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The acute hormonal response to kettlebell swing exercise differs depending on load, even when total work is normalized

Running Head: hormonal response to kettlebell swing

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Abstract

This study examined the acute hormonal response to kettlebell (KB) swing exercise using two loads but when total work was equalized. Ten strength trained males (25 ± 6 years) completed two KB swing trials, with an eight and 16kg KB respectively, in a counterbalanced order. Each protocol lasted twelve minutes comprising 30 seconds KB swings followed by 30 seconds rest. Swing cadence was manipulated in each trial to ensure total weight lifted was the same across conditions. Heart rate (HR) and rating of perceived exertion (RPE), using the Borg RPE scale 6-20, was taken at the end of each 30s exercise period. Saliva samples (min 0.5ml) were taken 15 minutes pre, immediately post and 15 and 30min post each condition from which cortisol (C) and testosterone (T) were determined. Results indicated a significant main effect for load for C ($P = 0.007$) and T ($P = 0.05$) where higher values for both C and T were evident for the 16kg load. There was also a significant main effect for time for T ($P = 0.001$) where T values were all significantly higher post exercise compared to pre. For HR there were significant main effects for load ($P = 0.004$) and time ($P = 0.001$) with higher HR seen in 16kg load and significant increases in HR evident with increasing repetition, irrespective of condition (all $P< 0.05$). RPE values increased with repetition for the 8kg and 16kg loads but the increase was more marked for the 16kg load compared to the 8kg load ($P = 0.002$). The present findings suggest that KB swing exercise produces an acute increase in hormones involved in muscle adaptation, but that KB load influences this response even when total work completed is the same.

Keywords: Testosterone; Cortisol; Interval Exercise; Endocrine

Introduction

Although the kettlebell (KB) and KB exercises are not new, there has recently been an upsurge in use and scientific interest in the utility of KB training for both recreational fitness and athletic strength and conditioning. The KB is a free weight with uneven weight distribution where the centre of mass extends beyond the grip of the athlete. Kettlebells provide a unique tool for full-body ballistic exercise (13) which has benefits similar to that of traditional weightlifting including improving muscular strength (13, 15), power, endurance, aerobic capacity and reduction in body fat when used appropriately (7, 17). Despite this, relatively few studies have examined KB training and there remain significant gaps in the literature relating to the use of KBs for strength and conditioning.

The most recent review of KB research suggested a need to examine the physiological and mechanical effects of different KB loads as research, to date, has seemingly used a wide range of KB loads (2). Understanding optimal loading for KB training is an important consideration for coaches and athletes for programing and planning but in research to date there is no consensus as to which KB load might be appropriate and on what basis. Due to the differing loads and swing cadences used in prior studies it is difficult to draw conclusions as to the effect of KB load on physiological and mechanical variables independent of total work completed. Total work is conceptualised as the number of repetitions (or swings in this instance) multiplied by the weight lifted. For example, Lake and Lauder (15) examined three KB loads (16kg, 24kg, 32kg) swung for 2x10 sets resulting in different total work completed (load X swings = 320kg, 480kg and 640kg for 16, 24 and 32kg KB loads respectively). Thus, any inferences made regarding the effect of KB load on mechanical variables are not independent of work done. To better understand the effect of KB load on any variable, it is important to ensure that the total work completed is equalized otherwise, the conclusions drawn may simply be a product of the additional work done rather than the load lifted. Modification of KB swing cadence may result in different intensity of exercise, particularly if swing volume results as a product of a set duration of exercise. Recently, Duncan et al (6) demonstrated no differences in physiological or mechanical responses to 4min of KB swing exercise with a 4kg load at a fast cadence and 2 min of exercise with an 8kg KB at a slow cadence, the time and cadence were modified between each condition to ensure total work was equal within both conditions. However, the KB loads (4 and 8 kg) used in the Duncan et al (6) study were relatively light compared to those used in the majority of the literature (e.g., 10, 15, 20). Likewise, while Duncan et al (6) demonstrate the importance of matching KB exercise for total work completed, their findings are restricted to heart rate, perceived exertion and peak net vertical force values.

The endocrine response to KB exercise are to date relatively underexplored, but potentially important. In some instances it is reported that both cortisol (C) and testosterone (T) play a potential role in the physiological adaptations to resistance training, where protocols high in volume, moderate to high in intensity, with short rest intervals are reported to produce the highest acute hormonal elevations compared with low-volume, high intensity protocols using long rest intervals (14). There are however some studies which do not support this assertion, demonstrating that resistance exercise may elicit little or no hormonal response and thus have little effect on muscle adaptation (16, 20, 27).

