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Psycho-physiological aspects of small combats in taekwondo: impact of area size and within-round sparring partners

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ABSTRACT: The study investigated physiological and psychological responses to taekwondo combat sessions as a function of different area sizes and within-round sparring partners. Twenty-four adolescent (age: 17 ± 1years) male (n = 12) and female (n = 12) taekwondo athletes participated in the study. Each athlete confronted 1 (1vs.1; no sparring partner change) or 2 (1vs.2; within-round sparring partner change every minute) opponents in different area sizes (i.e., 4 × 4 m, 6 × 6 m, and 8 × 8 m) for 2 min. Blood lactate concentration ([La]) was measured before and after bouts. Heart rate (HR) was measured throughout the contests and rating of perceived exertion was assessed after bouts. Mean HR (HRmean) and percentage of maximum HR (%HRmax) determined during a 20-m multistage shuttle run test were used for analysis. Mood states were assessed before and after bouts and physical enjoyment was analyzed after bouts. The results showed higher HRmean and %HRmax values for the 1vs.1 compared to the 1vs.2 condition ($p < 0.001$) and [La] values were higher at post-combat measurements ($p < 0.001$). Moreover, tension and fatigue were higher in 6 × 6 m compared with 8 × 8 m ($p = 0.022$ and $p = 0.023$, respectively) and anger was higher in 6 × 6 m and 8 × 8 m in comparison with 4 × 4 m ($p = 0.012$ and $p = 0.043$, respectively). Confusion increased from before to after bouts ($p < 0.001$), from 4 × 4 m and 6 × 6 m area sizes to 8 × 8 m ($p = 0.001$ and $p = 0.018$, respectively), and from 1vs.1 to 1vs.2 ($p < 0.001$). Furthermore, vigour decreased from before to after bouts ($p < 0.01$). Taekwondo combat sessions are a specific conditioning exercise for athletes. Thus, coaches can use the 1vs.1 condition to elicit higher HR responses and 6 × 6 m area size to induce higher psychological stress, mimicking what occurs during a competition.

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INTRODUCTION

To optimize performance of combat sports athletes, it is paramount to target specific training modalities that allow athletes to cope with the physical and physiological stress of competitions [1, 2]. Taekwondo is a striking Olympic combat sport that is spreading worldwide and a typical match is composed of three 2-min rounds with 1-min rest in between and performed in an 8 m × 8 m area size [3, 4]. To succeed in a competition, taekwondo athletes need to develop physical, physiological, and psychological responses as well as having technical and tactical excellence [3, 5]. Several studies in combat sports have tried to investigate the physiological responses and perceived exertion recorded during different training exercises, in taekwondo [6], kickboxing [1], and judo [2].

It has been reported that combat sports coaches, when performing technical-tactical sessions, often adjust the distance and/or opposition style (e.g., according to height, handedness, and attack system) between opponents during sparring exercises introducing one or more within-round sparring partners or modifying the effort/pause ratio [1, 2]. This strategy has been shown to be effective in varying physiological and perceptual responses during combat exercises [1, 2]. Ouergui et al. [1] reported that mean heart rate (HRmean) values and rating of perceived exertion (RPE) scores were lower when a kickboxer was confronted with a single opponent (1vs.1; no sparring partner change) compared with the other conditions (1vs.2 and 1vs.4; within-round sparring partner change every minute). However, blood lactate concentration ([La]) was similar between conditions. Recently, Ouergui et al. [2] showed that post-combat [La] values were higher after 4 × 4 m compared with 6 × 6 m and 8 × 8 m area size and that RPE scores were higher in 4 × 4 m compared to 8 × 8 m area size in female judo athletes.

Taking into consideration all performance aspects, psychological responses to exercise are determinant factors that have received particular attention from researchers in recent years. Moreover, psychological responses to exercise concern the education of young beginners as well as that of top-level athletes. In fact, mood, vigour, motivation, training adherence, and several other psychometric variables have been reported to be related to the degree of perceived physical pleasure [7]. Likewise, it was shown that, in twenty soccer players, perceived pleasure was associated with motivation during the training and the exercise modality. Yet, it was not related to physiological aspects of training, including training load, recovery quality, or fatigue accumulation [7].

