Development of a Noncontact Kickboxing Circuit Training Protocol That Simulates Elite Male Kickboxing Competition

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[1]Research Unit, "Sportive Performance and Physical Rehabilitation," High Institute of Sports and Physical Education, Kef, University of Jendouba, Jendouba, Tunisia; [2]Faculty of Sciences, Bizerte, Tunisia; [3]Combat Sports Performance, Essex, United Kingdom; [4]Department of Physiology and Functional Exploration, Farhat Hached University Hospital, Sousse, Tunisia; [5]Martial Arts and Combat Sports Research Group, School of Physical Education and Sport, University of Sao Paulo, Sao Paulo, Brazil; [6]Sultan Qaboos Sports Academy, Ministry of Sports Affairs, Sultanate of Oman; and [7]Laboratory of Physiology, Faculty of Medicine of Sousse, University of Sousse, Sousse, Tunisia

Abstract

Ouergui, I, Houcine, N, Marzouki, H, Davis, P, Zaouali, M, Franchini, E, Gmada, N, and Bouhlel, E. Development of a noncontact kickboxing circuit training protocol that simulates elite male kickboxing competition. *J Strength Cond Res* 29(12): 3405–3411, 2015—The aim of this study was to verify whether the specific kickboxing circuit training protocol (SKCTP) could reproduce kickboxing combat's hormonal, physiological, and physical responses. Twenty athletes of regional and national level volunteered to participate in the study (mean ± *SD*, age: 21.3 ± 2.7 years; height: 170 ± 0.5 cm; body mass: 73.9 ± 13.9 kg). After familiarization, SKCTP was conducted 1 week before a kickboxing competition. Cortisol, testosterone, growth hormone (GH), blood lactate [La], and glucose concentrations, as well as the Wingate upper-body test and countermovement jump (CMJ) performances were measured before and after SKCTP and combat. Heart rate (HR) and rating of perceived exertion (RPE) were measured throughout rounds (R) R1, R2, and R3. Testosterone, GH, glucose, [La], HR, RPE, and CMJ did not differ among the 2 conditions ($p > 0.05$). However, Cortisol was higher for competition ($p = 0.038$), whereas both peak ($p = 0.003$) and mean power ($p < 0.001$) were higher in SKCTP. The study suggests that SKCTP replicates the hormonal, physiological, and physical aspects of competition. It is therefore suggested as a good form of specific kickboxing training, as well as a specific assessment tool to be used by kickboxing coaches to quantify kickboxers' fitness levels, when physiological parameters responses to the test are measured.

Key Words combat sports, full-contact, hormones, performance, lactate

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Introduction

"Full-contact" is a discipline of kickboxing, which is spreading in popularity worldwide. Like all combat sports, it requires the athlete to command a high integration of physiological (18), physical (20,27), technical, and tactical (19) elements to excel in competition. Investigations into its physiological, hormonal, and physical demands are limited (17,18,20,27). There is no consensus in the literature as to whether there is a difference between parameters measured in official and simulated combats. Despite the importance of information from simulated combats, official combats obviously remain as the reference value (20). Studies conducted into official combats are limited to physical aspects (i.e., time-motion analysis) (20) and technical and tactical analysis (19). Physiological assessments into official combats are important for better understanding the related stress and therefore provide effective guidelines for physical conditioning of athletes. Nevertheless, there are restrictions for attaining this information from a competitive combat. Competition rules state that kickboxers are not allowed to wear any other equipment such as heart rate (HR) monitors in addition to official uniform. Additionally, constraints from governing bodies do not permit interventions near the combat area (20). Moreover, athletes did not desire to engage in invasive data collection methods (3,20), and the equipment used can result in risk of damage and injuries (20).

Because of these restrictions, a previous study (4) aimed to find alternative methods to better understand the physiological demands of other striking combat sports (Taekwondo) by suggesting specific exercises protocols that can simulate official combats. Despite the importance of this study, the exercise protocol proposed was not able to mimic the physiological responses of official taekwondo competition.

To the best of our knowledge, there are no studies that have investigated the physiological strain of official kickboxing combats through specific exercises or circuit training. Therefore, the objective of this study was to quantify the validity of specific kickboxing circuit training protocol (SKCTP) by measuring its ability to reproduce the physiological, hormonal, and physical demands of official combat.