The acute hormonal response to resistance exercise may be relevant for longer term exercise adaptation because some studies have demonstrated greater increases in strength and muscle mass from training using exercises that elicit a greater hormonal response (10,18). Despite this, the current research surrounding acute testosterone responses to resistance exercise are unclear (12) due to methodological inconsistencies and lack of ability to separate intensity of exercise (or load lifted) from total work completed. One study to date has examined the acute hormonal response to KB swing exercise (4). Using 12 rounds of 30s KB swings (16kg load) alternated with 30s rest, Budnar et al (4) reported that KB exercise prompted an acute increase in T and C immediately post and 15minutes post exercise and suggested that KB exercise might augment strength and hypertrophy responses to training via acute increases in endocrine factors. No other study appears to have investigated the acute response to KB exercise and the conclusions made by Budnar et al (4) are restricted to the one load examined in their study. Understanding if the acute hormonal response to KB exercise changes across different loads is an important factor for coaches when planning to implement KB exercise within their programs. The current study examined the acute physiological and hormonal responses to two KB loads whilst equalizing total work completed. This work, extends prior studies in the area, namely that of Budnar et al (4), and sought to determine whether there were any differences in hormonal responses to acute KB swinging as a function of KB load whilst equalizing for total weight lifted.

Method

Experimental Approach to the Problem

This study used a repeated measures design to evaluate the acute physiological and hormonal response to a KB swing protocol using two loads but with the same total work load. The KB swing protocol has been used in previous investigations on physiological responses to hip hinge KB swing exercise (4, 15) and has been demonstrated that training with the protocol improves lower-body strength and power (15). 10 resistance trained men performed 12 rounds of 30 seconds of KB swings alternated with 30 seconds rest on two occasions with either an 8kg or 16kg KB, separated by at least 48 hours, and performed in a counterbalanced order. The KB protocol followed that validated by Lake and Lauder (15) and used by Budnar et al (4).

Both 8kg and 16kg KB loads have been used in evaluating physiological responses to KB exercise in the literature (4, 6, 7, 12, 15, 21). Swing cadence was manipulated to ensure the total work was the same across conditions following procedures previously used with KB swing exercise (6). In this way the design built upon recommendations of prior work (1,6) by examining effects of different KB loads while equalised for total work completed. Saliva samples were collected before the warm up (PRE), immediately post exercise (IP), 15 minutes post exercise (P15) and 30 minutes post exercise (P30) and were analysed for T and C. Heart rate (HR) and ratings of perceived exertion (RPE) were taken on completion of each 30s bout of KB exercise.

Subjects

Ten, apparently healthy, resistance trained males (19-43 years; mean ± SD: 26 ± 8years, 175 ± 9cm, 82.2 ± 14.6 kg) volunteered for this study. All participants were informed of the risks and benefits of the study prior to any data collection and subsequently provided written informed consent. The study, and all methods discussed within this paper were approved by Coventry University's ethical review board. Volunteers completed a health screening questionnaire to ensure they had no pre-existing injuries, neuromuscular or any other health issue that would prevent participation. To be considered for the study, participants were required to have a minimum resistance training age of two years (mean ± SD: 6 ± 7years). They were also required to have experience of performing a hip hinge KB swing, have no history of anabolic steroid use, have no injuries, contraindications or limitations that would prevent exercise involvement.

Procedures

Prior to testing participants undertook a familiarisation session which included demonstration of the KB swing by a strength and conditioning professional. This was followed by performance of the hip hinge technique with both KB loads and familiarisation with both cadences. This was observed by strength and conditioning professionals to verify that KB technique was executed appropriately. Following this, participants undertook two experimental sessions at least two days post familiarisation. All data collection took place between 9.00-11.00am. Experimental sessions for each participant were performed at the same time of day to minimize any effects due to circadian variation. Participants were asked to refrain from strenuous exercise in the 24 hours before exercise and to attend the laboratory in a hydrated state (e.g., minimum water consumption of 500ml in the 3 hours before testing). Participants were also asked to replicate the same food and beverage intake prior to each trial and report to the laboratory post prandial. Hydration status and food intake were not directly assessed. Participants were reminded of the need to consume the water prior to each session and was verbally verified by participants on arrival at the laboratory on each testing session. Such a process has been employed previously in relation to saliva collection for hormonal analysis where hydration state was also reported to have no significant influence on saliva collection and analysis (19). In both experimental sessions, participants undertook twelve 30s bouts of KB swings interspersed with 30s rest following the protocol described Lake and Lauder (15).

