,[23] which disappeared from post10. In fact, it was shown that an improvement in performance could be achieved after high intensity muscle contraction.[24] In addition, there is evidence suggesting that neuromuscular fatigue dissipates after 5-10min of recovery period between the high intensity exercise and the following activity,[25,26] which may explain why at post5 CMJ height improved. We propose that CMJ height improvement at post5 was the result of supposedly greater force generated in H3 condition, which was facilitated by a longer time available to perform the strikes as compared to H1. Therefore, we could speculate that PAP was induced by possible greater muscle force in H3. Finally, from post20 an overall decrease (all data) was observed as compared to baseline for both conditions. It is likely that muscle temperature gradually declined [27] because participants passively sat on a chair waiting for successive testing, thereby impairing CMJ height.[27] Further research is necessary to explore the nature of kick-specific neuromuscular neuromuscular fatigue (i.e. central, peripheral).

Conclusions

The frequency at which a Muay Thai fighter performs middle kicks depends on the opponent actions. However, according to Muay Thai rules, scores are awarded when kicks are powerful.[4] Therefore, specific middle kick power should have a crucial role in training, and our data suggest that short or long striking time interval (pacing) between repeated maximal middle kicks are a good stressor for the neuromuscular system. As a result, Muay Thai, Kickboxing and MMA athletes together with their respective conditioning coaches, should focus on hard striking with both long and slow pacing during specific heavy bag or pad work training to develop middle kick power.

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Conflicts of interest. – The author reports no potential conflict of interest.

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TITLES OF FIGURES

Figure 1. Experiment setting – A = CMJ testing; B = striking procedure; C = experiment timeline; * post, 5, 10, 20, 30 = measurements at 0min, 5min, 10min, 20min and 30min respectively.

TITLES OF TABLES

Table 1. Standardised warm up.

Table 2. Vertical jump height, peak force and peak power measured before and after the kick-striking modes.

Table 1. Standardized warm-up.

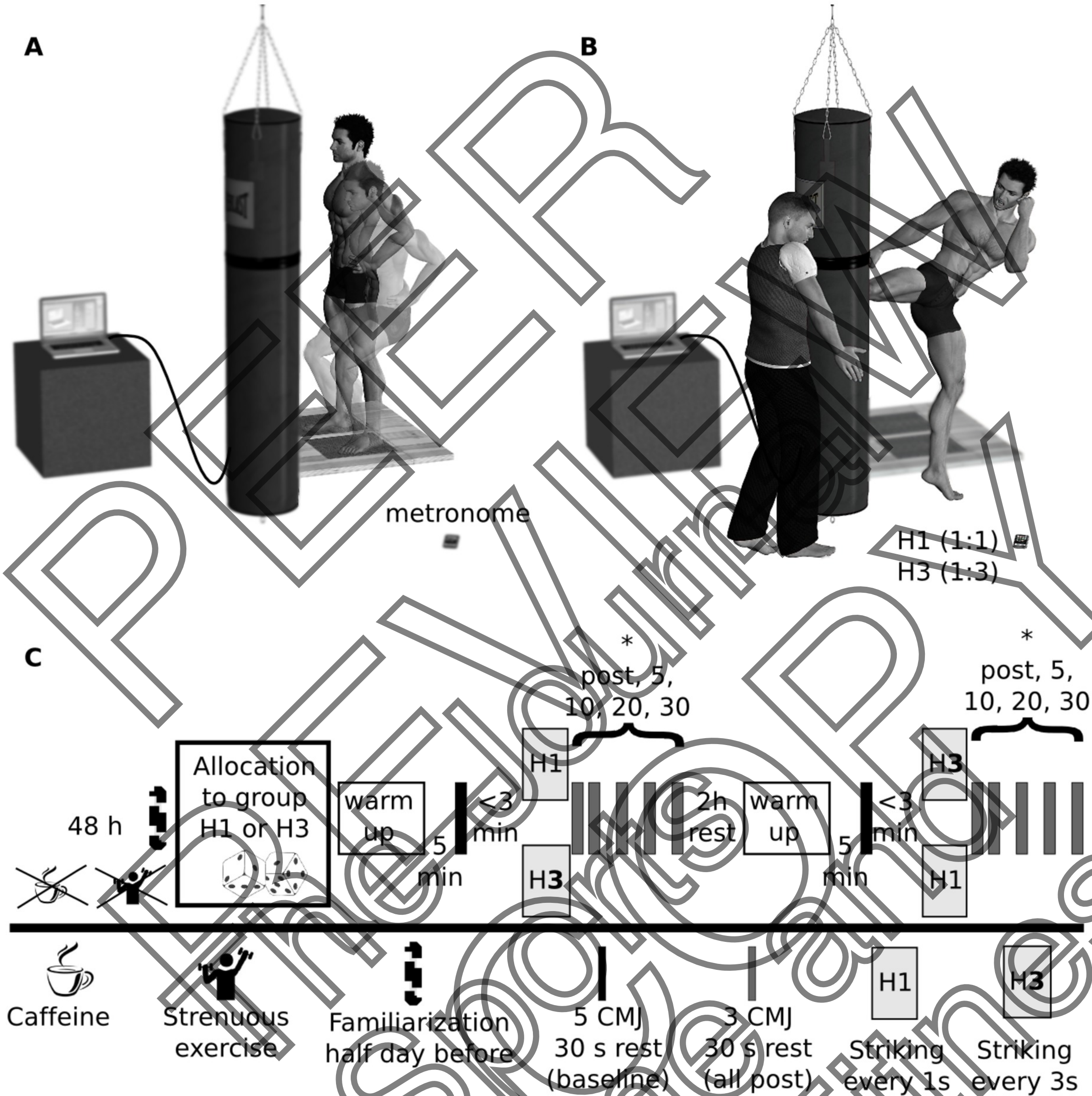
#	Drills	Volume	Intensity	Rest
1	*Bench press*	2 sets x 8 reps	30% body weight	1 min
2	*Parallel high bar squat*	2 sets x 8 reps	50% body weight	1 min
3	*Running (Treadmill)*	1 set x 5 min	Progressive 9 km.h^{-1} to 11 km.h^{-1} (□ 0.5 km.h^{-1} per minute)	3 min
4	*Heavy bag drill (Middle kicks)*	1 set x 3 min: a) 90 s 1:3 tempo b) 90 s 1:1 tempo	Perceived effort (50%)	NA
5	5 min rest before baseline testing			

