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Research article

Maximal and Submaximal Cardiorespiratory Responses to a Novel Graded Karate Test

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Abstract

The present study aimed to propose and assess the physiological responses of a novel graded karate test. Ten male national-level karate athletes (age 26 ± 5 yrs; body mass 69.5 ± 11.6 kg; height 1.70 ± 0.09 m) performed two exercise tests (separated by 2-7 days): 1) a running-based cardiopulmonary exercise test; 2) a graded karate test. The cardiopulmonary exercise test was comprised of an individualized ramp protocol for treadmill running, and the graded karate test was comprised of a sequence of 'kisami-gyaku-zuki" punching at a fixed frequency of a stationary target that becomes progressively distant. Cardiorespiratory responses, blood lactate concentration, and perceived exertion were measured. A verification phase was also performed in both tests to confirm the maximal physiological outcomes. The graded karate test evoked similar maximal responses to the running protocol: $\dot{V}O_2$ (57.4 ± 5.1 vs 58.3 ± 3.5 mL·kg^{-1}·min^{-1}; p = 0.53), heart rate (192 ± 6 vs 193 ± 10]beats.min^{-1}; p = 0.62) and blood lactate (14.6 ± 3.4 vs 13.1 ± 3.0 mmol·L^{-1}; p = 0.14) with a shorter duration (351 ± 71 vs 640 ± 9 s; p < 0.001). Additionally, the graded karate test evoked higher $\dot{V}O_2$ (72.6 ± 6.5 vs 64.4 ± 4.3 %$\dot{V}O_{2MAX}$; p = 0.005) and heart rate (89.4 ± 4.6 vs 77.3 ± 7.2 %HR_{MAX} p < 0.001) at the ventilatory threshold and a higher heart rate (97.0 ± 2.4 vs 92.9 ± 2.2 %HR_{MAX}; p = 0.02) at the respiratory compensation point. Incremental and verification phases evoked similar responses in $\dot{V}O_2$ and minute-ventilation during both tests. This novel displacement-based sport-specific test evoked similar maximal and higher submaximal responses, indicating a superior pathway to assess karate athletes.

Key words: Oxygen uptake, ventilatory thresholds, heart rate, blood lactate, martial arts.

Introduction

Kumite, the karate sparring discipline, is comprised of high-intensity intermittent bouts of activity, lasting up to 3 min with moves that vary between <1 to 5s (approx. 84% of moves are less than 2s), with an action/rest ratio typically near 1:1.5, and high-intensity/rest ratio that is 1:10 (Chaabène et al., 2014). Additionally, 76% of the attacks are comprised of upper limb techniques, with the *kisami-zuki* (jab) being the most frequent punch performed (Chaabène et al., 2014). Current literature suggests that elite karatekas present a moderate-to-high level of cardiorespiratory fitness, with a maximal oxygen uptake ($\dot{V}O_2$) ranging between ~33 and 43 mL·kg^{-1}·min^{-1} for female athletes, and between ~48 and 61 mL·kg^{-1}·min^{-1} for male athletes (Chaabène et al., 2012a). The *kumite* may evoke a heart rate (HR) of approximately 90% of the maximal HR, across 65% of the duration of combat, and a capillary blood lactate response of ~11 mmol·l^{-1} (Chaabène et al., 2015). The aerobic metabolic pathway is responsible for contributing 78% of the total estimated energy demands of a *kumite* round, followed by 16% and 6% for lactic and phosphagen systems, respectively (Beneke et al., 2004).

