Comparison of Cardiorespiratory and Metabolic Responses Between Kettlebell Half Marathon and Treadmill Running at the Same Average Oxygen Consumption: A Case Study

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Abstract

Purposes In kettlebell sport (KS) half marathon, the lift of the kettlebell is required for the highest number of repetitions in 30 min. No data are available on cardiorespiratory and metabolic responses during this exercise routine. The aim of the study was to evaluate cardiopulmonary and metabolic responses to KS half marathon compared to 30 min treadmill running, chosen as a reference paradigm of aerobic exercise, at the same average oxygen consumption (VO_2).

Methods A male elite KS athlete was enrolled in two trials separated by 7 days of rest. In the first trial, one-hand long-cycle KS exercise with a 1/3 body weight kettlebell was performed for 30 min (kettlebell half marathon, KT); in the second trial, 30 min treadmill running (TR) was performed at the same average VO_2 measured in the first trial (speed 9–10 km/h at 1° uphill inclination). Metabolic and cardiopulmonary assessments [respiratory exchange ratio (RER), tidal volume (TV), breathing frequency (f), minute ventilation (VE)], blood lactate (BL) kinetics, heart rate (HR), and blood pressure (BP) were measured in both experimental sessions.

Results The average VO_2 was 33.3 mL/min/kg in KT and 30.6 mL/min/kg in TR. The subject achieved RER_{peak} 1.17, RER_{mean} 0.98, HR_{peak} 172 bpm (94% HR_{max}), HR_{mean} 86% of HR_{max} , BP_{peak} 220/100 mmHg in KT, BL_{peak} 7.2 mmol/L (during trial) in KT and RER_{peak} 1.13, RER_{mean} 0.89, HR_{peak} 142 bpm (78% HR_{max}), HR_{mean} 70% of HR_{max} , BP_{peak} 160/80 mmHg, BL_{peak} 3.5 mmol/L (4 min after trial) mmol/L in TR.

Conclusion Data indicate that a KS half marathon determines much higher cardiopulmonary and metabolic responses to treadmill running performed at similar VO_2 .

Keywords Kettlebell sport · Blood lactate · Blood pressure · Heart rate · Oxygen consumption

Introduction

In kettlebell sport (KS), the lift of a heavy tool, the kettlebell, is required for the highest number of repetitions in an established period. In the frame of KS, KS marathon

and KS 1/2 marathon consists in lifting the load for 1 h and for 30 min, respectively, without releasing it on the ground. In 2010 the discipline has been coded by the International Kettlebell Federation (IKMF) and currently involves around 1000 athletes in Italy. Considering that in KS the heavy lifting is combined with the prolonged time of lifting, it is reasonable that unique features may represent the physiological cardiorespiratory and metabolic responses and long term adaptations compared to other exercise activities such as running or cycling. In fact, routines may include resistance and aerobic components as hypothesized in few studies [4, 5, 15], but their relative contribution during KS routines are still unclear.

To the best of our knowledge, the available studies only investigated the cardiorespiratory responses to interval [5, 6, 11, 15–17] and incremental [4] type of kettlebell exercises, with resting phases during trials whereas none analyzed the

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prolonged and steady-state kettlebell routines, with the KS technique. In particular, attempts have been made to compare the cardiorespiratory response determined by these routines to endurance exercise in order to unravel whether the use of kettlebell is to be considered effective in improving the subject's aerobic fitness.

From the physiological point of view, comparing the adjustments due to highly different activities is a particularly complex task and requires to set up equal intensity levels. To this aim, in the study by Greer et al. [10], the average VO_2 calculated in a resistance exercise (5 resistance exercises at 60% 1RM, 1 min rest between exercises for 45 min) was used to set up the intensity of an aerobic one (cycle ergometer). As regards KS, few attempts have been made to adjust intensities of KS and aerobic activities [11, 15]. In particular, Husley et al. [11] compared the kettlebell swings and the treadmill running at equivalent rate of perceived exertion (RPE) whereas, Thomas et al. [15] compared the cardiorespiratory response of KS (sumo deadlift and two hand swing) with walking at the same average VO_2 after a 7 days of rest between sessions.