Within this study two cadences were chosen to represent slow (42 BPM) and fast (84BPM). As no literature had examined the effects of KB cadence on any variables the cadence used was determined via a pilot study where two strength and conditioning professionals observed an athlete performing the KB swing at different cadences and judged these to be broadly representative of KB swinging in real world scenarios. Throughout all trials a metronome (Seiko SQ44, Japan) was used to regulate cadence with a full swing (upwards and downwards phase) being completed in two BPM. This resulted in 21 full swings being completed per minute in the 16kg condition and 42 full swings being completed in the 8kg condition. In this manner, the total work completed in the slow and fast swing speed condition was the same when comparing across 8kg and 16kg kettlebell loads due to the difference in cadence and load. All swings were performed in accordance with the technique reported by Tsatsouline (22) and as used in prior studies examining kettlebell swing performance (15). The swing technique Tsatsouline (22) describes swinging the kettlebell from between the legs up to chest level; arms are to stay straight but lose, the power is then generated from the hips. The technique described by Tsatsouline (22) involves movements similar to that of a sumo deadlift stance and performing a 'hike pass' to transfer the bell back between the legs until the forearms make contact with the inner thigh. Participants were positioned with feet shoulder width apart for each trial period.

Heart Rate and RPE

Heart Rate (HR) was measured using HR telemetry (Polar RS400 Kuopio, Finland) and RPE, using the Borg 6-20 RPE scale (3). RPE was administered using memory anchors, explained to participants on each experimental visit. Both variables were assessed at the end of each 30s bout of KB swings within the KB swing protocol.

Hormonal Analysis

Participants refrained from eating and drinking (except for water) for 30 minutes before the first saliva sample was collected. All participants adhered fully to the protocol as stated in the specimen collection section of the Salimetrics protocol. Saliva samples (passive drool) were provided pre, immediately post, and at 15 and 30 minutes post each condition. This protocol was employed to ensure post exercise saliva sampling coincided with the time frame suggested as optimal for determining any change in testosterone and cortisol as a consequence of exercise intervention (24), due to the delayed testosterone and cortisol response in saliva compared to blood (23). Collected saliva samples were transferred into cryo-freeze tubes and stored at –80°C for later analysis. Testosterone and cortisol levels were measured using an expanded range high sensitivity enzyme immunoassay kits (Salimetrics LLC, State College, PA, USA). All saliva specimens were assayed in duplicate and coefficients of variation (%CV) for within-between assay determinations of 10% or less were required (9). The intra-assay and inter-assay precision (%CV) for the cortisol assay were determined as 5% and 8% respectively. The intra-assay and inter-assay precision for the testosterone assay were determined as 3% and 9% respectively. All assays were performed by the same investigator.

Statistical analysis

Two, 2 (load 16kg vs. 8kg) X 12 (KB bout) ways repeated measures analysis of variance (ANOVA) were used to examine if there were any differences were evident in HR and RPE data. In order to examine any differences in testosterone and cortisol, data were analyzed using a series of 2 (load) X 4 (time) ways repeated measures ANOVAs. Partial η^2 was used as a measure of effect size with values of 0.01, 0.09 and 0.25 considered mall, medium and large effects (6). Where any significant differences were found Least Significant Differences (LSD) adjustment for pairwise comparisons were used to detect where those differences lay. Shapiro-Wilk test were also conducted to assess normality of data. The results from normality testing confirmed all data were normally distributed except for HR values (P = 0.01) and RPE values (P = 0.014) in the 12th KB swing bout in the 16kg condition. The Statistical Package for Social Sciences (SPSS, version 24, IBM Corporation, Chicago, Il, USA) was used for all analysis and P value was set at ≤0.05 a priori.

Results

Mean ± SE and 95% confidence intervals for HR and RPE during the 12 X 30 second KB swing bouts with 8 and 16kg KBs are presented in Table 1 and Mean ± SE and 95% confidence intervals for cortisol and testosterone pre, post, 15 minutes and 30 minutes the 12 X 30 second KB swing bouts with 8 and 16kg KBs are presented in Table 2. HR and RPE during the 12 X 30 second KB swing bouts with 8 and 16kg KBs For HR, analysis indicated no significant condition X time interaction ($F_{11,99} = 0.893$, $P = 0.550$, Partial $\eta^2 = 0.090$ (Medium effect)) but there was a significant main effect for Condition ($F_{1,9} = 14.479$, $P = 0.004$, Partial $\eta^2 = .617$), and Time ($F_{11,99} = 11.382$, $P = 0.001$, Partial $\eta^2 = .558$ (large effect)). LSD post hoc analysis indicated that

HR was significantly higher in 16kg condition compared to the 8kg conditions (See Figure 1.). The main effect for time is presented in Figure 2. LSD indicated that there were no significant differences in HR between bout one and two ($P>0.05$). HR significantly increased (all $P<0.05$) with increasing bout number in bouts 3-9. HR following bouts 9-12 was significantly higher than HR during preceding bouts ($P<0.05$) but was not significantly different from each other ($P>0.05$).