Classical running or cycling testing modes may not properly assess the physiological profile of high-intensity intermittent disciplines such as racket (Girard et al., 2005, 2006) and combat sports (Hausen et al., 2018), which require repetitive and explosive technique executions. Thus, specific incremental testing for these disciplines evokes different physiological responses from cyclic testing modes (Girard et al., 2005, 2006; Hausen et al., 2018), enhancing the ecological validity of determining training zones. Emerging research has focused on cardiorespiratory fitness for combat sports (Chaabène et al., 2018). Due to its intermittent nature, striking combat sports require the ability to recover from high intensity interval activity during technical training sessions, sparring drills, or competition bouts. Additionally, enhanced recovery is necessary to sustain multiple matches on the same day while maintaining optimum technical and tactical standards to succeed across tournaments. Moreover, specific tests have been proposed to assess karateka's cardiorespiratory fitness in a more ecologically valid setting suitable to determine athletes' maximal physiological responses, with good reliability and accuracy (Chaabène et al., 2012b; Tabben et al., 2014).

However, none of these protocols provide submaximal variables such as aerobic/anaerobic transition thresholds and all lack a verification phase to validate the maximal values attained during the incremental test. These are essential to planning specific conditioning sessions and periodization. The verification phase is an important methodological improvement that is characterized by a subsequent sub- or supramaximal short effort bout after few minutes of recovery (Schaun, 2017). It aims to ensure valid attainment of maximal responses within the testing session, and is more assertive than the use of the "one-fits-all" maximal criteria such as the plateau identification or secondary criteria (Schaun, 2017). Nevertheless, this option is still scarce in karate or combat specific cardiorespiratory testing proposals.

Moreover, increments of currently available tests are anchored on striking frequency increasing rather than distance across the stages. Since *kumite* is a point-based combat, propelling the body as fast as possible through space seems to be a determinant ability (Chaabène et al.,

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2012a) to score first or avoid a more successful counter-attack. Furthermore, the lack of striking impact control impairs proper power increments across more intense stages, with a decrease in power to compensate for the increased frequency of strikes, which may hinder the maximal outcomes of the specific test (Hausen et al., 2018). Therefore, a protocol based on the distance increment seems to be an interesting alternative to assess athletes' fitness with ecological validity and practical applicability. The present study aimed to propose a novel displacement-based sport-specific test to assess karate athletes.

Methods

Participants

Ten male karate athletes (mean [standard deviation] - age: 26 ± 5 years, body mass: 69.5 ± 11.6 kg, height: 1.70 ± 0.09 m, and karate experience: 12 ± 7 years) visited the laboratory on two occasions, with varying intervals of 2 to 7 days. Participants were first Dan or first Kyu holders (Black or Brown belt), engaged in a competitive training regimen and participants of official tournaments administered by the Brazilian Karate Confederation (an affiliate of the World Karate Federation), included by convenience. The training regimen comprised 12 ± 2 hours of training per week, with on average 10h dedicated to karate-specific training and about 2 h of strength and conditioning sessions. Participants were assessed in the competitive phase of the season. The Research Ethics Committee of the city of Rio de Janeiro approved this research study under registration number 96949518.1.0000.5279. Before the experiment, all participants were informed about the experiment's details and risks, and signed an informed consent document.

Testing procedures

An experiment was performed with two randomized counterbalanced visits, both scheduled at the same time in the morning, to perform either the criterion method (treadmill running cardiopulmonary exercise ramp test [CPET]) or a new testing method (graded karate test [GKT]). Cardiorespiratory, blood lactate, and perceptual responses were measured during both tests.

Regarding nutritional recommendations, participants were instructed to a) replicate their dietary intake in the eve of both testing days, b) avoid any food or beverage intake two hours before testing, and c) avoid any caffeine ingestion on testing days. None of the participants regularly used any ergogenic substances. Before completing the tests, 5-min of rest in a standing position was observed. All verbal encouragement statements were previously planned and standardized, conducted by a single experimenter, and hidden from the participants' view (Midgley et al., 2017). From the third minute, positive feedback such as "Well done" or "Very Good," was provided during the last ten seconds of each stage after the rating of perceived exertion (RPE) collection. Additionally, at every half stage, instructional and motivational feedback was provided.