In the present study we aimed to compare, for the first time, the cardiorespiratory and metabolic responses of KS one hand long cycle half marathon with 1/3 bodyweight load to treadmill running at the same average VO_2 . In particular, we chose to analyze the impact of the overhead press without resting phases for 30 min, which has never been studied before. To this aim an elite athlete was enrolled into two subsequent trials. In the first KS trial VO_2 was calculated to set up the average consumption to be maintained in the second treadmill session.

Methods

Subject

A male elite KS athlete (age 37, weight 85 kg, height 1.83 m, BMI 25.38 kg/m^2) with 5 years training experience, healthy, nonsmoker, normotensive, without musculoskeletal injuries or pains, took part in the study. The subject was asked to (a) refrain from training within 48 h before each trial, (b)

maintain his normal dietary habits, stay hydrated and refrain from alcohol intake 24 h before each trial, (c) sleep routine amount of time (8 h) the night before. A written informed consent and a medical history questionnaire were obtained. The study was approved by the Institutional Review Board of CRIAMS-Sport Medicine Centre of the University of Pavia.

In both trials the athlete came to the laboratory at 8:30 a.m. in a fasting condition. After 10 min in sitting position, resting blood lactate (BL) was measured with Lactate Pro 2 (Arkray, Kyoto, Japan) and left arm blood pressure (BP) was measured by a sphygmomanometer. Then a light breakfast of 186 kcal was provided (169 kcal from carbohydrates; 10 kcal from proteins, 7 kcal from fat). This meal was chosen in order to avoid a significant thermogenic response (glucydic meal), due to the short interval of time between its intake and the trial start, as previously demonstrated by Belko et al. [3]. During the first visit, anthropometric data were obtained using a stadiometer (Seca Ltd., Hamburg, Germany). The procedures for both trials are summarized in Fig. 1.

First Trial

The first trial (KT) was the one hand long cycle half marathon with a 26 kg kettlebell corresponding to 1/3 of bodyweight approximately, for 30 min, without releasing it on the ground and maintaining a constant rhythm (10 repetitions per minute, RPM) paced by a metronome (Fig. 2). After a self-determined mobility warm-up of 10 min, the trial was started. During the trial, BL and BP were assessed at 8, 15 and 30 min during trial and after trial at 4 and 8 min. Post-trial time points for BL determination were previously assessed as optimal for peak BL and 1/2 peak BL measurement after RT routine in the same subject. Metabolic and cardiopulmonary assessments [respiratory exchange ratio (RER), tidal volume (TV), breathing frequency (f), minute ventilation (VE)] were obtained with Quark CPET (COSMED, Rome, Italy); HR was measured with a chest strap HR monitor connected to Quark CPET. Substrate percentage oxidation was assessed from changes in RER along the trial [9].

Fig. 1 Procedures for both trials

Fig. 2 The one hand long cycle phases: swing, clean, rack position, loading, push and overhead lockout (reproduction authorization obtained by the subject)

At the end of the trial, the rate of perceived exertion was obtained with RPE 6–20 scale [4, 6, 11] (Table 1).

Second Trial

The second trial (TR) consisted of 30 min treadmill running performed at the same average VO_2 measured in the first trial (speed 9–10 km/h at 1° uphill inclination). After a self-determined mobility warm-up of 10 min, the trial started and BL, BP, metabolic, cardiopulmonary, and RPE assessments were obtained as previously described for KT.

Results

Results are summarized in Table 1. Although the mean VO_2 taken into consideration to set up TR was 33.3 mL/min/kg, the mean VO_2 reached in TR was 30.6 mL/min/kg. In KT the subject achieved a near maximal effort revealed by a RER_{peak} of 1.17, HR_{peak} of 172 bpm corresponding to 94% HR_{max} , BL_{peak} of 7.2 mmol/L (after 30 min of exercise) and RPE of 14. A BP_{peak} of 220/100 mmHg was measured 8 min after

KT start and returned to resting values after 4 min of rest. During exercise, the substrate percentage consumption, as revealed by changes in RER, mainly involved carbohydrates (around 90%). Also in TR the subject achieved a submaximal effort (RER_{peak} 1.13, HR_{peak} 142 bpm corresponding to 78% HR_{max} and a BL_{peak} of 3.5 mmol/L 4 min after the end of trial. The BP_{peak} of 160/80 mmHg was measured 15 min after start and returned to resting values 4 min after trial. During TR exercise substrate consumption involved carbohydrates (around 64%) with maintained fat oxidation (36%).