Methods

Experimental Approach to the Problem

To date, there are no studies that focused on giving a specific tool for kickboxing coaches to assess kickboxers' specific performance. To achieve our objective, the study consisted of comparing the hormonal, physiological, and physical parameters between the SKCTP and the full-contact kickboxing combat. Based on the analysis of Ouergui et al. (20), the subjects who participated in the study were chosen from all the kickboxing weight categories. The hypothesis of this study was that the SKCTP would recreate the hormonal, physiological, and physical parameters of the combat, allowing its use by coaches as a valid tool for training and assessment purposes.

Subjects

Twenty kickboxers of regional and national level volunteered to participate in the study (mean ± *SD*, age: 21.3 ± 2.7 years; age range: 19–23 years; height: 170 ± 0.5 cm; mass: 73.9 ± 13.9 kg). They had been involved in kickboxing for 8.1 ± 2.7 years, competing at regional and national level for >2 years, and training 5 days a week, 2 hours per day. The protocol was conducted at the end of the sports season. After receiving a thorough explanation of the protocol, they gave written consent to participate in this study. The study was conducted in accordance with the declaration of Helsinki and approved by the local ethics committee before the commencement of the assessments.

Procedures

The protocol consisted of performing the SKCTP twice and a full-contact kickboxing combat once. The first SKCTP session was used for familiarization before baseline testing. The effectiveness of the SKCTP as an analog of actual combat, reproducing its demands, was tested comparing the physical, physiological, and hormonal responses between the 2 conditions. Before the beginning of the tests, the athletes completed a standardized 15-minute warm-up, composed of jogging and dynamic stretching. Baseline measures were taken 5 minutes after warm-up. Anaerobic performance for both upper and lower body, blood lactate ([La]), cortisol, testosterone, testosterone to cortisol ratio (T:C), growth hormone (GH), glucose, and body mass were measured before and after the 2 conditions. The biological markers were chosen in an attempt to analyze the competition-related stress as used in previous studies that investigated the hormonal responses during combat sports competitions (4,6,17,22,23) and for specific exercises (4).

Anaerobic upper-body performance was evaluated using a Wingate upper-body test performed on a Monark cycle ergometer (Monark 894E, Vansbro, Sweden) with a load set at $4.9\ N \cdot Kg^{-1}$ of body weight (21). The test was chosen based on the fact that upper limbs are mostly and repeatedly used in kickboxing combats (19). Anaerobic lower-body performance was measured using countermovement jump test (CMJ) with an infrared jump system (Optojump; Microgate, Bolzano, Italy). The CMJ test was chosen because displacements during the kickboxing competition are preceded by plyometric phases (18). Blood samples were taken before and directly after combat from the fingertip. The [La] was determined using the Lactate Pro Analyzer (Arkray, Tokyo, Japan), and glucose was monitored by a portable blood glucose monitor Accu-Chek Active (Roche Diagnostics GmbH, Mannheim, Germany) (11). Heart rate was measured every 5 seconds through SKCTP and the combat (Polar team^2 Pro System; Polar Electro OY, Kempele, Finland). Rate of perceived exertion (RPE, Borg's CR-10 scale) (2) was collected after each round. Pre- and post-body mass was also measured. All sessions were conducted at the same time of day (15:00–17:00) to control for circadian rhythm influences.

Kickboxing Combats

As these measurements are not permitted in official kickboxing competition, the combats were held at a high institute of sports, organized as a local university tournament so that the kickboxers would give their full and realistic effort. The combats were directed by an official referee with duration of 3 × 2 minutes of rounds with 1-minute recovery between them. The participants were chosen from different weight divisions, that is, heavy (>75 kg), middle (<75 kg), and light (<60 kg) (20) in accordance with the rules of the World Association of Kickboxing Organizations.