The CPET on the Pulsar treadmill (h/p/cosmos, Nussdorf-Traunstein, Germany), was programmed to last 10 min with an individualized ramp increment (Da Silva et al., 2012) and the treadmill grade fixed at 1% (Jones and Doust, 1996). The individualized ramp increment was programmed with the non-exercise estimated maximal $\dot{V}O_2$ obtained by a questionnaire (Matthews et al., 1999), and inserted in the ACSM metabolic equation of running (Glass and Dwyer, 2007), as proposed by Da Silva et al. (2012). However, when participants completed 10 min, the increase in speed continued until participants' volitional fatigue which was defined as holding the sidebars and stepping off of the treadmill belt.

The graded karate test consisted of successive attacks delivered upon a stationary target. The attacking sequence was comprised of a) a forwarding slide step, b) followed by a kizami-gyaku-zuki (karate-specific sequence of a jab and a straight punch) delivered to the target, and c) a backward slide step to the starting mark (Figure 1 and Figure 2). The attack was performed on the same side stance, which was determined by athlete's preference, from an initial distance of 0.67 m. The distance to the target was increased every 1-min by increments of 0.33 m. The frequency of the attacking sequence was fixed at 15 attacks per min, providing a four-second interval for the forward displacement, attack completion, backward displacement, and active recovery with typical kumite bouncing and feints. A standardized sound signal guided the attack sequences. An audio file previously produced with beeps for warmup and testing and was played on through the speakers of a Windows PC. The test finished when the participant demonstrated volitional fatigue by either leaving the attack runway or failing to complete the attack sequence twice within 4s.

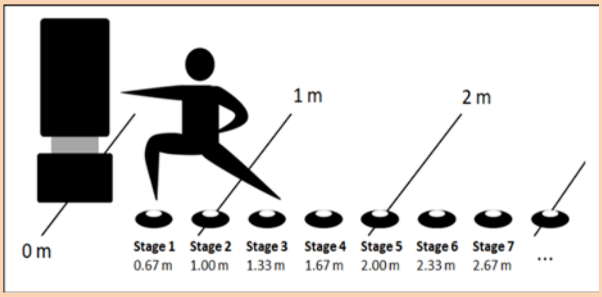

Figure 1. Schematic diagram of the Graded Karate Test.

Figure 2. Participant performing the Graded Karate Test with the portable gas analyzer.

After completion of both tests, participants underwent 10 minutes of recovery, in the supine position, followed by a verification phase. The CPET verification phase was performed in a square-wave bout at 105% of maximal speed from the incremental phase (Schaun, 2017), until the participant's volitional fatigue. The GKT verification phase was performed in a stage above the last completed stage of the incremental phase until the participant's volitional fatigue. A 1-min warmup was performed prior to the verification phase with three sub-stages of 20 s. For the CPET, sub-stages consisted of three equidistant speeds of 50, 66.7, and 83.3% of non-exercise-estimated $\dot{V}O_{2MAX}$ speed. For the GKT, 3 sub-stages of 20 s: 0.67m, and two intermediary equidistant marks between stage 1 and the verification distance.

Measurements and data processing

Cardiorespiratory measurements were continuously recorded, from the beginning of the initial 5-min standing rest, until the end of the verification phase. Measurements of capillary blood lactate concentration were taken immediately after the standing rest, shortly after the incremental testing, and at the first, third, sixth, and ninth minutes of recovery.

The measurements of cardiorespiratory variables were performed with the K5 portable gas analyzer (Cosmed, Rome, Italy) in the breath-by-breath sampling mode. For heart rate measurement, the HRM-Dual monitor (Garmin, Lenexa, USA) was placed in a chest strap, connected via Bluetooth to the K5 gas analyzer and the ventilatory variables were sampled breath-by-breath. The portable Lactimeter Accutrend Plus (Roche Diagnostics, Basel, Switzerland) was used to measure capillary blood lactate concentration, and the highest blood lactate value was determined to be the peak value. Capillary blood was collected from the participant's fingertip after cleaning the area with an alcohol swab and drying it with a sterilized cotton swab.