Although the previously cited studies provide important practical suggestions to coaches and athletes, generalization of the results to all combat sports is not possible as there are important differences in the physiological and psychological responses between activities. Moreover, examining sport-specific exercises that could associate and optimize the physiological, physical, and psychological responses and at the same time the technical aspects of the competition may be of great importance for the athletes' development. To the current authors' knowledge, no study has investigated the physiological and psychological responses to specific taekwondo exercises when varying combat area sizes and within-round sparring partners. We sought to provide support for using variation of these exercises regularly utilized empirically by coaches and athletes in taekwondo. Taekwondo is a striking Olympic combat sport that is spreading worldwide and a typical match is composed of three 2-min rounds with 1-min rest in between and performed in an 8 m × 8 m area size [3].

For that reason, the objective of this study was to investigate the physiological (i.e., HR, [La]), perceptive (i.e., RPE), psychological (i.e., mood states), and physical enjoyment responses during a 2-min taekwondo combat according to area sizes (i.e., 4 × 4 m, 6 × 6 m, and 8 × 8 m) and within-round sparring partners (1vs.1 and 1vs.2). Based on the data of Ouergui et al. [1, 2], we hypothesized that physiological and psychological responses would increase when increasing the number of partners and reducing the area size of the competition.

MATERIALS AND METHODS

This study used a quasi-experimental approach where athletes served as their own controls. To examine the physiological and perceptive responses during taekwondo combats varying in within-round sparring partners and area sizes, athletes were submitted randomly to six experimental conditions organized on separated days and with a minimum interval of 48 h. Specifically, two within-round sparring partner conditions (1vs.1 and 1vs.2) and three area sizes (4 × 4 m, 6 × 6 m, and 8 × 8 m) were combined. This strategy was adopted to create situations that could modify the intensity of sparring sessions. Area sizes were chosen in attempt to simulate combat distances [2]. Moreover, the strategy of varying within-round sparring partners was

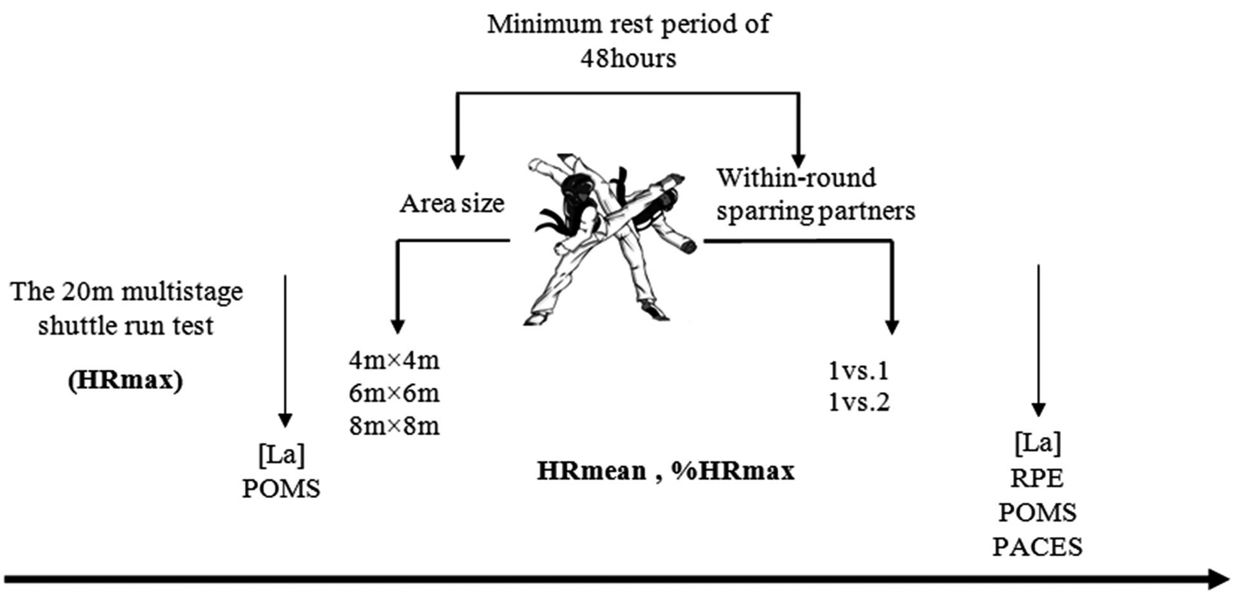

FIG. 1. Schematic representation of the study design. HRmean: mean heart rate; %HRmax: percentage of maximum heart rate; [La]: blood lactate concentration; POMS: profile of mood state; RPE: rating of perceived exertion; PACES: physical activity enjoyment scale.

adopted from the literature, where each athlete was confronted by 1 (1vs.1; no sparring partner change) or 2 partners (1vs.2; within-round sparring partner change every minute [1]). During all experimental conditions, HR, ([La]), RPE, mood states, and enjoyment were recorded. A schematic representation of the study design is presented in Figure 1.