Rest period between drills was 1 min.

Table 2. Vertical jump height, peak force and peak power measured before and after the kick-striking modes.

		Baseline	Post	Post5	Post10	Post20	Post30
				CMJ height (cm)			
H1	*Mean*	27.3	26.2	26.9	26.6	25.5[acd]	24.9[acde]
	95%CI	[26.1-28.5]	[24.4-28.0]	[25.6-28.1]	[25.1-28.2]	[23.9-27.0]	[23.5-26.2]
H3	*Mean*	27.7	26.7[a]	27.0[a]	26.0[abc]	25.3[abc]	25.0[abc]
	95%CI	[26.0-29.5]	[24.5-28.9]	[25.5-28.5]	[24.3-27.8]	[24.2-26.4]	[23.8-26.1]
				Peak force ($N.kg^{-1}$)			
H1	*Mean*	25.3	25.8	25.1	25.1	24.6[b]	24.4[ab]
	95%CI	[23.9-26.7]	[24.2-27.3]	[23.9-26.3]	[23.9-26.5]	[23.4-25.7]	[23.1-25.7]
H3	*Mean*	25.8	25.1	24.9	24.5[a]	24.1[abc]	24.7[a]
	95%CI	[24.2-27.4]	[23.1-27.0]	[22.8-27.0]	[22.6-26.4]	[22.1-26.1]	[22.8-26.5]
				Peak power ($W.kg^{-1}$)			
H1	*Mean*	47.5	45.4[a]	46.5[a]	46.0[a]	43.8[abcd]	43.3[abcd]
	95%CI	[44.6-50.4]	[42.1-48.7]	[43.8-49.2]	[42.7-49.4]	[41.3-46.2]	[40.2-46.5]
H3	*Mean*	47.9	45.6[a]	47.0[ab]	45.1[ac]	44.0[ac]	43.6[acd]
	95%CI	[44.8-50.9]	[42.7-48.5]	[44.0-50.0]	[42.1-48.0]	[41.2-46.8]	[40.8-46.3]

Values are mean and 95% confidence intervals (95%CI). H1: kick-striking every second. H3: kick-striking every three seconds. a, b, c, d, e: significant differences with baseline, post, post5, post10, post20, respectively ($P < 0.05$).


A
B
metronome
H1 (1:1)
H3 (1:3)
C
48 h
Allocation to group H1 or H3
warm up
5 min
<3 min
H1
H3
post, 5, 10, 20, 30
2h rest
warm up
5 min
<3 min
H3
H1
post, 5, 10, 20, 30
Caffeine
Strenuous exercise
Familiarization half day before
5 CMJ 30 s rest (baseline)
3 CMJ 30 s rest (all post)
H1
Striking every 1s
H3
Striking every 3s