Breath-by-breath sampled data was interpolated through a cubic spline method to 1.0 Hz. Subsequently, ventilatory variables underwent a 4th-order low-pass Butterworth filter, with a cut-off frequency of 0.04 Hz (Robergs et al., 2012). The filter was applied in direct and reverse directions to avoid phase distortions. The MATLAB 2019a software (Mathworks, Natick, USA) was used for signal processing. Average values of $\dot{V}O_2$, HR, and minute ventilation ($\dot{V}E$) were calculated at every decile of time-to-peak to assess the behavior of cardiorespiratory responses of the CPET and the GKT.

Ventilatory threshold (VT) and respiratory compensation point (RCP) were determined using ventilatory equivalents (Reinhard et al., 1979; Beaver et al., 1986) by two experienced evaluators. If there was a discrepancy of more than 5% of the $\dot{V}O_2$@VT or $\dot{V}O_2$@RCP, a third independent evaluator, without prior knowledge of the tests, defined the most appropriate point. Experimenters disagreed in 10% of VT and 5% of the RCP.

Statistical analysis

Statistical analysis was performed using SPSS v22 (IBM, Armonk, USA). Initially, the Shapiro-Wilk test was used to verify adherence to a normal distribution. Parametric data were presented as mean and standard deviation. Nonparametric data were presented as median and interquartile range. Comparisons between the CPET and GKT were performed with paired Student's T-test. Nonparametric data were compared with the Wilcoxon test. Comparisons of the cardiopulmonary responses (Tests [2] x Time-to-peak Deciles [10]) and Incremental and Verification phases' (Tests [2] x Phases [2]) responses were performed with two-way repeated-measures analysis of variance (ANOVA) and with the Bonferroni post hoc test, when necessary.

Effect Size (ES) of T-tests was computed with Hedges g and interpreted as 'Trivial' ($d < 0.10$), 'Small' ($d = 0.10 - 0.29$), 'Moderate' ($d = 0.30 - 0.49$), 'Large' ($d = 0.50 - 0.69$), 'Very large' ($d = 0.70 - 0.89$) or 'Extremely Large' ($d \geq 0.90$) (Hopkins et al., 2009). Wilcoxon Test's effect size was calculated as 'r' equals to Z-value divided by the square root of the sample size (Tomczak and Tomczak, 2014), and interpreted as a correlation: 'Trivial' if $r = 0.0 - 0.29$; Small if $r = 0.30 - 0.49$; 'Moderate' $r = 0.50 - 0.69$; 'Large' if $r = 0.70 - 0.89$; 'Very Large' if $r \geq 0.90$. ANOVA's ES was calculated with Cohen's f and interpreted as 'Trivial' ($f < 0.10$), 'Small' ($f = 0.10 - 0.24$), 'Moderate' ($f = 0.25 - 0.39$), 'Large' ($f \geq 0.40$) (Cohen, 1988). The alpha level was 0.05 for all variables.

Results

Similar maximal physiological responses were found for both tests ($p > 0.05$). The GKT presented a significantly lower test duration ($p < 0.001$; $g = 3.69$ [Extremely Large]) and an earlier $\dot{V}O_{2MAX}$ achievement ($p = 0.01$; $r = 0.93$ [Very Large]) (Table 1) than the CPET. The GKT ventilatory threshold presented a higher $\dot{V}O2$@VT ($mL \cdot kg^{-1} \cdot min^{-1}$ and %$\dot{V}O2MAX$) ($p = 0.02$; $g = 0.99$ [Extremely Large], and $p = 0.005$; $g = 1.47$ [Extremely Large]). The GKT also evoked a higher HR@VT ($beats \cdot min^{-1}$ and %HRMAX) ($p < 0.001$; $g = 1.55$ [Extremely Large]; and $p < 0.001$; $g = 1.99$ [Extremely Large]). Regarding the RCP, a higher HR ($beats \cdot min^{-1}$ and %HRMAX) was also observed for the GKT ($p = 0.02$; $g = 0.89$ [Very Large]; and $p = 0.02$; $r = 0.76$ [Large]).

