The Effects of Kettlebell Mass & Swing Cadence on Heart Rate, Blood Lactate and Ratings of Perceived Exertion during an Interval Kettlebell Swing Protocol

By

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Abstract

The purpose of this study was to determine the effects of kettlebell mass and swing cadence on heart rate, blood lactate and RPE during an interval kettlebell swing protocol in experienced female kettlebell users. Eighteen female participants completed 3 five-minute rounds of a 15-second on, 15-second off interval kettlebell swing protocol using an 8, 12 and 16 kg kettlebell on three separate testing sessions. Each testing session used a cadence of 8, 10 or 12 swing per 15 second interval (SPI^{15}). Mean values for heart rate, blood lactate and RPE were measured for each five minute round of each testing session. The results of the repeated measures analysis of variance revealed that significant main effects were found for kettlebell mass ($p < 0.05$) and swing cadence ($p < 0.05$) on both heart rate and RPE. No significant interaction effects were found between heart rate and RPE, however, interaction effects were found for blood lactate. Pairwise comparisons indicated that the blood lactate interaction effects occurred between the 8 and 12 kg kettlebell at each cadence level (8, 10, 12 SPI), and between the 8 and 10 SPI cadence while using the 8 kg kettlebell. The results revealed that the kettlebell swing, regardless of kettlebell mass or swing cadence, provided 'moderate' to 'vigorous' intensity exercise that was sufficient to increase cardiovascular health according to ACSM guidelines. The results suggest specific kettlebell swing mass and cadence combinations that can be implemented into a strength and conditioning program.

Review of Literature

Introduction

Since the turn of the new millennium, the kettlebell has seen a widespread re-emergence as a strength & conditioning tool amongst athletes, strength coaches and fitness enthusiasts. Many make anecdotal claims that the kettlebell is effective for increasing multiple parameters of athletic performance and fitness, however, the scientific literature is just now catching up. The present study describes the kettlebell, its history and the biomechanical and metabolic profile of the foundational movement, the kettlebell swing. In order to determine the effectiveness of the kettlebell swing, knowing the physiological responses at different intensity levels is critical. To date, no study has determined the effects of kettlebell mass and swing cadence on heart rate, blood lactate and ratings of perceived exertion. This study attempts to answer these questions by comparing variations in kettlebell mass and swing cadence on these physiological variables.

What is a Kettlebell?

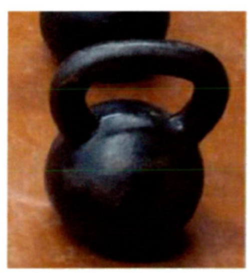

Figure 1. The Kettlebell. A 24 kilogram (kg) 'hardstyle' kettlebell.

A kettlebell (Figure 1) is a sphere shaped cast iron weight that resembles a cannonball with a handle attached. The kettlebell is used as a strength and conditioning tool that integrates multi-joint full body movements. The kettlebell differs from other training modalities as users work under a submaximal load completing many kettlebell lift repetitions over extended periods, usually in the form of intervals, as a result, blurring the line between 'traditional' cardiovascular and musculoskeletal training. The literature has shown that the kettlebell positively benefits muscular endurance (Manocchia et al., 2010), maximal strength and explosive power (Lake &

Lauder, 2012), however, the literature has shown contrary findings on the benefits of the kettlebell for increasing aerobic capacity. For example, Jay et al., (2010) found that aerobic capacity did not significantly increase during an 8 week, 3 times/week workplace kettlebell exercise intervention using basic kettlebell exercise progressions, whereas Falatic (2011) found a 6% increase in aerobic capacity between a control and experimental group ($p < 0.0125$) during a 4 week, 3 times/week intervention using a high intensity interval protocol in female varsity soccer players.

Kettlebell History

Kettlebells have been used for centuries as a strength and conditioning tool. The origin of the kettlebell is still a matter of speculation; however, archaeological records show evidence of their use in Ancient Greece (Sanchez, 2009, p.4). At the Archaeological Museum of Olympia in Athens Greece, a 143 kg kettlebell is stored with the inscription "Bibon heaved up me above a head by one hand" (p.4). Kettlebells made their way to Russia at the beginning of the 18th century, where in 1704, the word 'Girya' (meaning kettlebell), was first published in the Russian dictionary. From being used as a weight for market products, to a tool for health and athletic development, kettlebell lifting slowly developed into a sport of its own. By 1974 it had been officially declared the ethnic sport of Russia (Sanchez, 2009, p. 6) and in 1985 the first ever national kettlebell sport championships was held in Lipetsk, Russia. In 1981, the Russian government recognized the benefits of the kettlebell for increasing productivity and decreasing healthcare costs. As a result, an official commission was prompted, imposing compulsory kettlebell training for the population (Sanchez, 2009, p 7).

In the 1980's, special operation units of the Soviet military adopted a karate based style of kettlebell training, which evolved into what is now known as 'Hardstyle' (Tsatsouline, 2012). This approach to training stresses the importance of explosive power development, by performing all-out efforts for each kettlebell repetition, and is generally used as a form of general physical preparation (GPP) for athletes and fitness enthusiasts. It differs from other styles such as 'Sport style', where the main goal is energy conservation. In the latter part of the 20th century, 'Hardstyle' kettlebell training was introduced to North America. In 2001, Dragon Door Publications launched the Russian Kettlebell Challenge (RKC) instructor certification and began to manufacture kettlebells in America, resulting in the increasing prevalence of kettlebells in North America ever since. There are numerous movements one can do while training with kettlebells, such as the kettlebell snatch, clean & press, jerk, front squat, Turkish get-up, the kettlebell swing and its variations and others, however, this study focuses on the foundational kettlebell movement, the kettlebell swing.

The Kettlebell Swing

The kettlebell swing is considered a ballistic multi-joint movement, where the user accelerates and decelerates the kettlebell from between the legs up to chest level and back down between the legs. The kettlebell swing is considered ballistic in nature because of the alternating sequence of muscular tension and relaxation. A ballistic movement can be described as an explosive burst of muscular activity, followed by muscular relaxation as the motion of an object continues (Sanchez, 2009). As a result, the kettlebell swing develops explosive strength of the posterior chain musculature (Lake & Lauder, 2012; McGill & Marshall, 2012), while minimizing muscular hypertrophy due to minimal time under tension (Sanchez, 2009). The rapid muscular contraction and relaxation cycles during the kettlebell swing occur over half-second periods, specifically from inactive to 100% activation then back to almost complete relaxation (McGill & Marshall, 2012). It is suggested that the repetitive muscular contraction and relaxation cycles of the kettlebell swing works as a mechanism for reducing the accumulation of metabolic by-products (Jay et al., 2010), such as lactate and hydrogen ions, inorganic phosphate and adenosine di-phosphate (ADP) (Green, 1997). The relaxation portion of the swing allows these metabolite by-products to be cleared from the working muscles faster, therefore allowing swing performance to continue, reducing the effects of acidosis.

Mechanically, the kettlebell swing is similar to the barbell deadlift (Figure 2), as the hips hinge in a similar fashion (Cook & Jones, 2012).The power generated during the kettlebell swing is predominantly driven by the hips and the muscles of the posterior chain (Figure 3). The force during the swing originates from the ground up, commencing from the heels driving into the ground, up through the legs, hips, core, shoulders, arms, and extending beyond the hands as the kettlebell is projected out and upward, forming an extension of the straight arms at chest level. The force required to accelerate the kettlebell results in the recruitment of fast twitch muscle fibres to complete the movement (Fung, 2011), furthermore, McGill and Marshall (2012) found that the back extensors reached 50% of their maximal voluntary contraction (MVC) and 80% MVC for the gluteal muscles during the kettlebell swing using a 16 kg kettlebell. Additionally, Zebis et al., (2012) determined that the semitendinosus muscle reached 73 to 115% of MVC during the swing.

Figure 2. Kettlebell Swing vs. Barbell Deadlift. This picture demonstrates the mechanical similarities between the kettlebell swing and the barbell deadlift. The angles are not exact, however, the kettlebell swing is more similar to the barbell deadlift then it is to the barbell squat, which is a common misconception.

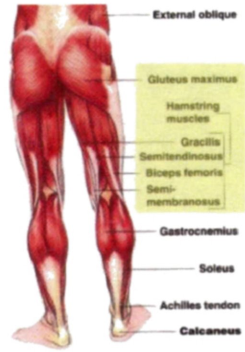

Figure 3. Muscles of the Posterior Chain. The muscles of the posterior chain include the erector spinae, the gluteus maximus, medius, and minimus, the semitendinosus, semimembranosus, biceps femoris, gastrocnemius, and soleus muscles.