Using the software G*Power with α and power fixed at 0.05 and 0.95 and the effect size fixed at 0.35, based on the study of Ouergui et al. [1], the sample size was calculated *a priori*. The required sample size was fifteen. Twenty-four male (n = 12) and female (n = 12) taekwondo athletes volunteered to participated in the study (mean ± SD: age: 17 ± 1 years; height: 1.70 ± 0.08 m; body mass: 63.1 ± 7.4 kg; BMI: 21.8 ± 1.7 kg/m^2; and taekwondo experience: 7 ± 1 years). They have regularly participated in taekwondo competitions for more than 2 years and trained 3 days a week (2 h per session). Participants did not present any medical restrictions or acute or chronic injuries and were not in the process of decreasing body mass during the whole experimentation period and were asked to refrain from any strenuous effort 24 h before conducting the sparring sessions. The study was conducted according to the Declaration of Helsinki for human experimentation [8] and the protocol was fully approved by the local research ethics committee before the start of the study. All athletes, their parents, and their coaches gave written informed consent after a detailed explanation about the aims, benefits, and potential risks involved in the investigation.

One week before the beginning of the experimentation, athletes were familiarized with tests, questionnaires, and session order and all sessions were conducted at the same time of day to avoid any diurnal variation of the performance [9]. The study was conducted in the pre-season period and outside of the menstruation period for female athletes to avoid any uncomfortable feeling and to guarantee a maximal effort by athletes during the experimental sessions. Before the beginning of the experimental sessions, athletes performed the 20 multistage shuttle run test [10] to determine the maximum HR (HRmax = the highest HR value achieved during the test). Experimental conditions were determined randomly and were completed in three weeks with an interval of 48 h between successive conditions and no more than 72 h [2]. Physiological measurements (i.e., HR, [La]), RPE, mood states, and physical enjoyment were determined for all combat sessions. All sparring sessions were directed by two investigators and a central referee ensuring athletes' safety, and the same verbal encouragements were addressed to all athletes to perform as over an official combat. Before each sparring condition, 15 min of standardized warm-up was performed, consisting of jogging, dynamic stretching, and taekwondo techniques, after which 3 min of passive rest was taken and baseline measures were conducted.

Blood lactate concentration was measured using the Lactate Pro2 Analyzer (Arkray, Tokyo, Japan) at pre- and post-match time points. Heart rate was measured every 5 s throughout the taekwondo combat sessions (Polar Team2 Pro System; Polar Electro OY, Kempele, Finland) and HRmean and percentage of HRmax (%HRmax) were used for the analysis. After familiarizing themselves with the scale, athletes were asked to report their RPE scores (RPE, Borg's CR-10 scale [11]) 15–30 min after each sparring session.

Mood states were measured before and after the combat sessions using the Profile of Mood State (POMS) questionnaire, which contains 65 items and includes 6 subscales: confusion-bewilderment, depression-dejection, anger-hostility, tension-anxiety, fatigue-inertia, and vigour-activity. The six POMS subscales can be combined into a Total Mood Disturbance (TMD) score calculated as follows: TMD = [(anger+confusion+depression+ fatigue+tension)–vigour)+100] [12].

Five minutes after each sparring sessions, the Physical Activity Enjoyment Scale (PACES [13]) was used to assess enjoyment. Athletes were asked: "How do you feel at the moment about the physical activity you have been doing?". The inventory contains 8 items rated with a 7-point score ranging from 1 to 7. This scale has 11 negative items and 7 positive items. Negative items are reverse scored. For each participant, total responses were summed to give a score ranging from 18 to 126. Higher PACES scores reflect greater levels of enjoyment.

