Sports **2015**, *3*, 202-208; doi:10.3390/sports3030202

OPEN ACCESS

sports

ISSN 2075-4663

www.mdpi.com/journal/sports

Communication

The Effect of Kettlebell Swing Load and Cadence on Physiological, Perceptual and Mechanical Variables

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Academic Editor: Lee E. Brown

Received: 16 July 2015 / Accepted: 4 August 2015 / Published: 7 August 2015

Abstract: This study compared the physiological, perceptual and mechanical responses to kettlebell swings at different loads and swing speeds. Following familiarization 16 strength trained participants (10 males, six females, mean age ± SD = 23 ± 2.9) performed four trials: 2 min kettlebell swings with an 8 kg kettlebell at a fast cadence; 2 min kettlebell swings with an 8 kg kettlebell at a slow cadence; 4 min kettlebell swings with a 4 kg kettlebell at a fast cadence; 4 min kettlebell swings with a 4 kg kettlebell at a slow cadence. Repeated measured analysis of variance indicated no significant differences in peak blood lactate or peak net vertical force across loads and cadences ($P > 0.05$). Significant main effect for time for heart rate indicated that heart rate was higher at the end of each bout than at mid-point ($P = 0.001$). A significant Load X cadence interaction for rating of perceived exertion (RPE) ($P = 0.030$) revealed that RPE values were significantly higher in the 8 kg slow cadence condition compared to the 4 kg slow ($P = 0.002$) and 4 kg fast ($P = 0.016$) conditions. In summary, this study indicates that the physiological and mechanical responses to kettlebell swings at 4 kg and 8 kg loads and at fast and slow cadence were similar, whereas the perceptual response is greater when swinging an 8 kg kettlebell at slow cadence.

Keywords: force; swing; nontraditional training; resistance exercise

1. Introduction

Kettlebells comprise a cast iron/steel weight, resembling a cannonball with a handle and are popular and widely used for resistance training. Their use has been advocated as a means to enhance muscular strength and endurance, and aerobic endurance whilst also reducing body fatness [1]. Unlike dumbbells, kettlebell training tends to comprise ballistic and swing movements where the centre of mass of the kettlebell is extended beyond the hand. Kettlebell training has also been recommended to condition occupation groups including the armed services [2] as well as being an efficacious rehabilitation tool [3,4]. While the use of the kettlebell dates back to circa 1700 s [1], scientific analysis of kettlebell training and individual movements with a kettlebell has only recently gathered momentum. Consequently, there are still significant gaps in the literature relating to the best use of kettlebells for strength and conditioning.

To date, studies examining kettlebell science have tended to focus on either physiological variables [5–7] or biomechanical variables [8,9]. A number of studies have also compared kettlebell exercise to treadmill running [7,10]. For example, Hulsey *et al.* [10] reported higher caloric expenditure, oxygen uptake (VO_2), metabolic equivalents and pulmonary ventilation during treadmill exercise, compared to 10 min kettlebell swinging. More recent work by Thomas *et al.* [7] compared a moderate-intensity kettlebell protocol with brisk walking performed on a treadmill. Ten novice participants performed a 30 min kettlebell protocol, comprising three continuous sets of 10 kettlebell swings followed by 10 sumo deadlifts (16 kg for males, 12 kg for females) with a 3 min rest between sets. This was compared to a 30 min treadmill walk (3,10 min bouts separated by 3 min rest) where VO_2 was matched from the kettlebell session. Their data indicated similar blood pressure, energy expenditure and respiratory exchange ratios between conditions but higher rating of perceived exertion (RPE) and heart rate during kettlebell exercise. Thomas *et al.* concluded that kettlebell training may therefore be used to enhance aerobic capacity to the same extent as brisk walking. Mechanically focused studies of kettlebell exercise have reported that kettlebell exercise results in a hip-hinge squat pattern, eliciting rapid muscle activation-relaxation cycles, opposite in polarity to that of traditional Olympic weightlifting techniques [9]. Other work [8] has reported on the mechanical demands of the kettlebell swing specifically. In their study, 16 males performed two sets of 10 kettlebell swings with 16, 24, and 32 kg kettlebells. Lake and Lauder [8] reported that swing mean and peak power was greater than power recorded during a back squat and comparable with power recorded from a jump squat.