Phases of the Kettlebell Swing

The kettlebell swing (Figure 4) can be broken down into four phases:

(i) The starting position/bottom swing

(ii) The eccentric acceleration/forward swing

(iii) The top swing

(iv) The concentric deceleration/backswing

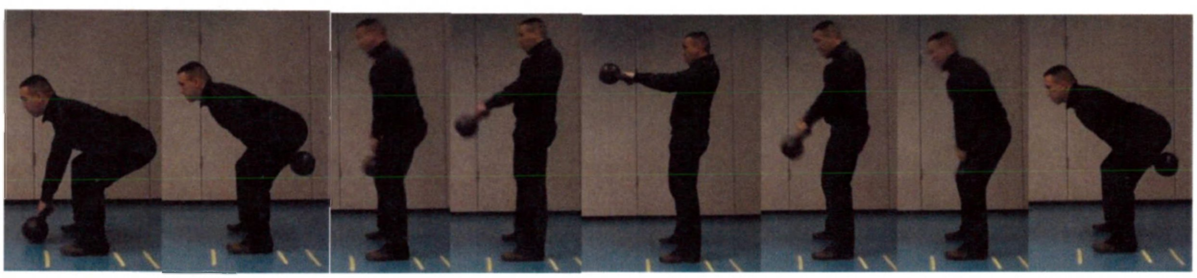

Figure 4. The Kettlebell Swing Sequence.

Starting Position/Bottom Swing. With the kettlebell approximately 30 centimeters anterior to the feet, the user assumes the preparatory deadlift position by hinging the hips posteriorly, causing the knees to flex. The spine remains neutral while the chest is out and forward by pulling the shoulders back and down, engaging the latissimus-dorsi muscles. The head and cervical spine remain neutral, or slightly extended. The user's weight is distributed over the entire foot. Grabbing the kettlebell handle with two hands, palms down, the user sharply inhales through the nose, and concentrically contracts the muscles to accelerate the kettlebell from the starting position back between the legs.

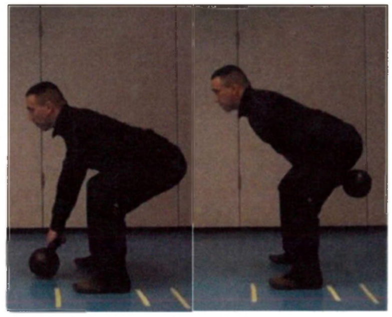

Figure 5. Kettlebell swing starting position (left), and the bottom position of the kettlebell swing (right).

Concentric Acceleration/Forward Swing. Once the kettlebell is back and between the legs, the kettlebell is projected up and forward in a curvilinear arc motion, by a powerful extension of the hip joint, causing the knees to also extend. At this stage the kettlebell accelerates from the concentric force of the posterior chain contraction, coasting up and outward to chest level from its own momentum, decelerating from the force of gravity and eccentric muscle action at chest level.

Figure 6. Forward swing. During the forward swing the kettlebell is projected forward and upward.

Top Swing. At this point the kettlebell has fully decelerated and momentarily floats prior to coming back down, forming an extension of the straight arms anterior to the body at chest level. The body forms a straight line as the hip and knee joints extend fully, creating a straight line from ankle to ear. At this point, the abdomen and the gluteal muscles visibly contract. This is referred to as 'Kime', which involves a 'pulse like' muscular contraction of the torso at the top of each kettlebell swing, stabilizing the spine, creating an "abdominal brace" of the core musculature (McGill & Marshall, 2012). Contracting all three layers of the abdominal wall, the erector spinae and the gluteal muscles has been proven to protect and stabilize the spine and discs (Kavic & McGill, 2004).

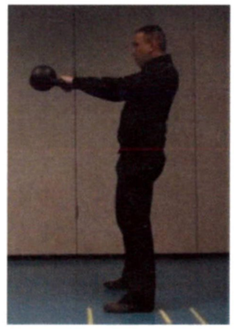

Figure 7. Top Swing. The kettlebell floats momentarily as the kettlebell forms an extension of the arms.

Eccentric Deceleration/Backswing. The kettlebell begins accelerating downwards between the legs while the hip and knee joints return to a flexed position. The kettlebell handle must pass above the knees during the backswing. When the kettlebell reaches back between the legs, the posterior chain muscles will decelerate the kettlebell and prepare to re-accelerate into the concentric acceleration phase for another repetition, or to be put down to complete the set.

Figure 8. The backswing. The kettlebell lowers eccentrically back to the bottom position.

Setting the Kettlebell Down Safely. Once the kettlebell user is done with the kettlebell swing set, they must safely set the kettlebell down on the ground. Following the deceleration of the eccentric phase, the user lets the bell passively swing forward slightly to set it down 30 centimeters anterior to the feet. The user must be sure not curve the back and to not relax until the kettlebell is safely set down on the ground.

Table 1

Features of the Kettlebell Swing.

Phase of Swing	Starting Position/ Bottom of Swing	Concentric Acceleration/ Forward Swing	Top of Swing	Eccentric Deceleration/ Backswing
Spine	Neutral, cervical spine also neutral or may slightly extend	Neutral	Neutral	Neutral
Shoulder/scapula	Shoulders 'packed', (retracted & depressed)	Retracted & depressed	Retracted & depressed	Retracted & depressed
Hips	Flexed	Forcefully contract	Fully extended, gluteus contracts	Flex posteriorly, not down.
Knees	The knees track over the toes	No forward knee movement/ankle dorsiflexion Knees extend	Fully extended, quadriceps contract by elevating patella	Knees flex, no forward knee movement.
Feet/Ankles	The heels, mid foot & toes are firmly planted	Feet drive into ground to produce force. Ankles do not dorsiflex	Firmly planted, toes grasp the ground	Firmly planted
Breathing	Sharp inhalation through nose	Forceful partial exhalation	Forceful partial exhalation	Sharp inhalation through nose

Metabolic Demands of the Kettlebell Swing

The kettlebell swing has been shown to deliver an adequate metabolic intensity to increase aerobic capacity and would be categorized as 'hard' exercise according to the American

College of Sports Medicine cardiovascular training guidelines (Farrar, Mayhew and Koch, 2010). Farrer et al., (2010) had participants (10 male subjects, age 20.8 ± 1.1 years) complete a 12 minute continuous kettlebell swing protocol. Working at their own pace and resting as needed, subjects completed as many swing repetitions as possible in the time allotted using a 16 kg kettlebell. They found that the kettlebell swing elicited a mean heart rate of 86.8 ± 6% of heart rate max, a VO_2 of 65.3 ± 9.8% of VO_2max and a mean respiratory exchange ratio (RER) of 1.00 ± 0.05. The mean swing count performed through the 12-minute protocol was 268 ± 68 swings (22 ± 6 SPM). Of the 10 male participants in this study, only one participant had experience with kettlebell training, and there is no mention that proper kettlebell swing instruction was presented to the participants, suggesting that kettlebell swing form may have varied among the participants.

Fung and Shore (2010), investigating the anaerobic and aerobic work during kettlebell exercise, conducted a maximal kettlebell stress test protocol. The researchers concluded that kettlebell exercise is high intensity work that is slightly more anaerobic than aerobic as seen by RQ> 1. They also noted that during exercise the RQ remained < 1 as long as kettlebell mass was less than or equal to 13% of body mass. Therefore, for a workout to stress only the aerobic energy system, it is recommended that kettlebell mass should be kept equal to or below this level of resistance. The maximal kettlebell stress test in this study consisted of progressive 3 minute stages of the two arm kettlebell swing, starting with a 4 kg bell, adding 4 kg per stage until exhaustion working at a 1:1 work/rest ratio of 30 seconds. Mean swing repetition counts, heart rate data for each stage and the stage the participants reached were not reported. The results showed a heart rate response of 95% of heart rate max and respiratory quotient (RQ) of 1.2 ± 0.08 in the final minute of a maximal kettlebell stress test protocol, however, the kettlebell mass of the last stage was not reported. Furthermore, kettlebell swing cadence was not controlled for in this study.

Hulsey, Soto, Koch and Mayhew (2012) compared the metabolic demand of the kettlebell swing, where13 subjects (11 male, 2 female, age 21.4 ± 2.1) completed a 10-minute kettlebell swing protocol consisting of 35 second swing intervals followed by 25 second rest intervals. Males used a 16 kg kettlebell and females used an 8 kg kettlebell. The subjects were not assigned a swing count for each interval, however they were told to maintain a steady rhythm and the numbers of swings were recorded. The kettlebell swing protocol resulted in an average heart rate of 180 ± 1.2 bpm and an RER of 0.95 ± 0.05. Gender was not controlled for in this study, and the two female participants used 8 kg kettlebells, half the size of male participant's 16 kg kettlebells. The researchers chose these masses as they are the recommended starting weights for males and females (Tsatsouline, 2006), for biomechanical reasons, however, no research has determined the differences physiologically between genders using these masses.

Jay, Frisch, Hansen, Zebis, Anderson, Mortenson and Anderson (2010) investigated the effectiveness of kettlebell swing progressions to improve cardiovascular health. Forty sedentary subjects were recruited. Three days per week for eight weeks, subjects completed interval training consisting of 10 intervals of 30 seconds with 30-60 second recovery periods. The intervals consisted of a progression of kettlebell swing exercises as follows: un-weighted swings, kettlebell deadlift, two handed kettlebell swing and the one handed kettlebell swing. Mass of the kettlebell increased as the participants graduated along the progression levels. Aerobic capacity remained unchanged after the 8 weeks of kettlebell swing training. Jay et al., (2010) attribute the lack of change in aerobic capacity to insufficient duration of cardiovascular stimulation.