Regarding the behavior of cardiorespiratory responses (Figure 3), a near significant interaction was observed for $\dot{V}O_2$ ($p = 0.051$; $f = 0.61$ [Large]). The GKT presented a different kinetics for some cardiorespiratory variables, compared to the CPET, with significantly higher responses of HR ($p < 0.001$; $f = 1.43$ [Large]) and VE ($p = 0.01$; $f = 0.75$ [Large]) across time, except for the last decile of the test, whereas $\dot{V}O2$ did not differ across the test.

Incremental and verification phases evoked similar $\dot{V}O2MAX$ ($mL \cdot kg^{-1} \cdot min^{-1}$) and $\dot{V}E$ ($L \cdot min^{-1}$) responses during both tests. Both the CPET and GKT presented higher HRMAX ($beats \cdot min^{-1}$) during the incremental phase ($p = 0.002$; $f = 1.41$ [Large]), without differences between tests. Test and phase factors interacted significantly for maximal respiratory exchange ratio (RERMAX) ($p = 0.03$; $f = 0.83$ [Large]) (Table 2). Finally, the CPET and GKT verification phases presented similar durations ($p = 0.06$; $r = 0.60$ [Large]).

Table 1. Comparison of the treadmill running cardiopulmonary exercise test and the graded karate test responses.

	CPET	GKT	p (ES)
Maximal Oxygen Uptake (mL·kg^{-1}·min^{-1})	58.3 (3.5)	57.4 (5.1)	0.53 (0.24)
Maximal Heart Rate (beats·min^{-1})	193 (10)	192 (6)	0.62 (0.11)
Maximal RER ($\dot{V}CO_2/\dot{V}O_2$)	1.17 (0.06)	1.23 (0.11)	0.09 (0.70)
Maximal $\dot{V}E$ (L·min^{-1})	129.1 (22.2)	132.1 (19.4)	0.44 (0.15)
Peak Blood Lactate (mmol·L^{-1})	13.1 (3.0)	14.6 (3.4)	0.14 (0.48)
Test Duration (s)	640 (86)	351 (71)	<0.001* (3.69)
Time-to-Maximum (%Duration) NP	98.2 (0.7)	80.5 (13.2)	0.01* (0.93)
Ventilatory Threshold			
Oxygen Uptake (mL·kg^{-1}·min^{-1})	37.6 (4.0)	41.6 (5.0)	0.02* (0.99)
Oxygen Uptake (%MAX)	64.4 (4.3)	72.6 (6.5)	0.005* (1.47)
Heart Rate (beats·min^{-1})	149 (16)	170 (10)	<0.001* (1.55)
Heart Rate (%MAX)	77.3 (7.2)	89.4 (4.6)	<0.001* (1.99)
Time (%Duration)	23.6 (8.5)	19.2 (5.9)	0.21 (0.59)
Rating of Perceived Exertion (0-10) NP	1 (1)	2 (2)	0.28 (0.34)
Respiratory Compensation Point			
Oxygen Uptake (mL·kg^{-1}·min^{-1})	50.3 (0.43)	51.7 (5.5)	0.43 (0.29)
Oxygen Uptake (%MAX)	86.5 (6.7)	90.1 (4.2)	0.16 (0.65)
Heart Rate (beats.min^{-1})	178 (8)	186 (9)	0.02* (0.89)
Heart Rate (%MAX) NP	92.9 (2.2)	97.0 (2.4)	0.02* (0.76)
Time (%Duration)	67.8 (8.6)	61.5 (11.0)	0.23 (0.64)
Rating of Perceived Exertion (0-10)	6 (2)	6 (2)	0.57 (0.22)