A recent review of kettlebell research suggested a need to examine the effects of different kettlebell loads, as research has not fully examined responses across the range of kettlebell loads available [11]. Understanding the optimal loads for kettlebell training is an important consideration for coaches and athletes, yet without this initial comparison type research, this aspiration will not be elucidated. Moreover, in by far the majority of research using kettlebell training, participants have used different loads. For example, in Thomas *et al.* [7] kettlebell load differed between males and females, whereas in Lake and Lauder [8] participants performed two sets of 10 kettlebell swings across a standardised spectrum of kettlebell loads. As such, it is difficult to compare across kettlebell loads as the total volume of work will differ and therefore making inferences about the effect of load alone may be open to debate. Further, in research studies employing the kettlebell swing, there has seemingly been no standardisation of swing speed or cadence. Modification of swing cadence may result in different intensities of exercise, particularly if swing volume is set as a product of a set duration. The current study seeks to address this issue by comparing the physiological and mechanical responses to kettlebell swings at different loads and swing speeds. We hypothesized that heavier kettlebell load and faster swing speeds would elicit greater physiological and mechanical responses compared to lighter kettlebell load and slower swing speed.

2. Method, Results, Discussion

2.1. Method

2.1.1. Participants

Following institutional ethics approval, briefing regarding the study and provision of written informed consent, 16 strength trained participants (10 males, six females; mean age ± S.D. = 23 ± 2.9 years, height = 176.2 ± 9.2 cm, body mass = 76.3 ± 14.7 kg) volunteered to participate. Participants were recruited from the pool of MSc Strength and Conditioning Students at the institution where the testing took place. All participants had experience performing resistance exercise, including work with kettlebells, and were free of any musculoskeletal pain or disorders. Inclusion criteria included currently participating in > 10 h week^{-1} programmed physical activity including strength and endurance based activities and prior experience using kettlebells. Exclusion criteria included any musculoskeletal injury that would have prevented engagement in the experimental protocol. Mean ± S.D. of years training experience was 4.5 ± 1.5 years.

2.1.2. Procedures

This study used a within groups, repeated measures design, where participants undertook five visits to the human performance laboratory. The first visit was for familiarisation, and the subsequent four visits were counterbalanced experimental trials, which were all performed at the same time of day to minimise circadian variation. Participants were asked to refrain from strenuous exercise in the 24 h before exercise and to attend the laboratory in a hydrated state (e.g., minimum water consumption of 500 mL in the 3 h before testing). Participants engaged in the following four trials: 2 min kettlebell swings with an 8 kg kettlebell at a fast cadence; 2 min kettlebell swings with an 8 kg kettlebell at a slow cadence; 4 min kettlebell swings with a 4 kg kettlebell at a fast cadence; 4 min kettlebell swings with a 4 kg kettlebell at a slow cadence. Heart Rate (HR) and RPE were assessed at mid and end points of each bouts of swings. Blood lactate (BLa) was determined following each swing bout using a 5 µL capillary blood sample taken from the fingertip (Lactate Pro, Arkray Instruments, Kyoto, Japan). Peak net vertical force was also calculated from force platform data (AMTI AccuGait, Watertown, MA, USA), collected throughout each bout of kettlebell swings. Slow and fast cadence was determined via pilot work where different swing speeds were performed by an experienced strength and conditioning professional with 4 and 8 kg kettlebells. From this the two cadences chosen to represent slow (40 BPM) and fast (80 BPM) were selected as being ecologically sound in terms of use within fitness and strength and conditioning programmes. Throughout all trials a metronome (Seiko SQ44, Tokyo, Japan) was used to regulate cadence with a full swing (upwards and downwards phase) being completed in 2 BPM. This resulted in 20 full swings being completed per minute in the slow conditions and 40 full swings being completed in the fast conditions. In this manner, the total work completed in the slow and fast swing speed condition was the same when comparing across 4 kg and 8 kg kettlebell loads. All swings were performed in accordance with the technique reported by Tsatsouline [1] and as used in prior studies examining kettlebell swing performance [8]. Participants were positioned with feet shoulder width apart and standing on the force platform for each trial. Prior to each trial, all participants completed a 5 min warm up protocol at 25 W on a cycle ergometer (Monark, Vansbro, Sweden). They then began each trial 2 min after completion of the warm-up.