Kettlebell Mass & Cadence Parameters

Two major factors contribute to the intensity level during the kettlebell swing: kettlebell swing cadence and kettlebell mass. Therefore, when training using the kettlebell swing, exercise intensity can be adjusted in three ways: (i) by increasing/decreasing the mass of the kettlebell,

(ii) by increasing/decreasing the cadence of the kettlebell swing (iii) or by increasing/decreasing both mass and cadence at the same time (Jay, 2009).

Kettlebell Mass Parameters. Traditionally, kettlebells are commercially manufactured in increments of 4 kilograms, starting from 4 kg all the way up to 48 kg (Figure 9).

Figure 9. RKC $^{(C)}$ Hardstyle Kettlebells. Starting at 8 kg, each kettlebell increases in size by 4 kg, ranging from 8 to 24 kg.

Due to the ballistic nature of the kettlebell swing, using a mass below 8 kg for females and 16 kg for males is not recommended (Tsatsouline, 2006). A mass below these levels promotes ineffective form as the kettlebell is so light that it stimulates an arm/shoulder dominated swing, rather than a hip dominated swing. During an arm/shoulder dominated swing, the kettlebell is lifted similar to a front raise shoulder exercise, and is not projected forward by the muscles of the posterior chain, therefore eliminating the ballistic projection of the kettlebell.

Kettlebell Swing Cadence Parameters. Kettlebell swing cadence can be measured in swings per minute (SPM) or swings per interval (SPI). For example, completing 40 continuous swings in 1 minute is considered a cadence of 40 SPM. Because the kettlebell swing is a ballistic movement, it is generally completed in time intervals less than 1 minute. Kettlebell swings in intervals of 15 seconds work to rest at a rate of 40 swings per minute (SPM), would also be considered 10 swings per interval (SPI), as only 10 swings would be completed in the 15 second time interval.

In terms of what are accepted swing cadence levels, the current literature is scarce. Glassman (2004), found a mean swing cadence of 47 swings per minute (SPM) when participants completed as many swings as possible in a one minute time frame. Hulsey et al., (2012), when using a 10 minute swing protocol of 35 seconds work to 25 seconds rest, found a mean swing cadence of 22-25 swings per 35 second interval (SPI), which corresponds to a swing cadence of 37 to 43 SPM. Due to the pendulum-like motion of the kettlebell swing, a natural swing frequency is produced, regardless of the kettlebell mass used. Lake and Lauder (2012) found that mean displacement remained the same among various kettlebell masses. A swing frequency below a certain threshold point would be too slow, as the projection of the kettlebell from the hips and posterior chain would be eliminated, and the shoulders and arms would raise the kettlebell similar to a deltoid front raise exercise. At the other end, fast swing cadence levels are only limited by the ability of the posterior chain to rapidly produce force and the anaerobic energy systems to maintain those cadence levels.

Swing cadences below a certain cadence level will utilize passive accelerations of the kettlebell during the backswing phase. This passive acceleration, as the kettlebell goes from chest level to back and down between the legs, is mostly accelerated by gravity. McGill and Marshall (2012) support this notion, stating that "gravity appeared to assist (in) most of the eccentric components of the swing" (p.23).

As kettlebell swing cadence is increased, and therefore the intensity of the kettlebell swing, an 'overspeed eccentrics' technique is utilized. Overspeed eccentrics refers to accelerating an object down faster than gravity does on its own (Jay, 2009). In addition to the ballistic concentric acceleration of the kettlebell during the forward swing phase (Table 1), an active acceleration of the kettlebell on the backswing is employed. Instead of letting the kettlebell accelerate downwards under gravitational forces, the user actively pulls the kettlebell down which increases the kettlebell speed and results in a greater speed of the eccentric muscle contraction of the posterior chain. Increases in force and velocity from eccentric contractions cause sensory muscle spindles to activate. It has been shown that the faster the muscle is stretched eccentrically, the greater the force will be on the following concentric contraction, due to the 'stretch reflex' phenomenon (Bosco & Komi, 1981). Therefore, in order to incorporate the 'stretch reflex' into the kettlebell swing, there must be (i) a fast backswing portion of the kettlebell swing and (ii) a rapid switch between the eccentric muscle contractions of the backswing into a concentric contraction of the forward swing. This is known as 'overspeed eccentrics'.

High Intensity Interval Training

High intensity interval training (HIIT) is accomplished through the use of intervals, and can be defined as repeated short to moderate duration (10 seconds to 5 minutes) exercise bouts at an intensity greater than the anaerobic threshold, separated by bouts of active rest and only allowing for partial recovery (Laursen & Jenkins, 2002). The purpose of HIIT is to perform repeated bouts at a velocity/cadence above the anaerobic threshold, stressing the physiological systems to a greater extent. In order to maintain this intensity, which is associated with increased lactate accumulation, muscular fatigue and decreased quality of performance, active rest intervals must be incorporated.

During HIIT bouts, phosphocreatine, glycogen and glucose become depleted, and their contribution as the main fuel source during subsequent interval bouts decreases, placing a greater demand on aerobic metabolism to meet this energy deficit (Gaitanos, Williams & Boobis, 1993). HIIT training has shown to improve aerobic capacity by enhancing the ability to resynthesize phosphocreatine sooner for the next interval bout and for the ability to oxidize the accumulation of lactic acid more efficiently through increased aerobic enzyme activity (Linossier, Dennis & Dormois, 1993). MacDougall, Hicks and MacDonald (1998) found that HIIT training significantly increased the activity of the aerobic enzymes citrate synthase , succinate dehydrogenase and malate dehydrogenase. As oxidative metabolism becomes more efficient, the reliance on phosphocreatine, muscle glycogen and blood glucose as the main source of ATP is decreased.

Benefits of HIIT Training. The main benefit of HIIT training is increased maximal stroke volume (Helgerud, Hoydal, Wang, Karlsen, Berg, Bjerkaas, Simonsen, Helgesen, Hjorth, Bach & Hoff, 2007; Brurok, Helgerud, Karlsen, Leivseth & Hoff, 2011). The increase in stroke volume is due to an increase in ventricular muscle contractility in which the overall size and volume of the chambers is enlarged (eccentric hypertrophy) (Jay, 2009). Helgurud et al., (2008) found that stroke volume increased by 10% over an 8 week period while performing an interval running protocol at 90-95% of HRmax three times per week. Additionally, Brurok, Helgerud, Karlsen, Leivseth and Hoff (2011) saw peak stroke volume increase 77.7 to 103.4 ml/beat (33%) over an 8 week period during interval arm ergometer exercise at 85-95% of maximum power output three times per week in subjects with serious spinal cord injury. An increase in stroke volume is beneficial as the heart becomes more efficient at supplying much needed oxygen to the working muscles. Moderate intensity continuous training, as compared to HIIT training, does not result in the same central cardiovascular adaptations (Laursen & Jenkins, 2002).

Moderate intensity continuous exercise protocols are a common training method for developing cardiovascular capacity, however, research indicates that vigorous intensity interval exercise (85-95% of HRmax) results in greater increases in cardiovascular capacity than does moderate intensity continuous exercise (Gormley, Swain, High, Spina, Dowling, Kotipalli & Gandrakota, 2008; Helgerud, Hoydal, Wang, Karlsen, Berg, Bjerkaas, Simonsen, Helgesen, Hjorth, Bach & Hoff, 2007).

Helgerud et al., (2007) found that high intensity interval running protocols at 90-95% of HRmax were significantly more effective at improving cardiovascular capacity than were moderate intensity continuous running at 70-85% of HRmax. Furthermore, Rognmo, Hetland, Helgerud, Hoff & Slordahl (2003) found high intensity interval treadmill exercise (80-90%

VO_2max) to be superior to moderate intensity treadmill exercise (50-60% VO_2max) for increasing cardiovascular capacity in patients with stable coronary arterial disease where cardiovascular capacity increased by 17.9%, compared to the 7.9% increase in the moderate intensity group ($p < 0.038$). Additionally, Thomas et al., (1984) supports that interval running at 90% of HRmax has the advantage of increasing aerobic capacity more effectively than continuous running at 75% of HRmax.

Additionally, HIIT training benefits anaerobic capacity, while simultaneously increasing aerobic capacity (Tabata et al., 1996). Using a cycle ergometer, Tabata et al. (1996) had subjects complete 8 intervals of 20 seconds on, 10 seconds rest at an exhaustive pace, 5 days per week for 6 weeks. Aerobic capacity increased by 7 ml/kg/min and anaerobic capacity increased by 28%. MacDougall, Hicks & MacDonald (1998) over 4 weeks of HIIT training, saw an increase in the enzyme activities of citrate synthase, hexokinase, phosphofructokinase (PFK), succinate dehydrogenase and malate dehydrogenase, key enzymes responsible for both anaerobic and aerobic metabolism. Furthermore, Rodas, Ventura & Cadefau (2000), saw increases in creatine kinase (+44%), PFK (+106%), lactate dehydrogenase (+45%), 3-hydroxyacyl coenzyme A dehydrogenase (+60%) and citrate synthase (+38%), during HIIT training 3 days per week for two weeks.