Results in respect to RPE revealed a significant condition x time interaction ($F_{11,99} = 3.047$, $P = 0.002$, Partial $\eta^2 = 0.253$ (large effect), See Figure 3). Post-Hoc analysis indicated no significant differences in RPE between 8kg and 16kg swing conditions following the first bout ($P>0.05$), thereafter RPE was significantly higher following each bout in the 16kg condition compared to the 8kg condition (all $P<0.05$). RPE also increased, with increasing bout number. However, the rate of increase was steeper for the 16kg condition ($\Delta = 6.7$) compared to the 8kg condition ($\Delta = 4.3$). There were no significant differences in RPE in the 16kg condition at the end of bout 7, 8 and 9. There were however significant ($P<0.05$) changes in RPE with increasing bout number at the end of all other bouts in the 16kg condition. For the 8kg condition, RPE increased linearly but there were no significant differences in RPE between bouts 5, 6, 7 and 8 ($P>0.05$). There were also no significant differences in RPE between bouts 10, 11, and 12 in the 8kg condition ($P>0.05$).

Salivary cortisol analysis indicated no significant condition x time interaction ($F3,24 = 1.12$, $P = 0.341$, Partial $\eta^2 = 0.128$ (medium effect)) or main effect for time ($F3,24 = 1.76$, $P = 0.221$, Partial $\eta^2 = 0.181$ (medium effect)). There was however a significant main effect for condition (F1,8 = 12.648, P = 0.007, Partial η^2 = 0.613 (large effect), See Figure 4). LSD post-hoc analysis indicated that salivary cortisol concentration was significantly higher in the 16kg condition compared to the 8kg condition (P = 0.007).

For salivary testosterone there was no significant condition x time interaction (F3,24 = 0.701, P = 0.561, Partial η^2 = 0.081 (small effect)) but there were significant main effects for condition (F1, 8 = 5.828, P = 0.05, Partial η^2 = 0.376 (large effect), See Figure 5) and time (F 3,24 = 13.648, P = 0.001, Partial η^2 = 0.630 (large effect), See Figure 6). LSD post-hoc analysis indicated testosterone concentration was higher in the 16kg condition compared to the 8kg condition (P = 0.05), and that, testosterone concentration was significantly higher post exercise (P = 0.001), 15 minutes post exercise (P = 0.001) and 30 minutes post exercise (P = 0.003) compared to pre exercise.

Recognising that aging beyond the age of 35-40 years is associated with a 1-3% decline per year in testosterone concentration in men (20) and one of the participants within the study was aged 43 data were reanalysed with this participant removed. This did not make any difference to the results of statistical analysis.

Discussion

The current study demonstrates that the hormonal response to KB swing exercise differs depending on load, even when total work is held constant. This is the first study to examine whether hormonal responses to kettlebell exercise differ depending on load and importantly used a design where swing cadence was modified to ensure total volume was constant between the two load conditions. This study is novel in examining the acute salivary response to the KB swing exercise using different loads when equalizing work load. The major finding of this study was that serum T and C concentrations were significantly higher following a 16kg KB exercise session compared to a lighter load (8kg) session when work load was held constant.

It is challenging to compare results of the present study to prior work that describes KB exercise as previous studies by Thomas et al (21), Hulsey et al. (12), Lake and Lauder (15) have all used varied protocols employing different loads and none equalized for total work completed. Therefore, their results may be an outcome of greater work completed in different conditions rather than a true difference between load conditions. Despite this, the results of the present study support prior work (6, 17) that has also reported increased metabolic measures (HR, RPE and lactate concentrations) over the duration of various KB protocols which supports studies that show a physiological benefit to resistance exercise (6, 21). It is important to note that RPE was significantly higher following each set of KB swings in the 16kg condition compared to the 8kg condition (all $P<0.05$) despite equalized total work, this shows that it is perceptually harder than the lighter load protocol. RPE increases reported in the current study were also similar to that of Duncan et al. (6), who used 8kg and 4kg KB loads, with RPE being significantly higher in an 8kg slow cadence condition compared to a 4kg slow and 4kg fast cadence ($P=0.016$). Duncan et al. (6) indicated that the physiological and mechanical responses to kettle bell swings at 4kg and 8kg loads and at a fast and slow cadence were similar and only the perceptual response differed. This is in contrast to the current study, which does show a significant physiological and acute hormonal change, whereby physiological and hormonal responses were elevated, in the 16kg condition compared to the 8kg condition.