(NP) denotes non-parametric data. Parametric data presented as mean (standard deviation). Non-parametric data presented as median (interquartile range). CPET - Running Cardiopulmonary Exercise Test. GKT – Graded Karate Test. RER – Respiratory Exchange Ratio. $\dot{V}CO2$ – Carbon dioxide production. $\dot{V}O2$ – Oxygen uptake. $\dot{V}E$ – Minute ventilation. (*) denotes significant difference ($p \leq 0.05$). Effect size (ES) was calculated with Hedge's g for parametric data, and Z-value was divided by the square root of the sample size (r) for non-parametric data.

Table 2. Verification phase maximal responses.

	CPET		GKT		p-value (ES)		
	VER	Δ%	VER	Δ%	Test p	Phase p	T*P p
Maximal Oxygen Uptake (mL·kg^{-1}·min^{-1})	58.1 (4.2)	-0.2 (7.1)	55.6 (6.1)	-0.1 (10.1)	0.13 (0.56)	0.22 (0.44)	0.36 (0.32)
Maximal Heart Rate (beats·min^{-1})	188 (9)	-2.1 (2.2)	190 (6)	-1.2 (1.1)	1.00 (0.00)	0.002* (1.41)	0.18 (0.48)
Maximal Respiratory Exchange Ratio ($\dot{V}CO_2/\dot{V}O_2$)	1.02 (0.07)	-12.9 (9.3)	0.97 (0.06)	-20.5 (9.2)	0.64 (0.16)	<0.001* (2.21)	0.03* (0.83)
Maximal Expired Minute Ventilation (L·min^{-1})	124.1 (15.2)	-2.6 (11.0)	127.5 (17.1)	-3.0 (7.3)	0.35 (0.33)	0.17 (0.50)	0.93 (0.03)
Verification Phase Duration (s) NP	96 (38)	-	94 (45)	-	0.06 (0.60)	-	-

Parametric data presented as mean (standard deviation) and non-parametric (NP) data presented as median (interquartile range). Physiological outcomes compared with Two-way repeated measures ANOVA. Verification Phase Duration was compared with Wilcoxon Test. CPET - Running Cardiopulmonary Exercise Test. GKT – Graded Karate Test. VER – Verification Phase. Δ% - Percentage difference of Verification phase and Incremental maximal outcomes [(Incremental-Verification)/Incremental]. *ES* – Effect size (Cohen's *f* for physiological outcomes and *r* ($Z\sqrt{n}$) for verification phase duration). * denotes significant difference ($p \leq 0.05$). T*P – Test and phase interaction.

Discussion

The present study aimed to propose and validate a new displacement-based sport-specific test for karate athletes. This test evoked similar maximal and higher submaximal physiological responses when compared to the 'gold-standard' running CPET. Moreover, the verification phase provided additional parameters to ensure maximal achievement during the specific protocol. The novel test was able to assess the cardiorespiratory fitness of karate athletes with ecological validity.

Regarding the testing structure, the GKT offered a shorter test duration than the CPET and in comparison to other testing protocols (Chaabène et al., 2012b; Tabben et al., 2014). The shorter duration of the GKT would optimize the assessment routine by improving the ability to assess a large team of karate athletes. Also, when compared to the CPET, the $\dot{V}O_{2MAX}$ occurred earlier, regarding the percentage of the test duration. We hypothesize that participants would not be able to sustain the maximal aerobic power for longer. Therefore, after attaining peak response, participants possibly decreased the mechanical work performed in the last minute (approx. at 80% of test duration), which is acceptable in an ergometer-free protocol that relies on motivation to advance across the various stages. Also, to the best of our knowledge, this was the first specific karate test with standardized encouragement, which is very important since this test lacks the mechanical power imposed by an ergometer. Regarding the proportion of increments, the GKT presented similar time to achieve the VT and RCP (approx. VT at 19% and RCP at 60% of duration), when compared to the CPET (approx. VT at 24% and RCP at 68% of duration), with similar perceived exertion ratings of 'very weak' for the VT and 'hard' for the RCP.