HIIT training may also be more effective for fat oxidation when compared to moderate intensity continuous training as more lipids and less glycogen are used during intervals (Hagenfeldt & Kaijser, 1977). Billat (2001) saw increases in the oxidative capacity of type II fast twitch muscle fibres during HIIT training, as the activity of the enzymes succinate dehydrogenase and cytochrome oxidase increased. In a study conducted on rats, Chilibeck, Bell & Farrar (1998) found that mitochondrial fatty acid oxidation rates increased to a greater extent after HIIT training than it did for continuous submaximal intensity training.

High Intensity Interval Kettlebell Protocols

In the published text, *Viking Warrior Conditioning*, Jay (2009) presented the 15:15 VO_2max protocol. This high intensity interval protocol, with a 15 second work to rest ratio, was designed to increase cardiovascular and anaerobic work capacity using the one arm kettlebell snatch. The protocol has the user snatch a single kettlebell one handed from back between the legs to an overhead locked out position in one uninterrupted motion, and back down at an 'overspeed eccentrics' cadence, stimulating a near maximal intensity. Females use a 12 kg kettlebell and males use a 16 kg kettlebell. The cadence is predetermined by a 5 minute incremental kettlebell snatch test.

Schnettler, Porcari and Foster (2010) conducted a study to determine the intensity of the kettlebell snatch 15:15 VO_2max protocol. Ten participants (8 males, 2 females, mean age = 36.9 ± 5.9), experienced in kettlebell training, completed 20 minutes of the protocol as outlined by Jay (2009). The researchers reported a heart rate maximum of 93 ± 4.5% (164 ± 14.7 bpm), a VO_2maximum of 78% (31.6 ± 3.71 ml/kg/min), a caloric expenditure of 13.6 ± 3.08 kcal/min, a RPE value 15.9 ± 2.21, and a blood lactate concentration of 7.8 ± 3.6 mmol. From these results, Schnettler et al., (2010) showed that kettlebell snatch intervals are sufficient for improving cardiorespiratory capacity based on ACSM guidelines.

Falatic (2011) conducted a follow up study to determine if the 15:15 interval snatch protocol (Schnettler et al., 2010) would indeed increase cardiovascular capacity over a 4 week period, training 3 times per week. Eighteen female collegiate soccer players (mean age = 19.7 ± 1.1) participated in the study, using a 12 kg kettlebell. The results indicated that the kettlebell snatch intervals significantly improved maximal oxygen uptake by 6%, suggesting that athletes who use kettlebells in their exercise program can potentially increase aerobic capacity in a short period of time by using the high intensity interval kettlebell snatch protocol.

Research Problem

The kettlebell swing is a ballistic multi-joint movement requiring full body integration to complete multiple powerful repetitions over extended periods of time. It has been shown to provide a cardiovascular intensity sufficient enough to promote and increase cardiovascular and overall health (Farrer et al., 2010; Fung & Shore, 2010; Hulsey et al., 2012), however, a limitation of the previous kettlebell swing research is that exercise intensity was not controlled. This makes it difficult to compare studies in regards to the physiological responses seen, and limits the ability to make recommendations from the results for improving fitness and performance.

The intensity of the kettlebell swing can be altered by either adjusting the kettlebell mass, and/or the speed of the kettlebell swing (swing cadence). To date, no study has examined the physiological effects of altering the intensity of the kettlebell swing. Knowing the effects of variations in kettlebell mass and swing cadence, both as independent and integrated factors, on physiological responses such as heart rate, blood lactate and RPE may help in the design of appropriate training protocols. In order for a HIIT protocol to be beneficial, the intensity level must be above the anaerobic threshold (Laursen & Jenkins, 2002). Determining if the intensity of the kettlebell swing is above the anaerobic threshold can be done by examining the cardiovascular and blood lactate response at various kettlebell swing intensities. To date, no study has examined the effects of varying kettlebell mass & swing cadence levels on heart rate, blood lactate and RPE during the kettlebell swing using a high intensity interval kettlebell swing protocol.

Purpose Statement

The purpose of this study was to determine the effects of kettlebell mass and swing cadence on heart rate, blood lactate and RPE during an interval kettlebell swing protocol in experienced female kettlebell users.

Research Questions

1. What effect does varying the kettlebell mass have on exercise intensity (as measured by percentage of maximum heart rate and heart rate reserve, blood lactate accumulation and ratings of perceived exertion) during a high intensity interval kettlebell swing protocol.
2. What effect does varying the kettlebell swing cadence have on exercise intensity during a high intensity interval kettlebell swing protocol?
3. Is there an interaction effect on exercise intensity when varying both kettlebell mass and swing cadence during a high intensity interval kettlebell swing protocol?

Hypotheses

1. Four kilogram kettlebell mass increments will result in significant increases in cardiovascular response, blood lactate and ratings of perceived exertion during an interval kettlebell swing protocol.
2. Kettlebell swing cadence increments will result in significant increases in heart rate, blood lactate and ratings of perceived exertion during an interval kettlebell swing protocol.
3. Increases in both kettlebell mass and kettlebell swing cadence will not result in significant interaction effects in heart rate, blood lactate and ratings of perceived exertion during an interval kettlebell swing protocol.

Methods

Participants

Eighteen female participants (Age = 30 ± 9.6 years, Height = 165.5 ± 7.4 cm, Mass = 68.2 ± 9 kg) were recruited from a fitness facility in Thunder Bay, Ontario, that offers kettlebell classes conducted by a certified Russian Kettlebell Challenge (RKC) instructor. All participants were previously instructed in performing proper kettlebell swing technique, and were required to have a minimum of three months experience in kettlebell training to participate in the study. In order to maintain homogeneity in the sample, only female participants were selected. A female sample was also chosen based on convenience, as there was a higher prevalence of potential participants who were female. All participants were screened by a Physical Activity Readiness Questionnaire (Appendix D) and a Movement Clearance Test (Appendix E) prior to participation in the study. Prior to data collection, ethical approval was received from the Lakehead University Research Ethics Board and biosafety ethical approval was also received for the blood lactate sampling procedures from the Lakehead University Biosafety Committee.

Testing Procedures

Testing Protocol. Testing took place in the Exercise Physiology Laboratory (SB 1025) in the School of Kinesiology at Lakehead University. This is a large, open space appropriate for kettlebell training. The procedure required the participants to attend three separate testing sessions each lasting between 60 and 75 minutes in duration, with a minimum of 48 hours between testing sessions. Each testing session was comprised of three 5 minute rounds of an interval kettlebell swing protocol. For each round of each testing session, the participants used an 8, 12 or 16 kg kettlebell to measure the effects of varying kettlebell mass. The kettlebell mass was randomized to control threats to internal validity. Each of the three testing sessions used a different cadence level, which were 8 swings per 15 second interval (SPI^{15}), 10 SPI^{15}, or 12 SPI^{15}, and was also randomized among each of the three sessions. Each participant completed the testing individually. To help ensure reliability during the testing, each testing session occurred at approximately the same time of day; furthermore, the participants were asked to observe the following guidelines:

- Do not eat a substantial meal within 5 hours before the test
- Abstain from alcohol 24 hours before the test
- Abstain from coffee, tea, or other caffeine sources for at least 1 hour before the test
- Do not train or do high intensity physical work for 24 hours prior to the test.

If any of the above guidelines were not adhered to on the day of testing, the participant was asked to return to complete the testing on another day.

Baseline Measurements. Participant's body mass (kg) was measured using a digital scale and height (cm) was taken using a wall mounted Health O Meter Height Rod. Resting heart rate (bpm) and resting blood lactate (mmol/l) were measured at the beginning of each session after having the participant lie supine on the floor for 5 minutes (Jouvonen, 2005) prior to commencing the testing protocol. The supine position is preferred when measuring resting heart rate, as heart rate has been shown to be 1 to 2 bpm lower when compared to other body positions (Vogel, Wolpert, & Wehling, 2004). Age predicted maximal heart rate was estimated for each participant using the Inbar method [205.8 – (0.685 x age)] (Inbar, Oten, Scheinowitz, Rotstien, Dlin & Casaburi, 1994). This method was selected for use in this study based on the findings of Robergs and Landwehr (2002), who evaluated 43 age-predicted maximal heart rate formulae in order to provide recommendations on which formula to use and when. Based on their extensive review, the authors determined that the Inbar method (205.8 – (0.685 x age)] was the most accurate, with a standard error of 6.4 bpm. For purposes of prescribing training heart rate ranges, the authors stated that standard errors less than 8 bpm are acceptable. Out of the 43 formulae evaluated, the Inbar method was the only formula below this acceptable range.