2.1.3. Statistical Analysis

In order to examine any changes in Heart Rate, Rating of Perceived Exertion and peak force, a series of 2 (4 kg *vs.* 2 kg kettlebell load) × 2 (slow *vs.* fast swing speed) × 2 (time, mid point *vs.* end point) ways repeated measures analysis of variance (ANOVA) were used. Any differences in post exercise blood lactate were examined using repeated measures ANOVA. Where any statistical differences were found, Bonferroni post-hoc multiple comparisons were used to determine where the differences lay. Partial η^2 ($P\eta^2$) was used as a measure of effect size. The statistical package for social sciences (SPSS, version 22, IBM Inc, New York, NY, USA) was used for all analysis and statistical significance was set as $P = 0.05$ *a priori*.

2.2. Results

In regard to heart rate, results indicated no significant higher order interaction or main effects due to load or cadence (all $P = > 0.05$). However, there was a significant main effect for time ($P = 0.001$, $P\eta^2 = 0.621$), whereby heart rate at mid-point in each trial was significantly lower than heart rate at the end point of each trial ($P = 0.001$). Mean ± SE of heart rate was 148.1 ± 4.1 BPM and 155.5 ± 3.8 BPM at mid and end points respectively. There was also no significant difference in peak Bla across conditions ($P = 0.377$). For RPE there was a significant Load X cadence interaction ($P = 0.030$, $P\eta^2 = 0.293$, see Figure 1) where RPE was higher during the 8kg slow cadence condition compared to the 4 kg fast cadence and 4 kg slow cadence condition. Post hoc analysis indicated that there was a significant difference between 8 kg load at a slow cadence and 4 kg load at a slow cadence ($P = 0.002$) and 8 kg load at a slow cadence and 4 kg load at a fast cadence ($P = 0.016$). When peak vertical force was examined there were no significant differences between loads, cadence or time points (all $P > 0.05$). Mean ± SE of heart rate, peak blood lactate concentration and peak vertical force across loads and cadences and at mid and end point in each trial are presented in Table 1.

2.3. Discussion

The current study compared physiological, perceptual and mechanical variables during the kettlebell swing at two different loads and two different cadences. This is the first study to date to examine this issue in a manner where total work can be equalised across loads and cadence. The results of this study demonstrate that when this is the case the physiological and mechanical responses are similar between 4 and 8 kg kettlebells. However, when the 8 kg kettlebell swings at a slow cadence produced significantly higher perception of exertion than any of the other conditions. For strength and conditioning coaches and athletes this has useful implications for the development of kettlebell training programmes in that a heavier load (8 kg) when swung more slowly results in higher RPEs when the physiological and mechanical response is the same. In such cases, adherence to training programmes might be more effective if using a 4 kg load on the basis that it will feel more comfortable but elicit the same physiological response as an 8 kg load.

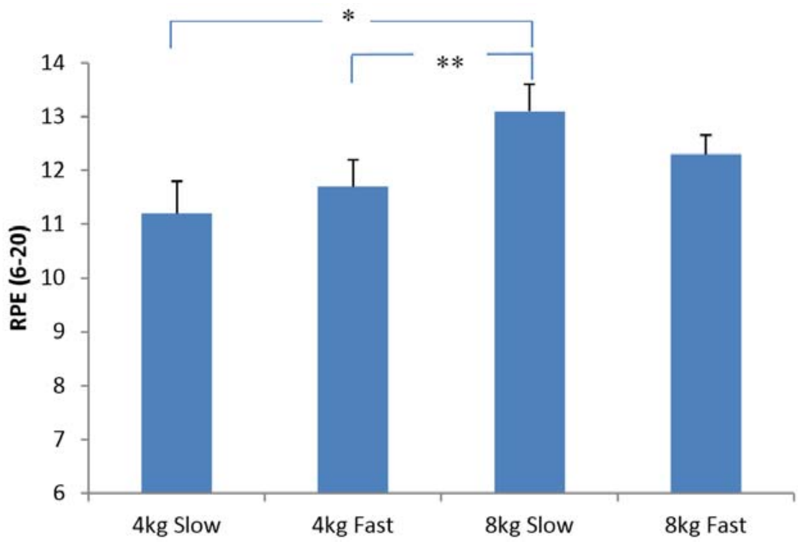

Figure 1. Mean ± SE of RPE values during kettlebell swings across loads and cadences (* $P = 0.002$, ** $P = 0.016$).