The Specific Kickboxing Circuit

The SKCTP was constructed in accordance of the time structure of the world championship of kickboxing. The appearance of different activity phases (i.e., high-intensity, low-intensity, and referee pause) were recorded in accordance with the literature (20). During the SKCTP, the participants used the most common techniques for punches (jab and cross), for kicks (roundhouse), singularly and in combination; multiple kick combinations were not used as they are not common in competition (19). The distribution of single and combined actions was recreated in an attempt to reproduce the acyclic nature of combat sports activity. At the beginning of the circuit construction, the time of different activity phases was obtained from the mean time reported in the literature (20). This was subsequently recorded using beeps, and actions were announced by one of the experimenters to increase the anticipatory/reactive responses of the athlete (4). However, the effort-pause sequence resulted in an excessive number of sound signals, causing confusion. Instead, the mean time of high-intensity

Round 1			
Block 1	*Block 2*	*Block 3*	*Block 4*
Free displacements (2,6s) J (1s) Bounce (2,6s) C (1s) Bounce (2,6s) R.K$_L$ (1s) Bounce (2,6s) J-C (2s) Bounce (2,6s) J-C (2s) Bounce (2,6s) J-C (2s) Bounce (2,6s) J-C + RK$_L$(3s) Bounce (2,6s) J-C + R.K$_L$ (4s)	Bounce (2,6s) Jab (1s) Bounce (2,6s) RK$_R$ (1s) Bounce (2,6s) J-C (2s) Bounce (2,6s) J-C (2s) Referee pause (6s) J-C (2s) Bounce (2,6s) J-C + RK$_L$ (3s) Bounce (2,6s) J-C + RK$_R$ (4s)	Bounce (2,6s) J (1s) Bounce (2,6s) J-C (2s) Bounce (2,6s) J-C (2s) Bounce (2,6s) J-C (2s) Bounce (2,6s) J-C + RK$_R$ (3s) Bounce (2,6s) J-C + RK$_L$ (5s)	Bounce (2,6s) J (1s) Bounce (2,6s) J-C (2s) Bounce (2,6s) J-C (2s) Bounce (2,6s) J-C (2s) Bounce (2,6s) J-C + RK$_L$ (3s) Referee pause (6s) J-C + RK$_R$ (6s)
Round 2			
Block 1	*Block 2*	*Block 3*	*Block 4*
Free displacements (2,7s) J (1s) Bounce (2,7s) RK$_L$ (1s) Bounce (2,7s) J-C (2s) Bounce (2,7s) J-C (2s) Referee pause (5,5s) J-C (2s) Bounce (2,7s) J-C + RK$_L$ (3s) Bounce (2,7s) J-C + RK$_L$ (4s)	Bounce (2,7s) J (1s) Bounce (2,7s) J-C (2s) Bounce (2,7s) J-C (2s) Bounce (2,7s) J-C (2s) Referee pause (5,5s) J-C + RK$_L$ (3s) Bounce (2,7s) J-C + RK$_R$ (4s)	Bounce (2,7s) C (1s) Bounce (2,7s) J-C (2s) Bounce (2,7s) J-C (2s) Bounce (2,7s) J-C(2s) Referee pause (5,5s) J-C + RK$_R$ (3s) Bounce (2,7s) J-C + RK$_L$ (5s)	Bounce (2,7s) J (1s) Bounce (2,7s) J-C (2s) Bounce (2,7s) J-C (2s) Bounce (2,7s) J-C (2s) Referee pause (5,5s) J-C + RK$_L$ (3s) Bounce (2,7s) J-C + RK$_R$ (6s)
Round 3			
Block 1	*Block 2*	*Block 3*	*Block 4*
Free displacements (2,8s) J (1s) Bounce (2,8s) RK$_L$ (1s) Bounce (2,8s) J-C (2s) Bounce (2,8s) J-C (2s) Bounce (2,8s) J-C + RK$_L$ (3s) Referee pause (6s) J-C + RK$_L$ (4s)	Bounce (2,8s) J (1s) Bounce (2,8s) J-C (2s) Bounce (2,8s) J-C (2s) Bounce (2,8s) J-C (2s) Bounce (2,8s) J-C + RK$_L$ (3s) Referee pause (6s) J-C + RK$_R$ (4s)	Bounce (2,8s) C (1s) Bounce (2,8s) J-C (2s) Bounce (2,8s) J-C (2s) Bounce (2,8s) J-C (2s) Bounce (2,8s) J-C + RK$_R$ (3s) Referee pause (6s) J-C + RK$_L$ (5s)	Bounce (2,8s) J (1s) Bounce (2,8s) J-C (2s) Bounce (2,8s) J-C (2s) Bounce (2,8s) J-C (2s) Bounce (2,8s) J-C + RK$_R$(3s) Referee pause (6s) J-C + RK$_R$ (6s)

Figure 1. Schematic representation of the specific kickboxing circuit training protocol. J = jab; C = cross; RK = roundhouse kick; L = lead; R = rear.

actions (HIAs) by the typical work intervals for fighting activities was replaced by calculating the mean number of each work interval. Moreover, the time of low-intensity activities (LIAs) and pause (P) was distributed accordingly to the number of intervals between HIAs obtained, respecting therefore their total times (i.e., ~178 seconds for HIA, LIA alike, and 58 seconds for P, overall circuit) as reported by Ouergui et al. (20).