Tabben et al. (2014) proposed a karate-specific test where the athlete delivers a punching and kicking sequence to a heavy bag, with increments in the striking frequency. The protocol was validated against a laboratory cycle ergometer test with a group of international-level athletes. They reported a $\dot{V}O_{2max}$ value of ~54 mL·kg.$^{-1}$·min^{-1} in line with our result of ~58 mL·kg^{-1}·min^{-1}. In other combat sports, $\dot{V}O_{2MAX}$ seems to be less affected by specificity, as observed in Judo (Santos et al., 2010; Shiroma et al., 2019) and Taekwondo (Araujo et al., 2017; Hausen et al., 2018) specific protocols.

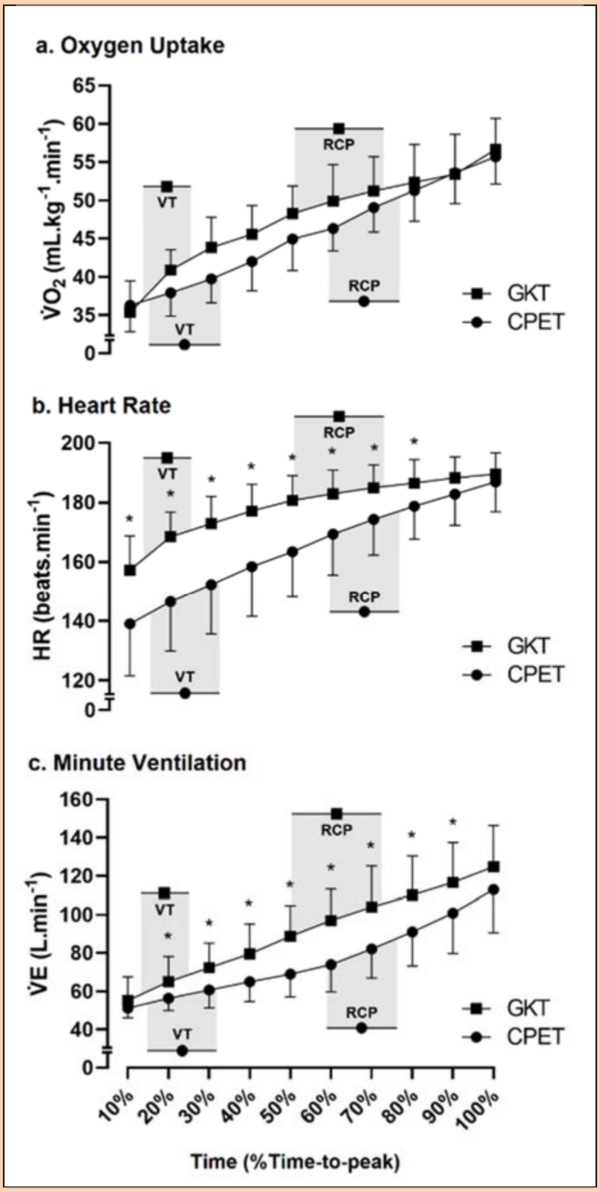

Figure 3. The cardiorespiratory responses during the treadmill cardiopulmonary exercise test (CPET) and the graded karate test (GKT). Data presented as mean and standard deviation. (*) Denotes significant difference between tests at the time point. Ventilatory threshold (VT) and respiratory compensation point (RCP) occurrences are indicated as mean and standard deviation.