Warm Up. A standardized 10 minute warm up was completed prior to testing, and involved a general warm up and a kettlebell specific joint mobility/dynamic stretching complex as adapted from Tsatsouline (2012) (see Appendix F). The general warm up, designed to increase core body temperature, consisted of 5 minutes on a cycle ergometer at a resistance of 2% of body weight at 60 revolutions per minute paced by a metronome. The 5 minute kettlebell specific joint mobility/dynamic stretching warm up emphasized the major muscles groups and joints used while executing the kettlebell swing, including the muscles and joints of the neck, shoulders, elbows, wrists, back, abdominals, hips, hamstrings, quadriceps, knees and ankles.

Following the general and specific warm up, in order to prepare for the cadence level used during the upcoming testing session, participants completed one 15 second swing interval at the specified cadence, using a 12 kg kettlebell. The participants were then given a 5 minute period before the testing protocol commenced.

The Interval Kettlebell Swing Protocol

Each testing session consisted of 3 rounds of an interval kettlebell swing protocol, lasting 5 minutes each, with each round utilizing a different mass kettlebell. The mass of the kettlebell for each round was randomly 8, 12 and 16 kilograms. Each round involved 10 intervals of 15 seconds work, followed by 15 seconds of rest, utilizing the two arm kettlebell swing. The participants were then given a 10 minute active recovery between rounds and were encouraged to stay loose by walking around. The purpose of the 10 minute recovery was to ensure that the participant's heart rate returned to resting levels before commencing the next round. The participant was required to swing the kettlebell with two hands back between the legs and concentrically accelerate it forward and up to chest level and back down between the legs. The number of kettlebell swing repetitions for each 15 second interval was paced to a metronome and randomly varied between each of the three testing sessions from 8 swings per 15 second interval (SPI), 10 SPI, or 12 SPI. For each swing cadence, the metronome was set at 64 bpm (8 SPI), 80 bpm (10 SPI) and 96 bpm (12 SPI), producing two beats per swing, one at the top swing and one at the bottom swing. The 15 second interval cadence (8, 10, & 12 SPI) for each of the three testing sessions was determined by a pilot study prior to the initial data collection, which ensured that the participants could complete each stage of the protocol for each kettlebell mass.

Participants were encouraged to go as long as possible, or until exhaustion. They were also told that they could withdraw from the testing protocol at any time. To ensure the safety of the participants, if the proper kettlebell swing mechanics could no longer be maintained, such as a neutral spine, retracted and depressed scapula and proper hip hinge mechanics (see Table 1), the participants were told to stop. All participants, however, completed each round of each session successfully at the specific cadence level and proper form was maintained.

Data Collection. Throughout the testing protocol, heart rate was measured and recorded at 15 and 45 seconds of each minute using a Polar RS 400 Heart Rate Monitor and chest strap. Immediately upon completion of each 5 minute round of the interval swing protocol, a rating of perceived exertion (RPE) was assessed using the 6-20 Ratings of Perceived Exertion Borg Scale (Appendix G). Lactate measurements were also taken immediately at the end of each 5 minute round of the protocol from the participant's fingertip using a Lactate Pro Portable Analyzer (Appendix C).

Lactate Pro Portable Analyzer Reliability and Validity. Pyne, Boston, Martin and Login (2000) evaluated the accuracy and reliability of the Lactate Pro Lactate Analyzer used in the current study and found that it is accurate, reliable and exhibits a high degree of agreement with other lactate analysers. Capillary blood samples were drawn from elite athletes and analyzed in relation to three other lactate analyzers, the ABL 700 Series Acid-Base Analyser (n=172), the Accusport Lactate Meter (n=118), and the YSI 2300 Stat Lactate Analyser (n=22 cases). The correlations between the Lactate Pro and the ABL 700 Series Acid-Base analyser, YSI 2300 and Accusport were $r = 0.98$, $r = 0.99$, $r = 0.97$, respectively. The correlation between the two Lactate Pro analysers on the same sample ($n = 96$) was $r = 0.99$.

Cool Down. After the testing protocol, participants performed a cool down consisting of 3 minutes on the cycle ergometer and static stretching focusing on the major muscle groups emphasized during the testing protocol, specifically, the muscles of the hamstrings, quads, hips, back, shoulders, neck and arms. They then remained on site until their heart rate lowered below a level of 100 beats per minute and their blood pressure had lowered below a value of 144/94 (Canadian Society for Exercise Physiology, 2003).

Kettlebell Masses Used for Testing. Due to the ballistic nature of the kettlebell swing, a weight lower than 8 kg for females is not recommended (Tsatsouline, 2006), as weights lower than this can promote ineffective form as the participant will be able to 'muscle' the weight up to chest level with their shoulders, eliminating the need for posterior chain activation to accelerate the bell.

Tsatsouline (2006) recommended that novice females start with a weight that is 8 kg (18 lbs.). Therefore, for the purposes of this study, we investigated the effects of kettlebell mass and kettlebell swing cadence on heart rate, blood lactate and ratings of perceived exertion with an 8 kg kettlebell, a 12 kg kettlebell and a 16 kg kettlebell in female participants between the ages of 18 and 48. Traditionally, kettlebells are commercially manufactured in increments of 4 kilograms, preventing the use of smaller increments.

Statistical Analysis. This study utilized a 3 (resistance) by 3 (swing cadence) repeated measures ANOVA design. Descriptive statistics, along with standard deviations, were calculated for participant age, height, mass, maximum heart rate (HRmax), resting heart rate, heart rate reserve and resting blood lactate (mmol/l). Predicted maximum heart rate was determined using the Inbar Method [205.8 – (0.685 x age)]. Descriptive statistics during each kettlebell mass and swing cadence for average heart rate, percentage of maximum heart rate (% of HRmax), percentage of heart rate reserve (HRR%), blood lactate and ratings of perceived exertion (RPE) along with standard deviations, were calculated. Average heart rate was determined as the average heart rate during the final minute of each 5 minute round. Statistical significance among the three kettlebell mass levels (8, 12, & 16 kg) and swing cadence levels (8 SPI, 10 SPI, and 12 SPI) were also measured using a repeated measures ANOVA. A Bonferroni's post hoc analysis was further used to determine where any significant differences occurred in heart rate, blood lactate and RPE between each level of kettlebell mass and swing cadence. Statistical significance was set at the $p < 0.05$ level. Pairwise comparisons were conducted on significant interaction effects.

Results

Physical and Anthropometric Characteristics

Physical and anthropometric of the participants are presented in Table 2.

Table 2

Physical Characteristics of the Participants (n = 18)

Variable	Mean ± SD	Range	Min – Max Value
Age (years)	30 ± 9.6	30	18 – 48
Height (cm)	165.5 ± 7.4	29	150 – 179
Weight (kg)	68.2 ± 9.0	33.9	46.1 – 80.0
Age Predicted Maximum Heart Rate (bpm)	184.8 ± 6.5	20	173 – 193
Resting Heart Rate (bpm)	63.9 ± 10.9	36	48 – 84
Heart Rate Reserve (bpm)	121 ± 14.4	48	93 -141
Resting Lactate (mmol/l)	1.1 ± 0.4	1.4	0.8 – 2.2

Values are presented as mean ± SD
*Max heart rate was predicted using the Inbar Method [205.8 – (0.685 x age)].

Descriptive Statistics

The mean heart rate and standard deviations in beats per minute (bpm) are presented for each swing cadence and kettlebell mass level in Table 3. Kettlebell swing cadence is presented in swings per 15 second interval (SPI), at a rate of 8, 10, or 12 SPI. Kettlebell mass is presented as 8, 12, or 16 kilograms (kg). Mean heart rate was determined as the mean of the means for each participant (n = 18) in the last minute of each 5 minute round. As cadence and mass was increased, increases average heart rate, blood lactate and RPE was seen.

Table 3

Mean Heart Rate in beats per minute (bpm)

Cadence	8 kg	12 kg	16 kg
8 SPI	124 ±16	135 ± 17	145 ± 16
10 SPI	132 ± 17	143 ± 17	153 ± 15
12 SPI	154 ± 15	165 ± 14	172 ± 11

Values are present as mean ± SD

Blood Lactate/RPE. Mean blood lactate in mmol/l and ratings of perceived exertion (RPE) values with standard deviations are presented in Tables 4 and 5, respectively. The data from the tables suggest that as cadence and kettlebell mass increased, blood lactate and RPE also increased.

Table 4

Blood Lactate Values (mmol/l)

Cadence	8 kg	12 kg	16 kg
8 SPI	1.7 ± 0.9	2.0 ± 1.1	2.9 ± 1.3
10 SPI	2.0 ± 1.2	2.6 ± 1.3	4.0 ± 1.9
12 SPI	3.6 ± 2.3	4.9 ± 2.4	6.9 ± 3.1

Values are presented as mean ± SD

Table 5

Mean Ratings of Perceived Exertion (RPE) Values

Cadence	8 kg	12 kg	16 kg
8 SPI	8.1 ± 1.5	10.7 ± 1.8	12.8 ± 1.3
10 SPI	9.1 ± 2	11.9 ± 1.4	14.1 ± 1.3
12 SPI	12.5 ± 1.7	15 ± 1.7	17.1 ± 1.4

Values are present as mean ± SD

Main Effects of Kettlebell Mass on Heart Rate, Blood Lactate and RPE

The repeated measures analysis of variance revealed a main effect for kettlebell mass amongst each of the three dependent variables (average heart rate: $F(2, 34) = 145.287$, $p < 0.05$, eta = 0.895: blood lactate: $F(2, 32) = 63.008$, $p < 0.05$, eta = 0.797, and RPE: $F(2, 34) = 247.03$, $p < 0.05$, eta = 0.936). A post hoc Bonferroni's analysis was performed to determine where the significant differences occurred for each of the three kettlebell mass levels on each of the three dependent variables. Because this study used three dependent variables, the Bonferroni's post hoc analysis significant level was corrected to the $p < 0.0167$ level ($0.05/3 = 0.0167$).