The time interval under 1 second was dedicated for single techniques, whereas time of 2 seconds was attributed to punches combinations. The time interval from 3 to 6 seconds was dedicated for punch and kick combinations.

During the SKCTP, the kickboxers wore their usual combat equipment, striking against a standard 50-kg kicking-bag hanging 150 cm above the floor. The choice of using a punching bag was based on the study of Arseneau et al. (1) who found that, for boxing, free punching a bag elicited higher values for percentage of HR than pad work with the same perceptive responses with that of sparring and pad work. The kickboxers were instructed to strike as powerfully as possible, and verbal encouragement was used to maintain high intensity. During the LIAs, the kickboxers maintained a bouncing motion, and, during referee pauses, the kickboxers remained in a standing position (Figure 1).

Blood Collection and Biochemical Analysis

Blood samples were obtained from an antecubital vein before and immediately after exertion. Plasma was separated by centrifugation within 15 minutes of collection and divided into 2 aliquots, frozen, and stored at −80° C for subsequent analysis. The samples were analyzed for cortisol, testosterone, and GH. Cortisol was determined by radioimmunoassay (Immunotech RIA, Marseille, France) with a sensivity of 7 $ng \cdot ml^{-1}$. Intra/interassay coefficient of variation (CV) was 2.9 and 5.3%, respectively. Testosterone was determined by radioimmunoassay (Immunotech RIA) with a sensitivity of 0.1 $ng \cdot ml^{-1}$ and an intra/interassay CV of 8.9 and 9.4%, respectively. Growth hormone was determined by immunoradiometric assay (Immunotech IRMA) with a sensitivity of 0.1 $ng \cdot ml^{-1}$ and an intra/interassay CV of 15 and 14%, respectively. Testosterone to cortisol ratio was also calculated.

Statistical Analyses

All statistical tests were processed using Statistica software for Windows (version 12.0; Statsoft, Tulsa, OK, USA). The normality of data sets was checked using the Kolmogrov-Smirnov test. Compound symmetry was tested using the Mauchly test. To establish the difference between the SKCTP and combat, a 2-way (2-condition type: SKCTP or combat × time of measurement: pre and post) analysis of variance with repeated-measures was used. When a difference was found, a Bonferroni post hoc test was applied. Effect sizes (η^2) were

Table 1. Body mass, metabolites, and hormones responses pre and post SKCTP and combat.*

	SKCTP		Kickboxing combat	
	Pre	Post	Pre	Post
Body mass (kg)	75.4 ± 14.1	75.1 ± 13.9†	75.2 ± 14.1	74.9 ± 14.0†
Lactate (mmol·L^{-1})	1.9 ± 0.5	13.6 ± 1.9†	2.0 ± 0.6	14.0 ± 1.8†
Glucose (mmol·L^{-1})	4.8 ± 0.4	8.0 ± 1.0†	5.0 ± 0.4	8.1 ± 1.2†
GH (ng·ml^{-1})	0.6 ± 0.8	10.47 ± 4.7†	0.6 ± 0.6	11.4 ± 4.1†
Testosterone (ng·ml^{-1})	3.2 ± 1.0	4.3 ± 1.2†	3.2 ± 1.3	4.5 ± 1.6†
Cortisol (ng·ml^{-1})	91.5 ± 34.9	122.0 ± 36.8†‡	97.7 ± 49.2	143.7 ± 39.4†
T:C	0.04 ± 0.01	0.04 ± 0.02	0.03 ± 0.01	0.03 ± 0.01

*SKCTP = specific kickboxing circuit training protocol; GH = growth hormone; T:C = testosterone to cortisol ratio.
†Different from pre-exercise ($p < 0.001$).
‡Different from combat ($p < 0.001$).

calculated for each output (8). Statistical significance was set at ($p \leq 0.05$). All data are reported as mean ± *SD*.