Data were presented as mean and SD. The statistical analysis was performed using SPSS 20.0 statistical software (IBM, Armonk, NY, USA). The normality of data sets was checked and confirmed using the Kolmogorov-Smirnov test. Sphericity was tested and confirmed using the Mauchly test. Data were analyzed using a three-way analysis of variance (area size [4 × 4 m, 6 × 6 m, and 8 × 8 m], sparring partners [1vs.1 and 1vs.2], and time [pre- and post-]) with repeated measurements to compare mood states and [La]. Moreover, a two-way analysis of variance (area size [4 × 4 m, 6 × 6 m, and 8 × 8 m], sparring partners [1vs.1 and 1vs.2]) with repeated measurements was performed to compare HRmean, %HRmax, RPE, and physical enjoyment. The Bonferroni test was used as a *post-hoc* test. Due to the substantial amount of results, only significant results were reported. Standardized effect size (Cohen's d) analysis was used to interpret the magnitude of differences between variables and classified according to Hopkins [14]: < 0.20 (*trivial*); 0.20–0.60 (*small*); 0.60–1.20 (*moderate*); 1.20–2.0 (*large*); 2.0–4.0 (*very large*); and > 4.0 (*extremely large*). Moreover, upper and lower 95% confidence intervals of the difference (95% CI_ds) were calculated for corresponding variation. The statistical significance level was set at $p < 0.05$.

RESULTS

The mean value of HRmax recorded during the multistage 20-m shuttle run test was 202 ± 8 b·min^{-1}. Table 1 presents HRmean, %HRmax, RPE, and [La] values recorded for different taekwondo sparring sessions.

For HRmean, there was an effect of number of within-round sparring partners ($F_{1,138} = 21.013$; $p < 0.001$) with higher HRmean values for 1vs.1 compared with 1vs.2 condition (95%CI_d = 7,16; d = 0.8 [*moderate*]; $p < 0.001$). In addition, for %HRmax values, an effect of number of within-round sparring partners was found ($F_{1,138}$ = 18.975; p < 0.001), with 1vs.1-inducing higher values compared with 1vs.2 (95%CI_d = 3,8; d = 0.67 [*moderate*]; p < 0.001).

For [La], an effect of time point was recorded ($F_{1,276}$ = 1556.656; p < 0.01) with higher values recorded at the post-combat time in comparison with the pre-combat time (95%CI_d = -9.83,-8.8; d = -4.5 [*nearly perfect*]; p < 0.001).

Table 2 presents the POMS and physical enjoyment values measured for different taekwondo sparring sessions. For tension scores, an effect of area size was observed ($F_{2,276}$ = 3.822; p = 0.027) with 6 × 6 m inducing higher values compared with 8 × 8 m

TABLE 1. Physiological and rating of perceived exertion responses during different taekwondo combat sessions (values are means ± SD; n = 24).

	[La]-pre (mmol·l^{-1})	[La]-post (mmol·l^{-1})	HRmean (b·min^{-1})	HR (%HRmax)	RPE (u.a.)
			1 vs. 1		
4x4m	2.9 ± 0.8	13.8 ± 2.8*	164 ± 7*	81 ± 5*	6 ± 1
6x6m	3.0 ± 0.5	13.4 ± 2.6*	171 ± 7*	84 ± 4*	7 ± 2
8x8m	2.8 ± 0.7	13.3 ± 3.6*	167 ± 14*	82 ± 6*	6 ± 1
			1 vs. 2		
4x4m	3.1 ± 0.7	14.5 ± 3.8*	155 ± 17	77 ± 10	6 ± 1
6x6m	3.2 ± 0.8	13.7 ± 3.1*	153 ± 27	75 ± 12	6 ± 1
8x8m	2.9 ± 0.5	11.4 ± 2.8*	156 ± 19	77 ± 11	7 ± 1

Note: * different at p < 0.001; [La]: blood lactate concentration; HRmean: mean heart rate; %HRmax: percentage of *maximum* heart rate; a.u: arbitrary unit.

TABLE 2. Mood state and physical enjoyment values during different taekwondo combat sessions (values are mean ± SD; n = 24).