Discussion

This study investigated, for the first time, if the physiological response to 30 min kettlebell overhead non-stop routine (KT) defines this exercise for the prevalence of cardiopulmonary and metabolic resistance-type or endurance-type components. To this aim, we compared the KT response to that of treadmill running (TR), considered as a paradigm of aerobic exercise, at the same average VO_2 . Results indicated that KT determines much higher cardiopulmonary and

Table 1 Summary of results obtained in kettlebell (KT) and running (RT) trials

Quark CPET parameters	Kettlebell	SD	Running	SD
VO _{2mean} (mL/min/kg)	33.3	7.15	30.6	5.56
VCO _{2mean} (mL/min/kg)	32.7	6.92	27.4	4.83
RER _{peak}	1.17		1.13	
RER _{mean}	0.98	0.06	0.89	0.04
TV _{mean} (L)	2.06	0.29	2.3	0.37
f _{mean} (breaths/min)	43.54	8.03	29.86	2.89
VE _{mean} (L/min)	89.25	18.51	68.23	9.54
% Cho	90.1		64.12	
% Fat	9.9		35.88	
% Pro	0		0	
ΔVO _{2ket.} —VO _{2run.} (mL/min/kg)	2.7			
ΔVCO _{2ket.} —VCO _{2run.} (mL/min/kg)	5.3			
HR (bpm)				
Mean	157 (86% HR _{max})	11.87	128 (70% HR _{max})	12.02
Peak	172 (94% HR _{max})		142 (78% HR _{max})	
Max (Tanaka's equation)	182			
BP (mmHg)				
Rest	120/80		120/80	
8 min	210/100		150/80	
15 min	220/80		160/80	
30 min	140/80		150/80	
4 min post	125/80		120/80	
8 min post	120/75		120/70	
BL (mmol/L)				
Rest	0.5		0.8	
8 min	4.5		2.9	
15 min	4.3		2.1	
30 min	7.2		2.3	
4 min post	5.3		3.5	
8 min post	5.2		1.5	
Trials				
Kettlebell weight (kg)	26			
RPM kettlebell	10			
Treadmill speed (km/h)			9–10	
Treadmill inclination (°)			1	

BL blood lactate, BP blood pressure, cho carbohydrates, f respiratory rate, fat fats, HR heart rate, pro proteins, RER respiratory exchange ratio, RPM repetitions per minute, TV tidal volume, VCO₂ carbon dioxide production, VE ventilation, VO₂ oxygen consumption

metabolic responses than TR, identifying it as a resistance-type exercise, notwithstanding the hypothetical endurance effort due to long lasting duration.

Considering that in KT the HR_{mean} set above 85% HR_{max} in our experimental conditions, the cardiopulmonary response to exercise was maintained close to maximal levels along the trial. The observed change in HR appeared similar to that found in previous studies analyzing the interval kettlebell swing and the kettlebell snatch routines. In particular, HR_{mean} of around 87% HR_{max} was found during interval kettlebell swing (as many repetitions as possible in 12 min,

16 kg kettlebell) by Ferrar et al. [5] and during an interval session (20 s exercise-10 s rest for 12 min, kettlebell weight from 10 to 22 kg depending on the exercise) including four kettlebell exercises by Williams and Kraemer [16] (HR_{mean} 86% HR_{max} in our study). Importantly, a sharp difference between VO₂ and cardiac response was observed in KT compared to TR trial. This observation confirms previous findings obtained in studies comparing the interval kettlebell swing to endurance type exercises trials [4, 5, 11]. Systolic blood pressure (SBP) values measured in KT were similar to those reported by Freedson et al. [8] for dynamic efforts in