HR results showed a significant increase over time which is similar to as Duncan et al. (6) which found a significant main effect for time, whereby HR at midpoint in each trial was significantly lower than HR at the end point of each trial, which again is reflected within the results of this current study as was similar within Thomas et al. (21) which showed HR being greater within a KB protocol compared to measures taken when treadmill walking.

In regard to the aforementioned hormonal response, the results of this study show an increase in hormones associated with muscle adaptation, thus KB swing exercise may provide a good protocol to be included within resistance training programs. Testosterone is a highly effective anabolic-androgenic hormone that stimulates muscle proteins synthesis and inhibits protein degradation depletion (17). A reduction of testosterone within males has been seen to result in a decrease in strength measured outcomes, whereas a supra-physiological dose of testosterone is associated with increased muscle strength and hypertrophy (2). In relation to this current study, the protocols provided, at least acutely, the sufficient intensity, volume and large muscle group recruitment to elicit an increase in testosterone, which was significantly higher within the heavier KB protocol. This assertion is also congruent with the conclusions made by Budnar et al (4) who observed acute hormonal changes following a KB swing protocol using a 16kg load.

The results of the current study extend the prior work of Budnar et al (4) by demonstrating that it is the load and not the total work completed which may be the key stimulus for the observed hormonal responses.

The physiological relevance of the acute hormonal response of resistance exercise for long-term strength and hypertrophy training has been questioned, several studies eliciting a greater hormonal response following resistance training programs (8, 18) and on the contrary, several studies finding no relationship between resistance exercise and acute hormonal responses (26, 27). If indeed the acute hormonal response to resistance exercise does provide the stimulus for increased strength and hypertrophy then this study demonstrates a key role for load over volume in prompting this response.

In summary, the key outcomes of this study were that a 16kg KB swing protocol elicited a greater acute hormonal response in testosterone, cortisol, and heart rate compared with an 8kg swing protocol with an equal workload. Due to the effect that these hormonal measures have on strength development and hypertrophy the findings suggest that swinging a heavier KB may better contribute to improvements in strength and muscle mass compared to a lighter KB, even when the same total work is completed. However, swinging a heavier KB was found to be perceptually more difficult.

There are some limitations of the current study. Due to lack of prior literature relating to optimum swing speed, cadence was determined via a pilot study performed by strength and conditioning professionals. The two swing cadences employed may not however be ‘optimal’ and additional research across the spectrum of possible swing speeds might be useful in determining whether there is an ‘optimum’ kettlebell swing speed. Nevertheless, the current study employed a KB swing protocol that has been used in the literature (3, 15). Research designs employed by previous authors have used kettlebell loads in excess of those used in the current study, and up to 32kg (e.g., 14). It is not known if using loads in excess of 16kg might produce a different hormonal response to that reported in the current study. Conditions were counterbalanced in the current study but not randomized. We also acknowledge that the findings reported here need to be verified with a larger sample where there is counterbalancing and randomization in condition allocation. Although the current study employed a participant group similar to that used by previous authors (4,21) in KB research, a posteriori power analysis indicated that, the current study is only powered to detect a large effect size in hormonal variables, at 80% power with an alpha of 0.05. For a medium effect size, a sample of 24 participants would be needed. Given the need to recruit participants familiar with hip hinge and KB swing exercises, obtaining such a sample size was difficult.

Data regarding participant’s baseline strength levels were not assessed. As a consequence, any differences in load as a result of baseline strength could not be controlled for. Although determining baseline strength specific to the KB swing is not straightforward, future research may therefore benefit from controlling for baseline strength determined via 1 repetition maximum testing of whole body, multi-joint resistance exercise (e.g., back squat). Also, although the results of our analysis did not differ when the participant over 40 years of age was included or omitted from analysis, future researchers should be aware of the potential impact of age on hormonal responses in men (20) and seek to recruit participants that are more homogenous in age than was the case in the current study.

Practical Applications

The KB swing is a widely used type of full-body resistance exercise which can increase muscular strength and in some cases cardiovascular endurance. Although other types of resistance training programs may elicit greater physiological benefits than KB swinging, the addition of KB swinging to a conditioning program may augment the overall hormonal response to strength training. Strength and conditioning professionals may find use of KB exercise beneficial as supplementary to other resistance exercise and if so should be aware that it is load and not total work completed which appears to promote an increased hormonal response, at least acutely.