		1vs.1			**1vs.2**		
		4x4m	**6x6m**	**8x8m**	**4x4m**	**6x6m**	**8x8m**
Tension (a.u.)	**Pre**	8 ± 7	11 ± 7*	9 ± 6	8 ± 6	6 ± 4*	7 ± 5
	Post	10 ± 7	12 ± 8*	7 ± 6	9 ± 7	6 ± 5*	8 ± 6
Anger (a.u.)	**Pre**	8 ± 8	13 ± 9§	10 ± 8+	9 ± 7	10 ± 8§	10 ± 7+
	Post	8 ± 7	14 ± 9§	10 ± 7+	9 ± 6	10 ± 7§	10 ± 6+
Confusion (a.u.)	**Pre**	4 ± 4[b,d]	6 ± 5[c,d]	3 ± 3[d]	3 ± 3[b]	3 ± 3[c]	3 ± 3
	Post	5 ± 4[a,d]	6 ± 6[a,d]	4 ± 3[a,d]	4 ± 3	4 ± 2[a]	4 ± 3[a]
Depression (a.u.)	**Pre**	11 ± 10	14 ± 8	12 ± 11	12 ± 8	10 ± 7	13 ± 9
	Post	12 ± 10	14 ± 9	12 ± 10	13 ± 8	11 ± 7	13 ± 8
Fatigue (a.u.)	**Pre**	4 ± 4	6 ± 4[e,f]	4 ± 3	4 ± 3	4 ± 4[e]	4 ± 3
	Post	5 ± 4	7 ± 4[e,f]	3 ± 2	5 ± 4	5 ± 3[e]	5 ± 3
Vigour (a.u.)	**Pre**	19 ± 5[g]	17 ± 5[g]	19 ± 5[g]	17 ± 5[g]	18 ± 6[g]	17 ± 6[g]
	Post	16 ± 5	17 ± 6	17 ± 6	17 ± 6	17 ± 6	16 ± 5
TMD (a.u.)	**Pre**	116 ± 34	133 ± 33[h]	118 ± 38	119 ± 29	116 ± 28	120 ± 27
	Post	123 ± 34	136 ± 35[h]	119 ± 31	123 ± 31	119 ± 27	125 ± 28
PACES (a.u.)	**Post**	78 ± 11	84 ± 11	79 ± 8	80 ± 8	73 ± 9	77 ± 11

Note: * different from 8 × 8m (p = 0.022); § different from 4 × 4m (p = 0.012); + different from 4 × 4m (p = 0.043); [a] different from pre-combats values (p < 0.001); [b] different from 8 × 8m (p = 0.001); [c] different from 8 × 8m (p = 0.018); [d] different from 1vs.2 (p < 0.001); [e] different from 8 × 8m (p = 0.023); [f] different from 1vs.1 in 8 × 8m (p < 0.001), [g] different from post-values (p < 0.01); [h] different from 1vs.1 in 8 × 8m (p = 0.030). a.u.: arbitrary unit; TMD: total mood disturbance; PACES: physical activity enjoyment scale.