Results

Body mass decreased pre-to-post combat and SKCTP alike ($F_{1,19} = 58.5$; $p < 0.001$, $\eta^2 = 0.755$) with no difference between the 2 conditions ($F_{1,19} = 1.4$; $p = 0.245$) and no interaction between pre-to-post and condition ($F_{1,19} = 0.02$; $p = 0.881$) (Table 1).

Growth hormone and testosterone increased pre-to-post combat and SKCTP alike ($F_{1,19} = 2{,}143.5$ and $F_{1,19} = 71.4$; $p < 0.001$, $\eta^2 = 0.910$ and $\eta^2 = 0.790$, respectively) with no difference between the 2 conditions ($F_{1,19} = 0.4$ and $F_{1,19} = 0.6$, respectively; both $p > 0.525$) and no interaction between pre-to-post and condition (both $F_{1,19} = 0.6$; $p > 0.461$). Cortisol also increased from pre-to-post combat and SKCTP alike ($F_{1,19} = 137.7$; $p < 0.001$, $\eta^2 = 0.879$) with the combat producing higher post values than the SKCTP ($F_{1,19} = 5.0$; $p = 0.038$, $\eta^2 = 0.207$). Interaction effect revealed that pre-SKCTP concentration was lower than both post-SKCTP and post-combat, that precombat concentration was lower than both post-SKCTP and postcombat ($F_{1,19} = 5.9$; both $p < 0.001$), and post-SKCTP was lower than postcombat ($F_{1,19} = 5.9$; $p < 0.001$). Furthermore, the T:C did not differ pre-to-post combat ($F_{1,19} = 1.0$; $p = 0.330$) with no difference between the combat and SKCTP ($F_{1,19} = 3.4$; $p = 0.079$) and no interaction between pre-to-post and condition ($F_{1,19} = 0.2$; $p = 0.666$). Glucose and [La] increased significantly from pre-to-post combat and SKCTP alike ($F_{1,19} = 198.2$ and $F_{1,19} = 1{,}652.2$; both $p < 0.001$, $\eta^2 = 0.913$ and $\eta^2 = 0.989$, respectively); however, there was no difference between the SKCTP and combat for glucose ($F_{1,19} = 1.6$; $p = 0.218$) and for [La] ($F_{1,19} = 0.8$; $p = 0.393$). No interaction between pre-to-post and condition was found ($F_{1,19} = 0.8$ and $F_{1,19} = 0.2$; $p = 0.794$ and 0.702, respectively) (Table 1).

Heart rate and RPE increased pre-to-post combat and SKCTP alike ($F_{1,19} = 2{,}084.2$ and $F_{1,19} = 70.9$; all $p < 0.001$, $\eta^2 = 0.991$ and $\eta^2 = 0.789$, respectively) with no difference

Table 2. Heart rate and perceived exertion responses pre and post SKCTP and combat.*

	HR (b·min^{-1})		RPE	
	SKCTP	Combat	SKCTP	Combat
Before	85 ± 10	89 ± 8		
After round 1	184 ± 7†	183 ± 7†	7.6 ± 0.9	7.3 ± 1.0
After round 2	187 ± 7†	187 ± 8†	8.7 ± 0.8‡	8.3 ± 0.7‡
After round 3	190 ± 6†§	188 ± 8†§	9.3 ± 0.7‡‖	9.0 ± 0.7‡‖

*HR = heart rate; RPE = rating of perceived exertion; SKCTP = specific kickboxing circuit training protocol.
†Different from previous measurement ($p < 0.001$).
‡Different from round 1 ($p < 0.001$).
§Different from round 1 ($p = 0.005$).
‖Different from round 2 ($p < 0.001$).

Table 3. Upper-body and lower-body anaerobic performances pre and post SKCTP and combat.*

	SKCTP		Combat	
	Pre	Post	Pre	Post
CMJ (cm)	39.2 ± 4.8	35.4 ± 5.1†	39.3 ± 4.7	35.7 ± 5.0†
MP (W·kg^{-1})	3.7 ± 0.8	2.8 ± 0.9†‡	3.6 ± 0.9	1.9 ± 0.6†
PP (W·kg^{-1})	5.8 ± 1.3§	4.6 ± 1.4‖	5.6 ± 1.2	3.7 ± 1.0

*SKCTP = specific kickboxing circuit training protocol; CMJ = countermovement jump; MP = mean power; PP = peak power.
†Different from before ($p < 0.001$).
‡Different from postcombat ($p < 0.001$).
§Different from precombat ($p < 0.001$).
‖Different from postcombat ($p = 0.002$).

between combat and SKCTP for HR ($F_{1,19} = 0.02$; $p = 0.890$) and RPE ($F_{1,19} = 3.0$; $p = 0.098$), respectively. There was also no interaction between pre-to-post and condition found for HR ($F_{1,19} = 1.6$; $p = 0.196$) and RPE ($F_{1,19} = 0.2$; $p = 0.794$) (Table 2).