The Bonferroni's post hoc analysis revealed that as kettlebell mass increased by 4 kilograms, heart rate significantly increased between all three levels of kettlebell mass. The post hoc analysis revealed that the difference from the 8 kg kettlebell (137 ± 4 bpm) to 12 kg kettlebell (148 ± 4 bpm) was 11 ± 1 bpm and significant at the $p < 0.001$ alpha level. The difference between the 12 kg to 16 kg kettlebell (157 ± 3 bpm) mass was also significant ($p < 0.001$) with a difference of 9 ± 1 bpm. The mean difference from the 8 kg kettlebell mass to the 16 kg kettlebell mass was 20 ± 2 bpm, and was also significant ($p < 0.001$).

The Bonferroni's post hoc analysis for kettlebell mass main effects on blood lactate revealed significant differences among all three levels of kettlebell mass on blood lactate. The Bonferroni's post hoc analysis revealed a mean significant difference from the 8 kg (2.5 ± 0.3

mmol/l) to the 12 kg kettlebell (3.2 ± 0.3 mmol/l) of 0.8 ±0.1 mmol/l, $p < 0.001$. The difference between the 12 kg to 16 kg kettlebell (4.6 ± 0.5 mmol/l) mass was also significant with a mean difference of 1.4 ± 0.2 mmol/l, $p < 0.001$. The significant difference from the 8 kg to the 16 kg kettlebell mass was 2.1 ± 0.2 mmol/l, $p < 0.001$.

The Bonferroni's post hoc analysis for kettlebell mass main effects on RPE also revealed significant differences between all three levels of kettlebell mass. The significant difference in RPE from the 8 kg (10 ± 0.3) to12 kg kettlebell (12.6 ± 0.3) was 2.6 ± 0.2, $p < 0.001$. The difference between the 12 kg to 16 kg kettlebell (14.7 ± 0.3) mass was also significant with a RPE difference of 2.1 ± 0.2, $p < 0.001$. The RPE difference from the 8 kg to the 16 kg kettlebell mass was 4.8 ± 0.3, $p < 0.001$.

Main Effects of Swing Cadence on Heart Rate, Blood Lactate and RPE

The results from the repeated measures ANOVA performed to determine if there were differences in kettlebell swing cadence (8, 10, & 12 SPI) resulted in significant differences between each of the three dependent variables (average heart rate: $F(2, 34) = 97.302$, $p < 0.05$, eta = 0.851: blood lactate: $F(2, 32) = 33.273$, $p < 0.05$, eta = 0.675, and RPE: $F(2, 34) = 118.3$, $p < 0.05$, eta = 0.874. A Bonferroni's post hoc analysis was performed to determine where the significant differences occurred for each of the three swing cadence levels (8, 10, 12 SPI) on each of the three dependent variables. As with kettlebell mass, the Bonferroni's post hoc analysis significant level was corrected to the $p < 0.0167$ level (0.05/3 = 0.0167). As with kettlebell mass, swing cadence saw significant differences among all three swing cadence levels for each of the three dependent variables, however, unlike kettlebell mass, the increase in the physiological variables from 10 to 12 SPI was much larger than the increase from 8 to 10 SPI.

The Bonferroni's post hoc analysis revealed significant differences among all three levels of swing cadence on average heart rate. Heart rate increased significantly from 8 SPI (135 ± 4 bpm) to the 10 SPI (143 ± 4) ($p < 0.003$), with further significant increases seen from 10 SPI to

12 SPI (164 ± 3 bpm) ($p < 0.001$) with a difference of 21 ± 2 bpm. The significant increase from 8 SPI to 12 SPI reflected a mean difference of 29 ± 2 bpm ($p < 0.001$).

The Bonferroni's post hoc analysis for swing cadence revealed significant differences among all three levels of swing cadence on blood lactate. Swing cadence increased significantly from 8 SPI (2.2 ± 0.2 mmol/l) to 10 SPI (2.9± 0.4) of 0.7 ± 0.2 mmol/l ($p < 0.006$), with significant increases also seen from 10 SPI to 12 SPI (5.3 ± 0.6 mmol/l) ($p < 0.001$) with a difference of 2.4 ± 0.4 mmol/l. The significant increase from 8 SPI to 12 SPI was a mean difference of 3.0 ± 0.5 mmol/l ($p < 0.001$).

The post hoc Bonferroni's test revealed significant differences among all three swing cadence levels on RPE. RPE was significantly greater at 10 SPI (11.7 ± 0.3) as compared to 8 SPI (10.6 ± 0.3) ($p < 0.005$) with a mean difference of 1.1 ± 0.3. Similarly, RPE was significantly greater at 12 SPI (14.9 ± 0.3) as compared to 10 SPI ($p < 0.001$) with a difference of 3.0 ± 0.3. The significant increase from 8 SPI to 12 SPI reflected a mean difference of 4.3 ± 0.3 ($p < 0.001$).

Interaction Effects

There was no interaction effect between kettlebell mass and swing cadence for average heart rate, $F(4, 68) = 1.122$, $p = 0.354$, eta = 0.062 (Figure 10). Similarly, there was no interaction between kettlebell mass and swing cadence on RPE, $F(4, 68) = 0.316$, $p < 0.866$, eta = 0.018 (Figure 11).

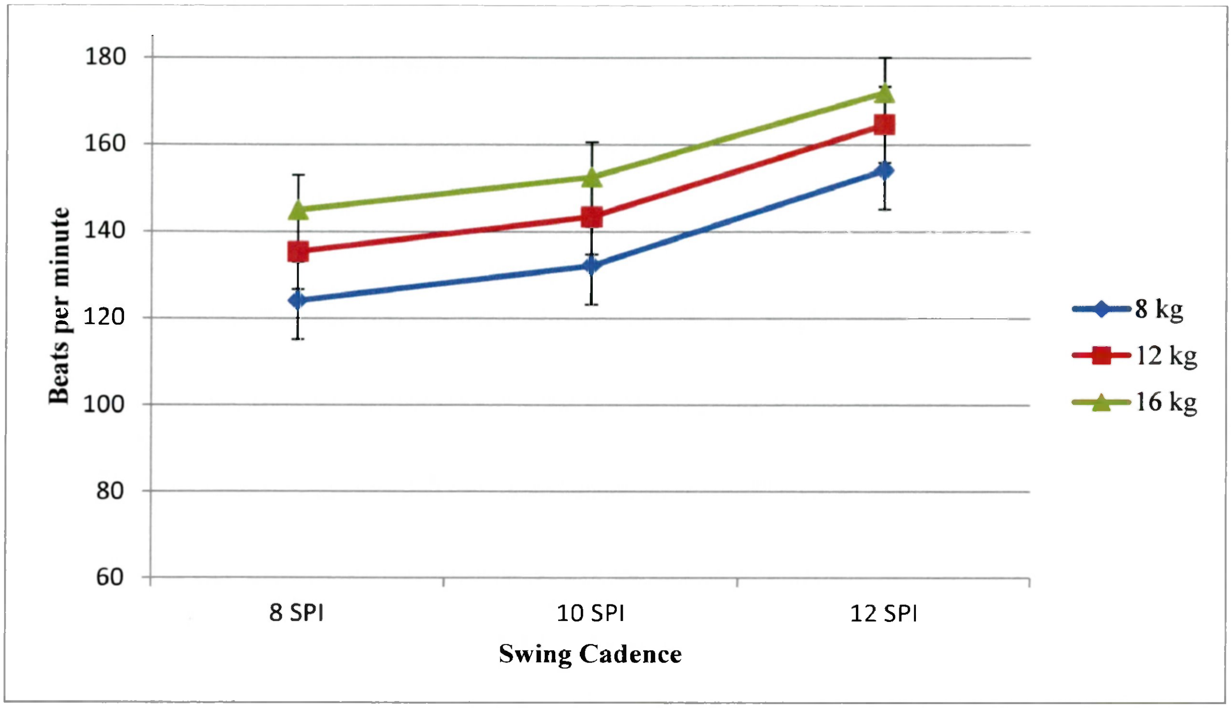

Figure 10. Mean Heart Rate for each kettlebell mass and swing cadence. Mean heart rate was taken from the mean of the means of each participant from the last minute of each 5 minute round.