($95\%CI_d$ = -0.8,2.7; d = 0.16 [*trivial*]; p = 0.022). For anger, an area size effect was observed ($F_{2,276}$ = 4.911; p = 0.008), with 6 × 6 m- and 8 × 8 m inducing higher values compared with 4 × 4 m ($95\%CI_d$ = 1.5,5.8 and 0.2,3.8; d = 0.47 and 0.3 [*small*]; p = 0.012 and 0.043, respectively). Moreover, confusion differed across time points ($F_{1,276}$ = 14.246; p < 0.001), with values increasing from before to after sparring sessions ($95\%CI_d$ = -1.6,-0.2; d = -0.2 [*trivial*]; p < 0.001). Also, an area size effect was found ($F_{2,276}$ = 7.274; p = 0.001), with 4 × 4 m- and 6 × 6 m inducing higher values compared with 8 × 8 m (95% CI_d = 0.5,1.4 and 0.4,2.5; d = 0.1 and 0.4 [*trivial* and *small*]; p = 0.001 and p = 0.018, respectively). Similarly, an effect of number of within-round sparring partners was observed ($F_{1,276}$ = 18.925; p < 0.001), with 1vs.1 inducing higher values compared with 1vs.2 ($95\%CI_d$ = -0.4,2.1; d = 0.3 [*small*]; p < 0.001). Moreover, an interaction effect between time point and area size was found ($F_{2,276}$ = 6.181; p = 0.002), with confusion increasing for 4 × 4 m from before to after training ($95\%CI_d$ = -2.3,0.7; d = 0.22 [*moderate*]; p < 0.001). An interaction effect was observed between area size and number of within-round sparring partners ($F_{2,276}$ = 7.434; p = 0.001), with 1vs.1 in 4 × 4 m- and 6 × 6 m inducing higher values compared with 8 × 8 m ($95\%CI_d$ = 0.5,2.4 and 1.2,4.7; d = 0.3 and 0.7 [*moderate*], respectively; p < 0.001 for both comparisons). Similarly, an interaction effect between time point, area size, and number of within-round sparring partners was found ($F_{2,276}$ = 6,642; p = 0.002) with higher post-combat values in 1vs.1 compared with 1vs.2 in 4 × 4 m ($95\%CI_d$ = 1.9,2.6; d = 0.1 [*trivial*]; p < 0.001). Likewise, fatigue was different across area sizes ($F_{2,276}$ = 3.611; p = 0.028), with 6 × 6 m inducing higher values compared with 8 × 8 m ($95\%CI_d$ = 0.3,3.7; d = 0.5 [*small*]; p = 0.023). An interaction effect between area size and within-round sparring partners was found ($F_{2,276}$ = 4.492; p = 0.012), with 1vs.1 for 6 × 6 m area size inducing higher values compared with 8 × 8 m ($95\%CI_d$ = 0.8,3.8; d = 0.63 [*moderate*]; p < 0.001). Furthermore, vigour varied across time points ($F_{1,276}$ = 3,773; p = 0.05), with values decreasing from before to after sparring sessions ($95\%CI_d$ = 0.02,2.5; d = 0.23 [*moderate*]; p < 0.01). For TMD, an interaction effect between area size and number of within-round sparring partners was found ($F_{2,276}$ = 4.826; p = 0.009), with 1vs.1 in 6 × 6 m presenting higher values compared with 8 × 8 m area size ($95\%CI_d$ = 3.0,29.3; d = 0.5 [*small*]; p = 0.030).

DISCUSSION

The present study showed higher HRmean and %HRmax values for 1vs.1 compared with 1vs.2 condition and higher [La] values at post-combat measurement in comparison with pre-combat measurement. For POMS variables, tension and fatigue were higher for 6 × 6 m compared with 8 × 8 m and anger was higher in 6 × 6 m and 8 × 8 m compared with 4 × 4 m. Moreover, confusion increased from before to after sparring sessions, 4 × 4 m and 6 × 6 m area sizes induced higher values compared with 8 × 8 m and 1vs.1 induced higher values compared with 1vs.2. Furthermore, vigour decreased from before to after combat sessions. In contrast, RPE, depression, TMD, and physical enjoyment did not vary over different experimental conditions.

Our results showed that HRmean during combat sessions ranged from 153 to 171 $b\cdot min^{-1}$. These values are in agreement with those reported in previous studies for taekwondo combats and specific exercises [5, 15, 16] and were slightly lower than those recorded in international taekwondo combats [17]. Moreover, intensities expressed as %HRmax recorded during different experimental conditions varied from 75 to 84 %HRmax, indicating that they were within the intensity range (i.e., 64–95 %HRmax) able to improve cardiovascular and respiratory fitness [18]. Similarly, Bridge et al. [6] showed that the different taekwondo exercises induced HR values ranging from 64.7 to 81.4 %HRmax and that sparring exercises and combats induced higher HR values (i.e., 80.8 and 81.4 %HRmax, respectively). Therefore, it is suggested that combat-based exercises are the most suitable exercise modality to develop cardiovascular fitness during specific taekwondo conditioning.

However, our study showed that HRmean and %HRmax did not vary according to the area size. This result is in agreement with previous studies in kickboxing [1] and female judo combats [2] that reported that the area size variation was not an effective strategy for varying HRmean. However, Ouergui et al. [1] showed that 4 × 4 m area size elicited a higher percentage of HRpeak when compared with 2 × 2 m and 6 × 6 m area sizes. The absence of difference in HRmean between area sizes in taekwondo sparring sessions could be explained by the specific nature of this sport. Indeed, whereas in other combat sports (e.g., judo and kickboxing) athletes are observed to use displacement over extended trajectories altering cardiovascular responses, taekwondo athletes generally, during preparatory and non-preparatory combat phases, use foot movements (e.g., standing, bouncing, stepping) that are classified as small range movements [19].