Table 1. Mean (SE) of heart rate, peak blood lactate concentration and peak vertical force at the mid point and end point of kettlebell swings at different loads and cadences.

	4 kg Slow		**4 kg Fast**		**8 kg Slow**		**8 kg Fast**	
	Mid Point	**End Point**	**Mid Point**	**End Point**	**Mid Point**	**End Point**	**Mid Point**	**End Point**
HR (BPM)	144 (4.8)	151 (4.4)	148 (3.9)	155 (3.7)	148 (7.1)	160 (4.3)	150 (3.7)	155 (4.2)
Bla (mmol/L)	-	5.8 (1.1)	-	4.9 (.55)	-	7.5 (1.6)	-	5.8 (1.1)
Peak Force (N)	562.5 (67.0)	551.2 (63.1)	516.2 (126.3)	462.9 (136.8)	623.1 (60.1)	585.4 (56.3)	557.6 (112.2)	539.3 (112.1)

In some respects it is difficult to compare the results of this study to prior work that has employed kettlebells as previous studies by Thomas *et al.* [7], Hulsey *et al.* [10], Lake and Lauder [10] have used discrete bouts of kettlebell exercise at different loads. Thus, the differences they report may be a consequence of greater work completed rather than a difference in the load employed. The results present in the current study build on this work by also examining different swing cadence. Prior research [7,8,10,12] has not tended to standardise or consider the effect of swing speed/cadence on responses to this type of exercise.

There are some limitations of the current study, due to lack of prior literature relating to optimum swing speed, cadence was determined via pilot study by strength and conditioning professionals. The two swing cadences employed may not however be "optimal" and additional research examining across the spectrum of possible swing speeds might be useful in determining whether there is an "optimum" kettlebell swing speed. Likewise, two relatively light loads (4 kg and 8 kg) were utilised in the present study. This was again based on pilot data in terms of what loads might conceivably be used for kettlebell swing durations over 2 min in duration. Research designs employed by previous authors have used kettlebell loads in excess of those used in the current study, and up to 32 kg e.g., [8]. They have also tended to use much longer durations of kettlebell swinging, which may lack ecological validity. For example, Hulsey *et al.* [10] employed a continuous 10 min period of kettlebell swings and Thomas *et al.* [7] employed three sets of 10 min kettlebell swings, each separated by a 3 min rest period. Such durations of kettlebell exercise seem in excess of what would realistically be engaged in within a gym setting, and particularly physically demanding. Hence the decision in the present to design to employ a smaller duration of swings, more akin to what might be used by the general exercising public. In addition only net peak net vertical force was assessed in the present study and future work that presents an analysis of overall mechanical demands, as well as asymmetry, may elucidate further information in relation to the biomechanics of the kettlebell swing. In regard to practical application, this study suggests that, when matched for work, 4 kg and 8 kg kettlebells when swung at fast or slow cadence, produce similar physiological and mechanical responses but the perceptual response was greater when the kettlebell was swung with an 8 kg load at a slow cadence. Thus, coaches and athletes may likely benefit to the same extent by swinging a 4 kg kettlebell than an 8 kg kettlebell.

3. Conclusion

The present study indicates that the physiological response to kettlebell swings at slow and fast cadences with 4 and 8 kg kettlebells is similar, as is the peak net vertical force. Perceived exertion values are higher when using an 8 kg kettlebell with a slow swing cadence. For coaches and athletes a 4 kg kettlebell swing protocol may be preferable as it results in similar physiological and mechanical response but lower RPE as compared to an 8 kg protocol.

Author Contributions

Michael J. Duncan, Rosanna Gibbard, Leanne M. Raymond and Peter Mundy designed the study, Rosanna Gibbard and Leanne M. Raymond collected the data. Michael J. Duncan and Peter Mundy analysed and interpreted the data. Michael J. Duncan, Rosanna Gibbard, Leanne M. Raymond and Peter Mundy wrote the manuscript. All authors critically reviewed, contributed to and approved the manuscript.

Conflicts of Interest

The authors declare no conflict of interest

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