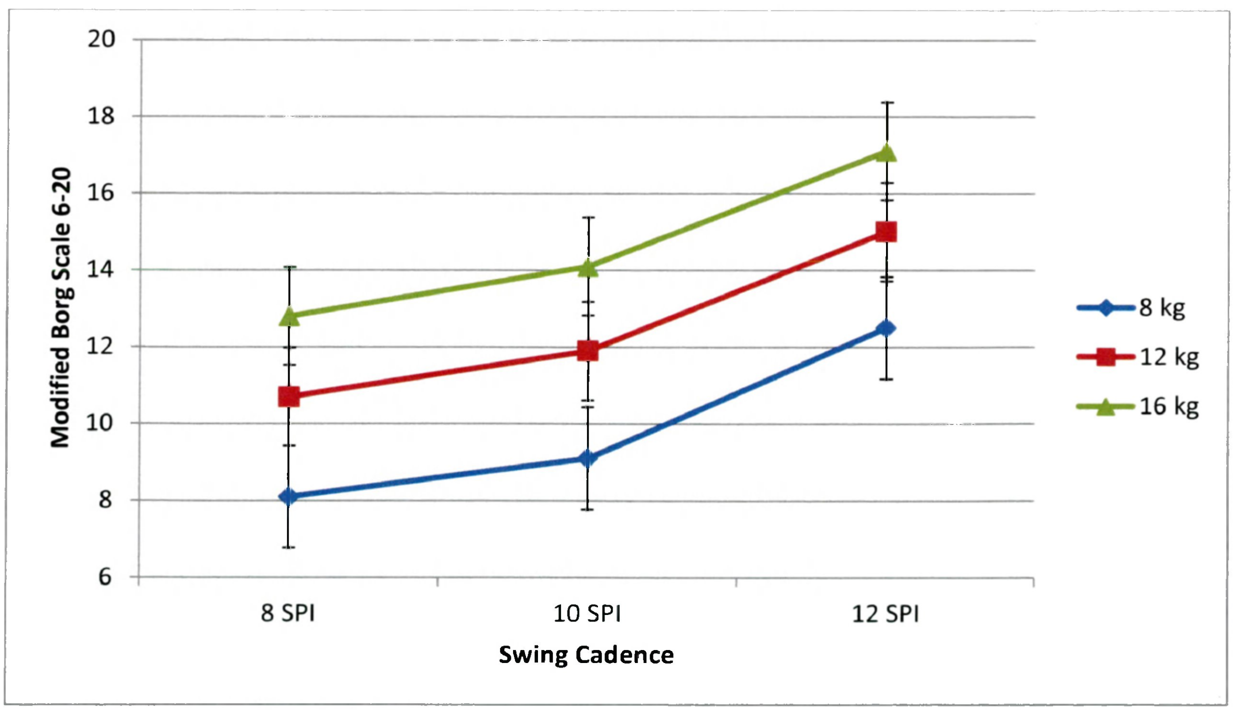

Figure 11. Ratings of Perceived Exertion (RPE). RPE values for each swing cadence and mass level using the Borg 6-20 scale.

An interaction effect was found between kettlebell mass and swing cadence for blood lactate, $F(4, 64) = 6.621$, $p < 0.001$, eta = 0.293 (Figure 12). Pairwise comparisons were run between each kettlebell mass at each swing cadence in order to determine where the interactions occurred. The results revealed that there was no significant difference in blood lactate between the 8 and 12 kg kettlebell mass at each of the three swing cadence levels (8, 10 and 12 SPI) ($p > 0.05$). Furthermore, the results revealed that blood lactate did not significantly differ from the 8 SPI to the 10 SPI level when using the 8 kg kettlebell ($p > 0.05$), however, significant differences were found between the 8 and 10 SPI cadence level when using the 12 and 16 kg kettlebells ($p < 0.05$).

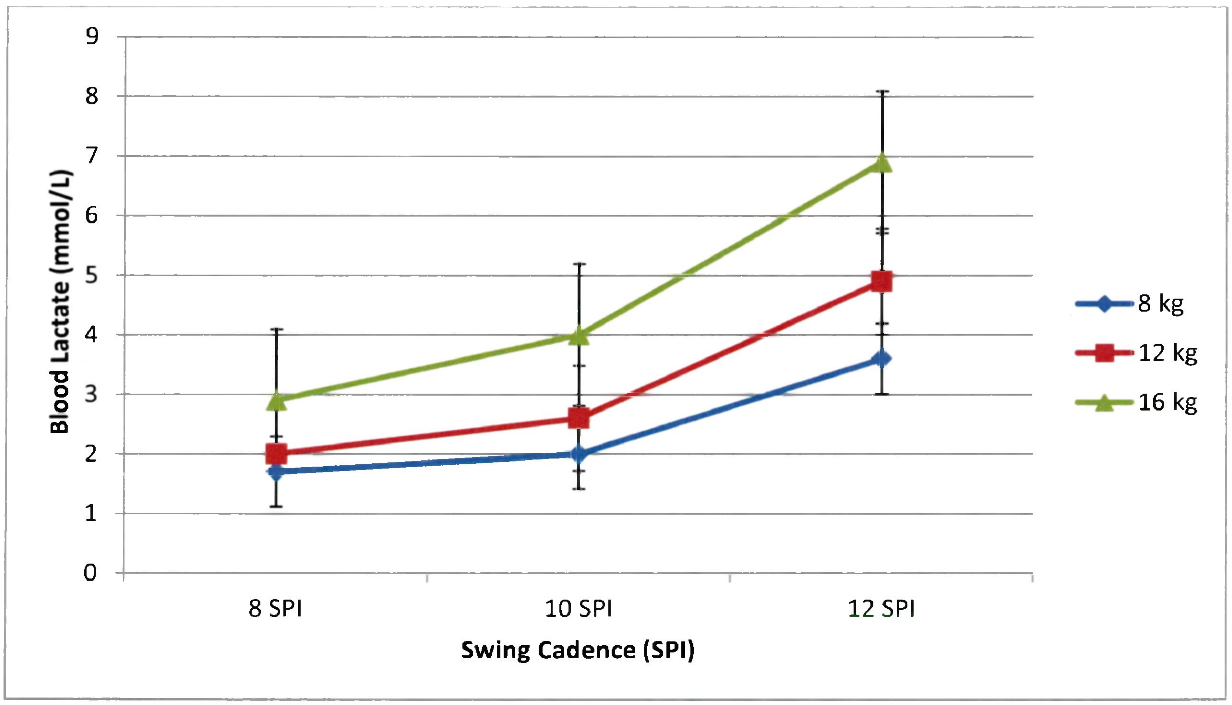

Figure 12. Blood Lactate Values. The lactate values for each swing cadence and mass level.

Discussion

Given the lack of published research on the kettlebell and its use as a training tool, this study attempted to determine how varying kettlebell mass and swing cadence would influence heart rate, blood lactate and RPE during kettlebell swing intervals. It was hypothesized that higher kettlebell mass and swing speeds would result in greater heart rates, blood lactate accumulation, and subjective effort, and the results revealed this to be true. These results were not surprising, as higher KB mass and/or faster swing speeds equates to greater power output and consequently increased HR, blood lactate and RPE. It was further hypothesized that no interaction effects would be seen as mass and cadence increased; however, statistically significant interactions were detected for blood lactate at the lower workloads, and the blood lactate gap increased as mass and cadence increased.

The current study was the first to determine the effects of both kettlebell mass and swing cadence on the physiological response to kettlebell swing exercise. Kettlebells are traditionally manufactured in 4 kilograms increments, although 2 kg increments are now seen. As heart rate, blood lactate and RPE were found to increase significantly as the kettlebell mass was increased by 4 kilograms, the smaller 2 kg increments may be justifiable from a physiological perspective. For example, kettlebell users seeking to gradually increase cardiovascular intensity during subsequent training sessions can implement 2 kg increases, progressively overloading the intensity level without drastic increases in the physiological response. The limited research on the effects of kettlebell mass variations has focused on biomechanical factors, where significant differences in power, force and impulse have been found between 8 kilograms increments (Lake & Lauder, 2011). The few studies that have assessed the physiological response to kettlebell swing exercise did not control for mass, as the mass selected was based on fitness level, experience or gender (Hulsey et al., 2012: Farrer et al., 2010; Fung & Shore, 2010), making it difficult to determine the physiological response at a specified mass. For example, Hulsey et al, (2012), had male participants use a 16 kg kettlebell, while females used an 8 kilogram kettlebell. The current study provides insight into the physiological response at specific mass levels (8, 12, or 16 kg) during kettlebell swing exercise. Furthermore, in addition to the physiological response at specific mass levels, the current study can tell us the physiological response for three cadence levels (8, 10, 12 SPI) for each of the three masses used during an interval kettlebell swing protocol.