resistance training (bench press at 50% of maximal isometric force), unlike diastolic blood pressure (DBP) (150 mmHg in Freedson et al. data and 100 mmHg in our). During KT, the SBP values assessed at 8 min and 15 min (210 and 220 mmHg respectively) resemble the upper acceptable values reported in the ACSM guidelines (≤ 210 mmHg in males) (2018) and confirm the physiological increase of 10 mmHg every MET. In fact, in our experimental condition, a total of 9.34 METs was reached corresponding to a theoretical SBP of 213 mmHg ($9.34 \times 10 \text{ mmHg} + 120 \text{ mmHg}$ at rest $\approx 213 \text{ mmHg}$). These data disagree with values reported by Thomas et al. [15], observing a rise in SBP not above 150 mmHg and a slight decrease of the DBP, probably due to the low kettlebell weight (16 kg), not-overhead exercises (swing and sumo deadlift), and the interval type trial. Instead, the BP values observed in TR (SBP 160 mmHg and DBP 80 mmHg) correspond to values reported during an aerobic exercise of 4 METs in healthy subjects with a sufficient training experience (> 5 years) [12]. Importantly, although a linear correlation between VO_2 and BP and HR has been proved during cranking and cycling trials [2], higher values are expected when exercise is performed with the upper limbs, and this response appears to be strictly related to the muscle mass involved. In our experimental condition, despite similar VO_2 , the observed KT SBP and DBP probably reflect higher peripheral resistance due to a change in sympathovagal balance towards increased sympathetic activity compared to TR. In fact, in physiological conditions, the acute control of blood flow occurs in few seconds or minutes as a result of the integration between vasoconstriction (chemoreceptors) and vasodilator (baroreceptors) signals. Overall, the exercise could influence the baroreceptors activity [13], altering their role in the HR and BP regulation, by increasing BP levels (operating point) from which they start their regulatory activity [14]. Importantly, the sympathovagal balance resulting in the regulation of blood flow during exercise is closely related with the exercise intensity. In particular, at moderate intensities, a vasoconstriction should be appreciated mostly due to increased sympathetic activity [7], whereas at lower intensity levels HR and BP may increase as a consequence of the inhibition of the vagal output till maximal lactate steady state levels [7, 14], due to its quicker alteration compared to the sympathetic system [14]. Wong et al. [17] found that the sympathovagal balance was sharply altered after an interval kettlebell bout (30 s work, 30 s rest for 12 rounds) assessing the Heart Rate Variability and a similar change may be also hypothesized in a non-stop KT routine. As regards the change in BL, in KT measurements showed higher levels despite the lower VO_2 in comparison with what observed in an interval kettlebell trial by Fortner et al. in 2014, which evaluated 1 min post-exercise BL. In our setting, BL levels exceeded those reported as anaerobic threshold and, probably, a major contribution

to this result may be attributed to the robust involvement of the upper body as previously found [1]. This result was mirrored by a higher increased VE and f to dispose of BL excess and hypercapnia compared to TR. Finally, an interesting result concerned to the rating of perceived exertion that, in both trials, reported a lower value than that expected on the basis of the cardiorespiratory response (14 following KT and 10 following RT, corresponding to moderate/ somewhat hard and light exertion respectively). In KT the excess of the cardiorespiratory response, probably due to the change in sympathovagal balance, and/or the high technical skill in the execution of the overhead gesture may have contributed to this apparent discrepancy.

Limitations and Future Directions

This study has limitations. As already observed by Greer et al. [10], in the two trials the VO_2 could not be exactly the same. This was due to the difficulty in maintaining a constant VO_2 in the 30 min exercises and, in accordance to Thomas et al. [15], continuous adjustments of the treadmill speed were required to reduce this difference as much as possible.

Further, although theoretically it could be of help to refer exercise intensities to $\text{VO}_{2\text{max}}$, technical constraints avoided us to proceed in this way. In particular, the aim to compare two different activities (KT and RT) and the lack of validated maximal tests for KT, mainly due to the number of parameters impacting on results (type of exercise, repetitions per minute, and KT load), avoided us to refer intensity to a maximal value.

Based on data obtained in this case study, non-stop KT routine determines a high intensity cardiopulmonary response and caution should be put forward before its practice, particularly in the presence of cardiovascular diseases. Future studies are needed to elucidate whether these results can be extended to lower level athletes which generally perform the same routine with lower loads.

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Compliance with Ethical Standards

Conflict of interest The authors declare non conflicts of interest.

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