When reported in terms of within-round sparring partners, HRmean and %HRmax were higher in 1vs.1 compared with 1vs.2, in contrast to the study of Ouergui et al. [1], which showed that lower HRmean values were recorded in the 1vs.1 condition compared with other conditions (i.e., 1vs.2 and 1vs.4). This difference may be attributed to the nature of these different striking combat sports. Indeed, whereas taekwondo athletes adopt a combat strategy based on spending a longer time in preparatory and non-preparatory actions [20], changing sparring partners may result in much more time spent in combat phases, inducing lower effort/pause ratios. In other sports (i.e., kickboxing and judo), athletes generally spend more time in offensive and defensive actions during fighting activities. Thus, changing sparring partners will result in practically equal time for effort and pause in kickboxing or a little longer for judo, altering the HR responses.

Despite the importance of using specific exercises to reach intensities able to match those recorded during combats, the use of combat-based exercises remains – in reproducing the combat nature (i.e., acyclic activity) – more efficient than repeated technical exercises, which are more cyclical in nature [21].

[La] values were higher in post-combat compared to pre-combat measurement. [La] recorded during the different combats ranged from 11.44 ± 2.78 to 14.55 ± 3.84 $mmol \cdot l^{-1}$. These values were similar to those reported in other studies [15–17, 22]. However, [La] values were higher than those recorded in other studies [23–25]. The significant increase in [La] values over 2-min taekwondo sparring bouts, which is equivalent to the first round in an official match, results in moderate activation of the glycolytic system. Indeed, Campos et al. [26] demonstrated that the first round results in lower peak [La] compared with the two subsequent rounds. However, as the glycolytic contribution is estimated based on the post-pre [La], the first round is the one with higher glycolytic absolute and relative contribution to the total energy expenditure [25]. [La] did not vary across different conditions, showing that these situations can be used to develop similarly the anaerobic glycolysis for taekwondo athletes [1]. Our results are in agreement with those reported by Ouergui et al. [1], which showed that [La] did not change during kickboxing sparring sessions according to ring size and within-round sparring partners. However, Ouergui et al. [2] reported that a 4 × 4 m space induced higher [La] compared with 6 × 6 m and 8 × 8 m area sizes during female judo combats [2], where shorter distances likely induced more grip disputes. In contrast, in taekwondo the area size probably did not affect the number of attacks, resulting in a similar glycolytic activation.

For RPE scores, values recorded under different conditions were approximately perceived as "difficult". Bridge et al. [15] reported that RPE scores during a taekwondo competition, using the 6–20 Borg scale, varied from "easy" to "a little difficult". This small difference can be attributed to the type of competition (simulated vs. official), the athletes' ability level (amateur vs. international athletes) and the sparring bout duration (2 min vs. 3 × 2-min with 1 min of rest) despite the similarity for HR and [La] values recorded in the two studies (i.e., the present and Bridge et al. [15] study).

Regarding the area size effect, similarly to our study, Ouergui et al. (1) found that RPE during kickboxing sparring sessions did not vary across area sizes. However, Ouergui et al. [2] reported that RPE scores were higher in the 4 × 4 m compared to 8 × 8 m area size during female judo combats. In addition, whereas within-round sparring partners variation did not induce a change of RPE scores, Ouergui et al. [1] observed that RPE scores were lower in the 1vs.1 condition compared to the other conditions (1vs.2 and 1vs.4) in kickboxing combat bouts. Despite the similarity in terms of sparring session duration used in these studies, the difference between these sports can be attributed to effort/pause ratio variation [2].

Concerning the mood states, POMS scores before sparring sessions were similar/close to those reported by other studies in combat sports [5, 26], which resembled the desired "iceberg" pattern [27] featured by lower values of negative indices (i.e., tension, anger, depression, fatigue, and confusion) and high values for vigour, which is in line with the desired mood profile before the competition to promote success for athletes [5].

However, different POMS scores did not change from before to after combat sessions except for confusion, which increased after combat, and vigour, which decreased. This result is in agreement with the results reported by Chiodo et al. [5], who reported an increase in anger and depression and a decrease in vigour after a taekwondo competition in young athletes.