To the best of our knowledge, this was the first time that the verification phase was proposed for a specific karate test. No differences were found between incremental and verification phases for $\dot{V}O_{2MAX}$, HR_{MAX}, and $\dot{V}E_{MAX}$. These findings indicate the utility of the verification phase for a karate-specific test, which is already widely employed in the CPET (Schaun, 2017). Both tests presented a lower maximal HR in the verification phases, compared to the respective incremental phases, which might be explained by the shorter duration of the verification phases. The use of a verification phase in combat sport protocols is scarce. It was included successfully in a Judo-specific test (Shiroma et al., 2019), confirming the maximal responses of $\dot{V}O_{2MAX}$, HR_{MAX}, blood lactate and perceived exertion evoked in the incremental phase. Therefore, verification strategies should be considered to improve the validity of specific testing for combat sports, ensuring the attainment of a ceiling response in a "field" test.

Besides maximal aerobic power, submaximal thresholds are strong predictors of endurance performance (Jones and Carter, 2000). All the VT and some of the RCP responses were significantly higher during the GKT. After a thorough search of the relevant literature, no other specific test was found to identify the thresholds for karate athletes. Unspecific VT and RCP responses may not be transferrable for specific training zones for karate athletes. Hausen et al. (2018) found similar differences in a Taekwondo-specific aerobic testing proposal where $\dot{V}O_2$@VT, HR@VT, and HR@RCP were higher in the specific protocol when compared to the running CPET. Thus, the behavior of the cardiorespiratory responses in the present study confirmed the importance of specificity to assess submaximal responses to minimize imprecise training prescription. The use of specific HR or displacement rhythm (attacks·min^{-1}) can be easily transferred to a) regenerative (<VT), b) extensive (VT-RCP), and c) intensive (>RCP) training zones (Meyer et al., 2005). These zones can be transferred for both continuous or high-intensity interval sessions of specific drills, as suggested by the polarized training model (Seiler and Kjerland, 2006). A field test, such as the GKT, enables the determination of submaximal thresholds in a way that is directly transferable to the athletes, in contrast to the CPET.

The GKT yielded higher responses of blood lactate concentration (~14.6 mmol·L^{-1}) compared to other karate-specific protocols presented in literature (~8 and 10 mmol·L^{-1}) (Chaabène et al., 2012b; Tabben et al., 2014). This difference can be explained by the nature of the movements performed in the different protocols or by the sample of the training profiles. In previous proposals, the athletes increased the striking frequency (Chaabène et al., 2012b; Tabben et al., 2014), whereas the GKT provided an active displacement between attacks. We hypothesized that progressive displacements are more specific to karate than increasing striking frequency, which can best represent continuous sparring disciplines such as boxing and taekwondo. Thus, the GKT seemed to evoke a higher demand for anaerobic lactic metabolic pathways, without compromising maximal achievement of aerobic power. The higher glycolytic pathway activity observed through the blood lactate response obtained in the present protocol did not hamper the proper determination of maximal and submaximal outcomes of the novel displacement-based GKT.

Conclusion

The displacement-based sport-specific GKT presented similar maximal and higher submaximal physiological responses compared to the ‘gold-standard’ CPET, with an enhanced ecological validity. Significant differences in the VT and RCP responses confirm the need for a specific cardiopulmonary assessment for enhanced conditioning planning based on ecologically valid training zones. The Graded Karate Test provides a new approach to assess karate athletes, with the use of increasing displacements across stages. Manipulation of target distances and striking frequencies presents itself as a novel strategy that allows coaches and sports scientists to develop cardiorespiratory fitness and the ability to sustain propelling power, while optimizing the training regimen for this group.

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Key points

- The displacement-based graded karate test (GKT) yielded similar maximal and higher submaximal physiological responses than the 'gold-standard' CPET.
- The graded karate test (GKT) provides a more ecologically valid approach to assess the cardiorespiratory conditioning of karate athletes.
- Manipulating the target distance presents itself as a novel strategy that allows for the development of cardiorespiratory fitness combined with the specific ability to sustain propelling power.

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