Anaerobic lower-body power performance decreased pre-to-post combat and SKCTP alike ($F_{1,19} = 132.1$; both $p < 0.001$, $\eta^2 = 0.874$) with no difference between the 2 conditions ($F_{1,19} = 2.2$; $p = 0.157$) and no interaction between pre-to-post and condition ($F_{1,19} = 0.1$; $p = 0.807$) (Table 3).

The Wingate test resulted in a decrease in peak power (PP) and mean power (MP) pre-to-post combat and SKCTP alike ($F_{1,19} = 143.8$ and $F_{1,19} = 143.2$; all $p < 0.001$, $\eta^2 = 0.883$ and $\eta^2 = 0.883$ for PP and MP, respectively) with values higher after the SKCTP compared with the combat ($F_{1,19} = 11.4$ and $F_{1,19} = 18.8$; both $p < 0.001$, $\eta^2 = 0.375$ and $\eta^2 = 0.498$, respectively). For PP, interaction revealed that SKCTP values were higher than combat values ($F_{1,19} = 9.6$; $p < 0.001$). Peak power was higher in the pre-SKCTP compared with both post-SKCTP and postcombat ($p < 0.001$), and values for post-SKCTP were higher than postcombat values ($p = 0.002$). For MP, interaction revealed higher values in the SKCTP compared with the combat condition ($F_{1,19} = 13.5$; $p < 0.001$). Moreover, pre-SKCTP values were higher compared with both post-SKCTP and postcombat ($p < 0.001$) and MP was higher in the post-SKCTP condition compared with postcombat condition ($p < 0.001$) (Table 3).

Discussion

This study shows that the SKCTP accurately replicates a typical combat for GH, testosterone, glucose, [La], body mass changes, HR, RPE, and CMJ.

Growth hormone in both conditions resulted in similar postexertion increases confirming that both conditions were a potent stimulator of GH secretion. Growth hormone has been previously reported to correlate with [La] (28); therefore, the same GH increase during SKCTP and combat was attributed to a similar [La] increase during both exercises. In this study, GH correlated with [La] ($r = 0.72$ and $r = 0.875$, both $p < 0.001$) for SKCTP and combat, respectively. Moreover, GH has been shown to be of great interest to exercise physiologists as it is a potent anabolic agent (28). The SKCTP, which showed the same GH response as combat, could be used to maximize the anabolic effect of the kickboxers "training regimen" (28).

Similarly, testosterone increased pre-to-post SKCTP and combat at the same rate. A positive relationship has been previously reported between testosterone and attacking movements in judo (25). The results of Salvador et al. (25) lead us to advance the idea that the attacking actions during the SKCTP could increase testosterone level similarly to competition. However, there is no consensus in the literature about the rate of testosterone release during combat sports performance, some studies have reported a decrease (16,23,29), whereas another (9) reported a precompetition increase suggested to be due to an anticipatory effect (29).

In this study, cortisol increased significantly pre-to-post for both conditions; however, post values were higher for combat. These results indicated an increase in stress before and during combat, which corroborates the hypothesis that a kickboxing combat can generate considerable acute stress and amplify the hormonal response by evoking greater sympathetic nerve activity (17). Moreover, it was shown that a noncombat kickboxing session (7 sets of 6 techniques, 20 seconds per technique completed as fast as possible with 1-minute rests in between) was also able to increase the cortisol level (10). The larger increase of cortisol in the combat compared with the SKCTP may be attributed to psychological factors as reported in taekwondo (6). Furthermore, the T:C ratio is an indicator of anabolic/catabolic balance. During this study, this ratio remained the same for both conditions and unchanged pre-to-post. Surprisingly, both conditions resulted in a low T:C ratio suggesting that both conditions had a catabolic effect, and similar low T:C ratio results were also found during wrestling competition (22).