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Figure Legends

Figure 1. Data (Mean ± SE) showing the main effect for heart rate between 8kg and 16kg kettlebell swing conditions.
(*P=0.05)

Figure 2. Data (Mean ± SE) showing the time main effect for heart rate (bpm) across kettlebell swing bout number.
(*P=0.05)

Figure 3. Mean ± SE of RPE across kettlebell swing bouts in 16kg and 8kg kettlebell swing conditions.
(* P=0.05, ~P=0.01, #P=0.001)

Figure 4. Data (Mean ± SE) showing the main effect for salivary cortisol (nmol/L) between 8kg and 16kg kettlebell swing conditions.
(*P<0.02 for main effect between conditions)

Figure 5. Data (Mean ± SE) showing the main effect for salivary testosterone (nmol/L) between 8kg and 16kg kettlebell swing conditions.
(*P=0.05)

Figure 6. Data (Mean ± SE) showing the time main effect for salivary testosterone (nmol/L) between 8kg and 16kg kettlebell swing conditions.

(*P=0.003, **P =0.001)

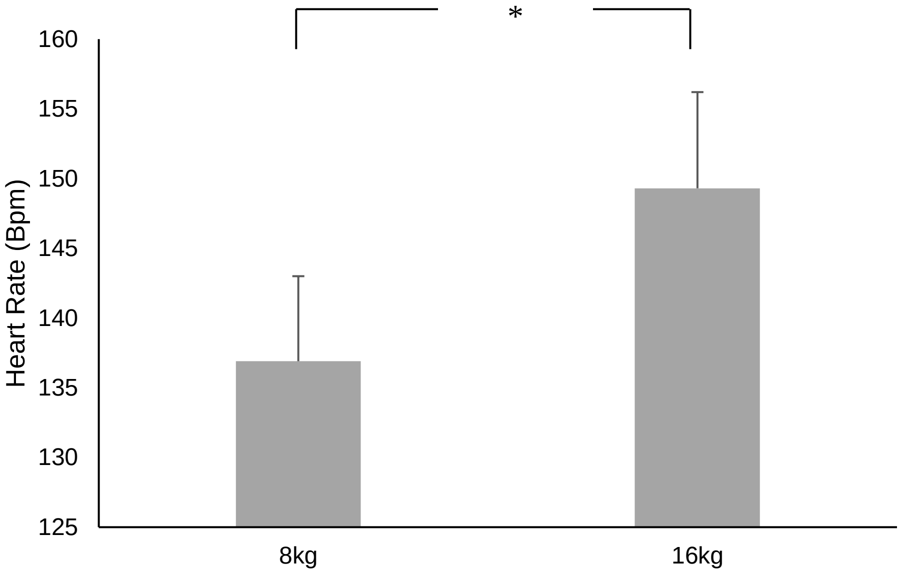

Figure 1.

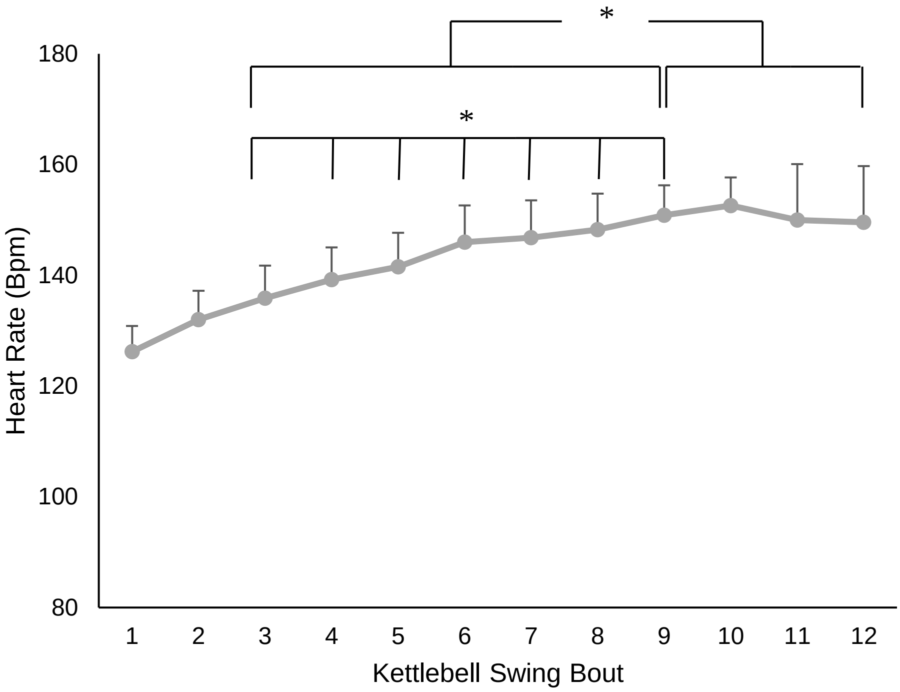
*
*
180
160
140
120
100
80
Heart Rate (Bpm)
1
2
3
4
5
6
7
8
9
10
11
12
Kettlebell Swing Bout