Indeed, the absence of beneficial effects of different combat sessions on mood states of athletes can be explained by an effect of combat duration and intensity, the as 1vs.1 condition, where negative signs of POMS (i.e., anger, confusion, tension, and fatigue) are recorded, was the condition that induced higher intensities. Sure enough, it has been reported that the effect of an exercise on the athlete's mood may be related to the duration and intensity of the exercise. Despite the absence of a minimum duration required to affect mood, studies have shown that 10-min to 1-h exercise duration has been effective in improving mood [28–30]. Likewise, despite the absence of consensus about the effect of exercise intensity on mood, it was reported that low-intensity exercises (i.e., 25 W) produced a small mood improvement. In contrast, high-intensity exercise (i.e., 100 W) increased negative moods [31, 32]. Campos et al. [25] reported that the first round of a simulated taekwondo bout resulted in a metabolic power of 1.24 ± 0.14 kW. Likewise, Chiodo et al. [5] reported that taekwondo competition qualifies as high-intensity activity and there may be a strong association between high-intensity exercise and decreased vigour. Thus, the short duration (i.e., 2 min) of combat sessions and intensities ranging between 75 and 84% HRmax may have been the cause of the vigour decrease associated with the absence of improvement in negative mood.

Furthermore, another possible explanation of the lack of improvement in mood states may be the absence of motivational factors during combat sessions. Indeed, in the present study, it was reported that physical enjoyment did not vary over within-round sparring partners variation and area size. This result showed that these variations were not effective in providing more motivation and did not bring a feeling of physical enjoyment, which can positively affect the mood of athletes. Conversely, it was found that tension, anger, fatigue, and confusion were higher in the 6 × 6 m area size and that the 1vs.1 condition for the 6 × 6 m space presented higher values for TMD score compared with the 8 × 8 m area size. These results can be explained by the fact that these situations are those which induced higher intensities, confirming that intense exercise is the cause of the increased negative mood signs and the vigour decrease [5]. Moreover, it can be concluded that there was possibly a dissociation between intensity and mood. In fact, whereas sparring situations induced similar intensities (i.e., similar %HRmax values), the mood state of athletes was significantly changed, confirming therefore that, despite different physiological responses, the athletes perceived the combat simulation differently [33–35].

Finally, the physical enjoyment did not change over the different experimental conditions, showing that these variables (i.e., area size and number of within-round sparring partners variations) were not effective in providing intrinsic motivation and satisfaction and therefore did not bring positive feeling and enjoyment [13].

We acknowledge some limitations in this study. Specifically, there is a lack of information about the time-motion and technical variables, which would be relevant to explain the physiological and psychological responses during all taekwondo combat conditions. Time-motion analysis would have allowed us to feature physical activity variables strictly related with corresponding metabolic demand. Moreover, the study did not use high-level taekwondo athletes. Thus, further studies with higher level athletes are highly recommended. Only 2-min bouts were used, whereas the official match is composed of 3 × 2-min rounds and this may affect differently the variables investigated in the present study. Finally, the use of combat simulations, where there may be a lack of competitive challenge, did not allow us to investigate extensively the studied variables.

CONCLUSIONS

The present study showed that HRmean and %HRmax values were higher for the 1vs.1 compared with 1vs.2 condition and [La] values were higher at post-combat measurement in comparison to pre-combat measurement. For POMS variables, tension and fatigue were higher for 6 × 6 m compared with 8 × 8 m and anger was higher in 6 × 6 m and 8 × 8 m compared with 4 × 4 m. Moreover, confusion increased from before to after sparring sessions, the 4 × 4 m and 6 × 6 m area sizes induced higher values compared with 8 × 8 m, and the 1vs.1 condition induced higher values compared with 1vs.2. Furthermore, vigour decreased from pre-combat to post-combat evaluation. In contrast, RPE, depression, TMD, and physical enjoyment did not vary over different experimental conditions. The results of this study can provide theoretical support of great importance for taekwondo coaches and physical conditioning coaches by allowing them to structure their training combining both physiological and psychological as well as the technical-tactical aspects of taekwondo combats. Coaches could implement that by establishing a progression in terms of training intensities based on those recorded here in the different combinations obtained by manipulating area size and number of within-round sparring partners. It was suggested that 1vs.1 induced higher intensity and that 6 × 6 m area size caused mood disturbance similar to those recorded during taekwondo competition, which suggests using these sessions not only for the physical preparation of athletes but also to create psychological stress similar to that occurring during a competition.

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Conflict of interest

The authors declare that they do not have any conflict of interest.

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