Glucose increased postcondition and did not present difference between SKCTP and combat. A similar result was obtained for a noncontact kickboxing session (10). The increased glucose production may be indicative of enhanced cortisol activation of hepatic gluconeogenesis through enhanced substrate delivery to the liver ensuring a steady supply of glucose (12,13). Although the rate of cortisol release obtained in magnitude to the combats did not involve associated results for the combat's glucose, despite there being a difference but not significant in favor of the combat, further investigation is needed.

The [La] also increased postcondition at the same concentration for both conditions to $\sim$14 $mmol \cdot L^{-1}$, indicating high solicitation of anaerobic glycolysis (18). The rate of [La] accumulation was approximatively 2 $mmol \cdot L^{-1} \cdot min^{-1}$ showing that SKCTP and combat were both anaerobic in accordance with the classification of Buchheit and Laursen (5). This result is similar to values obtained in a previous study using simulated kickboxing competition ($\sim$14.9 $mmol \cdot L^{-1}$) (18). It was shown that an increase in [La] mediates the activation of the somatotropic axis and therefore can increase GH synthesis/release during exercise (15,24).

Likewise, an increase in HR from precondition to round 3 was the same for both conditions, confirming that the intensity of the SKCTP was able to stress the cardiovascular system to the extent of combat. Contrary to our investigation, Bridge et al. (4) reported that specific taekwondo exercise was not able to mimic the physiological and hormonal responses of the official combat.

The RPE results in this study showed that the kickboxers perceived the effort similarly for both conditions. The ability of the SKCTP to induce similar perception of intensity may be explained by its time structure, which mimics the cadence of international kickboxing competition (20). This demonstrates that the association of physical stress in a given exercise increases the hormonal and physiological responses but not necessarily the individual perceptions of effort (13).

The decrease in body mass postcondition can be attributed to loss of body water (26). To the best of our knowledge, there are no studies reporting the effect of combat or specific combat sports circuit on body mass, although others (7,30) investigated its change through longer durations (i.e., whole training session). The aforementioned increase in GH release during this study can be a factor that stimulates sweat secretion and therefore body water loss (14). Furthermore, as the percentage of water loss is much less than 3% body mass ($\sim$0.39 and 0.41% for SKCTP and combat, respectively), it is mainly derived from the extracellular space (26).

Anaerobic lower-body power as quantified by CMJ performance decreased similarly in the 2 conditions demonstrating that the powerful kicks to the punch bag were able to reduce the power of lower limbs to the same degree as observed in the combat. This decrease was also observed in another study using simulated competition, sighting the reason as a reduction in the shortening contraction velocity (18).

For upper limbs muscle power, there was a significant difference between performance (i.e., PP and MP), with values higher for post-SKCTP compared with postcombat. This result may be explained by the fact that during combat the different actions were executed with higher intensity compared with SKCTP. Besides, the performance decrease may be attributed to a high anaerobic solicitation of upper limbs inferred by the high level [La] obtained (18). However, the marked difference in baseline values for PP and MP in favor of SKCTP training condition is not clear.

This study is the first to verify if a specific kickboxing exercise can reproduce similar responses as competition. Results showed that GH, testosterone, glucose, [La], body mass, HR, RPE, and CMJ did not differ between SKCTP and combat. However, cortisol was higher after the combat condition and PP and MP were higher for SKCTP. Thus, SKCTP, a noncontact kickboxing exercise, was able to mimic the hormonal, physiological, and physical responses of kickboxing competition, although stress-related hormone response was lower and the decline in subsequent upper-body anaerobic performance was less affected by this protocol compared with the combat. The SKCTP should be able to be used as a tool for assessing specific fitness of kickboxers because it mimics the activity pattern with respect to techniques used in elite male competition. Further investigations are needed to test if this specific circuit can be reliable, and, if it has the ability to discriminate between different levels of kickboxers, this will further reinforce its usefulness.

Practical Applications

The SKCTP can be considered as a sport-specific exercise reproducing similar demands to kickboxing competition. For that reason, it can be used by trainers and strength and conditioning coaches as a training tool to prepare athletes to handle the physiological stress of the competition and as an effective and inexpensive tool that can be used by coaches and trainers for the determination of specific fitness levels of elite kickboxers, when physiological parameters responses to the test are measured. Furthermore, this circuit can be used as a type of training for kickboxers to enhance their physical performance by exposing them to an effort-pause ratio and technique execution close to that of international competitions.

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