Figure 2.

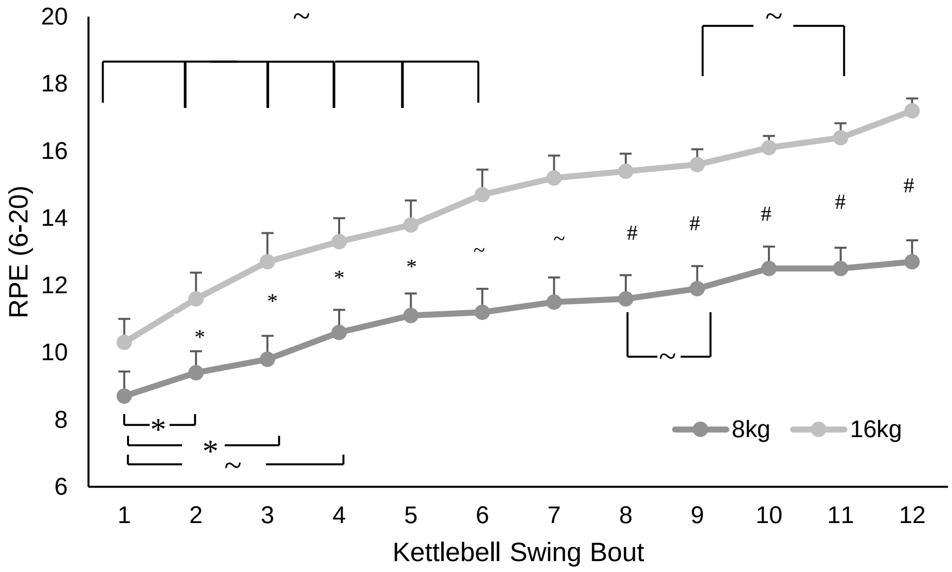
20
18
16
14
12
10
8
6
RPE (6-20)
1
2
3
4
5
6
7
8
9
10
11
12
Kettlebell Swing Bout
8kg
16kg
~
~
*
*
*
*
~
~
#
#
#
#
#
~
*
*
~

Figure 3.

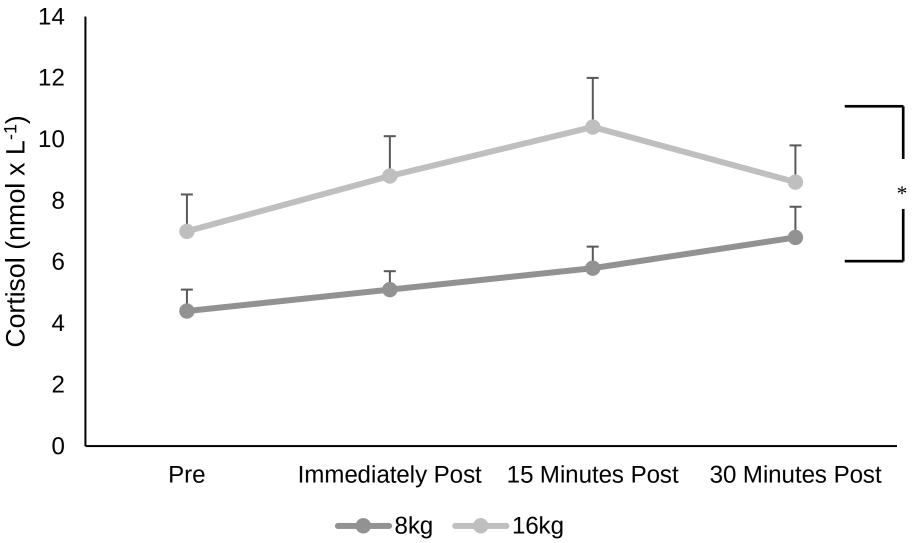
14
12
10
8
6
4
2
0
Cortisol (nmol x L-1)
Pre
Immediately Post
15 Minutes Post
30 Minutes Post
*
8kg
16kg

Figure 4.

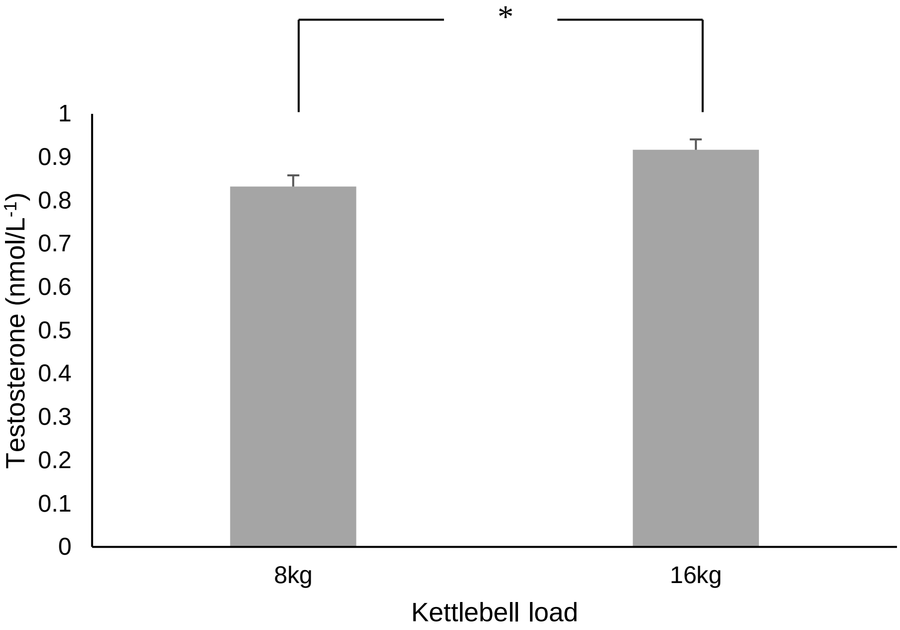
*
Testosterone (nmol/L-1)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
8kg
16kg
Kettlebell load

Figure 5.

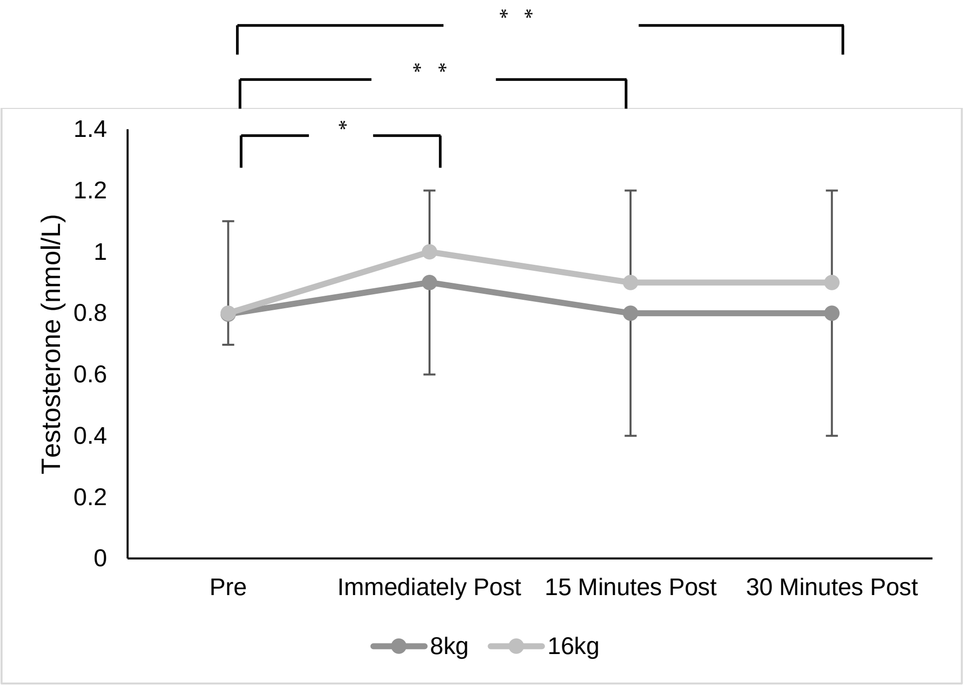
* *
* *
*
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Testosterone (nmol/L)
Pre
Immediately Post
15 Minutes Post
30 Minutes Post
8kg
16kg

Figure 6.