Fung and Shore (2010) stated that as long as kettlebell mass was equal to or below 13% of body mass, aerobic metabolism remained the primary energy provider during kettlebell exercise. The upper exercise intensity where aerobic metabolism is the main provider is referred to as the aerobic threshold (Faude et al., 2009). Although the best means of assessing energy metabolism is through the use of gas exchange data (Bassett et al., 2001), previous research has established the relation between the aerobic threshold and lactate production. Kindermann et al., (1979) reported that aerobic threshold is seen when lactate is at 2 mmol/l, with Coyle et al., (1983) identifying it at 1 mmol/l above the resting blood lactate value. In the current study, the mean resting lactate was 1.1 ± 0.4 mmol/l, which would place the aerobic threshold at 2.1 mmol/l. Based on this previous research, the lactate data in the current study for the 8 kg kettlebell at a cadence of 8 and 10 SPI supports the claim by Fung and Shore (2010) that equal to and below 13% of body mass represents predominantly aerobic metabolism, as blood lactate remained below and/or equal to 2 mmol/l. Conversely, as swing cadence increased beyond 10 SPI using the 8 kg kettlebell, blood lactate increased above the aerobic threshold value to 2.9 ± 1.3 mmol/l, suggesting anaerobic metabolism was likely more prevalent. Fung and Shore did not control for cadence; therefore, the current study suggests that cadence, as well as mass, contribute to the metabolic energy profile during kettlebell swing exercise. Future studies using indirect calorimetry can be done to further support this.

Farrar et al., (2010) reported a heart rate of 87 ± 6% of HRmax (165 ± 13 bpm) using a 16 kg kettlebell in ten male subjects who were required to complete as many swings as possible in 12 minutes. In comparison, the female participants in the current study who used the 16 kg kettlebell produced heart rates ranging from 78 ± 8% of HRmax (145 ± 16 bpm) at 8 SPI, to 83 ± 7% of HRmax (153 ± 15 bpm) at 10 SPI, to 93 ± 5% of HRmax (172 ± 11 bpm) at 12 SPI. The Farrar study did not control the length of the work and rest intervals, as subjects were told to work at their own pace and rest as needed, resulting in an average of 22 SPM. This is similar to the 40 SPM cadence used in the current study, if total number of repetitions including rest was taken into account. The 10 SPI cadence physiological response was also in close proximity to the physiological response during the study by Farrar, 83 ± 7% of HRmax vs. 87 ± 6% of HRmax respectively. Not only does the current study demonstrate the physiological response using different cadences with a 16 kg kettlebell, it also demonstrates the physiological response using 8 and 12 kg kettlebell workloads at different swing speeds. Hulsey et al., (2012) reported an average heart rate of 85-93% of HRmax and an RPE of 15.3 ± 1.2 during a 10 minute kettlebell swing protocol consisting of 35 second swing intervals followed by 25 second rest intervals with a 16 kg kettlebell. The RPE values was approximately equivalent to the 12 kg kettlebell at a cadence of 12 SPI (15 ± 1.7) in the current study. The 16 kg kettlebell at 10 SPI resulted in an RPE of 14.1 ± 1.3, and 17.1 ± 1.4 at 12 SPI.

The current study was also the first to determine that increases in swing speed equate to increases in heart rate, blood lactate and RPE. Due to the pendulum-like motion of the kettlebell swing, swing speed can have upper and lower parameters, meaning that slow cadence levels would be unnatural and fast cadence levels may be limited by physiological and biomechanical factors. A swing frequency below a certain cadence threshold may be perceived as unnatural, as the dynamic swinging motion becomes a static resistive motion. At 8 SPI (32 SPM), the researchers observed, and the participants reported that this swing cadence was unnaturally slow. In order to maintain this cadence the participants were either forced to (i) resist the kettlebell momentum during the backswing, (ii) hold the kettlebell up during the top swing, which was only possible with the 8 kg kettlebell, or (iii) make the kettlebell float higher during the top swing with the heavier kettlebells. Resisting the momentum in order to maintain the unnatural cadence may increase the risk of injury, as the ballistic movement is eliminated and the swing resembles a shoulder dominated exercise. As a result of this unnatural pace, the physiological variables may have been over-exaggerated, as the user was forced to resist the mass of the kettlebell during the relaxation phase of the tension/relaxation cycle. Nevertheless, this cadence was significantly lower than the 10 and 12 SPI cadence levels. Based on these observations, a cadence of 8 SPI would not be recommended.

Hulsey et al., (2012), conducting a 10 minute protocol consisting of 35 second swing intervals followed by 25 second rest intervals, reported a mean swing frequency of 22-25 swings per 35 second interval (SPI^{35}). This cadence corresponds to a swing cadence of 37 to 43 SPM, which is very similar to the 40 SPM (10 SPI^{15}) used in the current study. The researchers had the subjects maintain a steady rhythm throughout each interval; however, a swing count for each interval was not assigned. Due to the fact the researchers did not control for cadence, it is possible that the cadence level produced was a natural swing frequency as the backswing would have been accelerated by gravity and not resisted as was seen in the current study at a cadence of 8 SPI (32 SPM); however, more research is needed to investigate this natural swing frequency phenomenon.

As swing cadence increased to 12 SPI (48 SPM), in addition to the ballistic forward swing acceleration of the kettlebell, the users were forced to actively pull the kettlebell down during the backswing in order to keep pace, emphasizing an 'overspeed eccentric' action during the backswing, which was not seen at the 8 or 10 SPI level. Exercise at fast overspeed eccentric speeds result in the 'stretch reflex' phenomenon, which caused the force produced during the following forward swing to be visibly greater in the participants at the 12 SPI cadence. As a result of this overspeed eccentrics pace, significant increases in heart rate (14.7%), blood lactate (83%) and RPE (27%) were seen from the 10 SPI to 12 SPI cadence level, noticeably higher than from 8 SPI to 10 SPI (5.9%, 32% & 10% respectively). These increases are possibly due to the elimination of the relaxation phase (backswing) during the tension/relaxation cycle of the kettlebell swing, as the users were forced to pull the kettlebell down during the backswing to keep pace.

Practical Application.

Based on the heart rate response, the kettlebell swing intensity ranged from 'moderate' to 'vigorous' in the current study, depending on the combination of cadence and mass used. This suggests that the intensity was sufficient for meeting existing criteria for aerobic capacity development and could offer an alternative training method to more conventional training practices (ACSM, 1998).

The results from this study suggest that different combinations of mass and cadence may be used during a two-handed interval kettlebell swing exercise protocol in order to produce the same physiological response. For example, kettlebell users who may lack the strength to swing the 16 kg kettlebell or who may be recovering from an injury may benefit by swinging a lighter mass kettlebell at faster cadences. Likewise, increasing the ability to swing heavier loads without increasing the physiological response can be done by increasing the mass and lowering the cadence speed. Furthermore, simply changing the mass and cadence combination on any given training session for variety can be accomplished while maintaining the desired physiological response. For example, the 16 kg kettlebell at 8 swings per 15 second interval elicited a heart rate response of 145 ± 16 bpm (78 ± 8% of HRmax). Increasing the cadence to 10 SPI and decreasing the mass to 12 kg stimulated a similar response of 143 ± 17 bpm (76 ± 9% HRmax). Similarly, the 16 kg kettlebell at 10 SPI produced a heart rate response of 83 ± 7% of HRmax. Increasing the cadence to 12 SPI and decreasing the mass by one half to 8 kilograms elicited the same heart rate response of 83 ± 8% of HRmax, suggesting that different cadence and mass combinations may be used to attain the same cardiovascular response.

As the purpose of high intensity interval training (HIIT) is to complete repeated bouts of exercise above the anaerobic threshold (Laursen & Jenkins, 2002), the results of the current study can provide recommendations for kettlebell swing workloads that will result in the benefits associated with HIIT training during kettlebell swing intervals. The anaerobic threshold is generally around 85% of HRmax (Helgerud et al, 2007; ACSM, 1998) and at a blood lactate concentration of 4 mmol/l (Tanaka, Matsuura, Kumagai, Matsuzaka, Hirakoba & Asano, 1983; Sjödin and Jacobs, 1981; Heck and Mader, 1985), however, several studies have shown that blood lactate accumulation at the anaerobic threshold can vary considerably and is not equal in all individuals (Faude et al,. 2009); even so, strong correlations between the 4 mmol/l and the anaerobic threshold during running and cycling exercise have been found (Heck, Hess & Mader 1985; Jones & Doust, 1998). The only two workloads to surpass the 85% of heart rate maximum and 4 mmol/l anaerobic threshold were the 12 and 16 kg at 12 SPI. Based on these findings, it can be suggested that in order to benefit from high intensity interval training using the kettlebell swing, the kettlebell mass must remain at 12 or 16 kg, and cadence must be 12 SPI, however, gas exchange data may have further supported these claims.

The 16 kg load at 12 SPI in the current study elicited a heart rate of 93 ± 0.5% of HRmax and a blood lactate of 6.9 ± 3.1 mmol/l. Schnettler et al., (2010) produced a similar response using the kettlebell snatch with the same protocol in 10 males and 2 females (93 ± 0.5% of HRmax, 7.8 ± 3.6 mmol/l). Males used a 16 kg kettlebell while females used a 12 kg kettlebell. As the physiological results between the previous studies and the current study are similar, the kettlebell swing can potentially make a viable alternative to the more technical kettlebell snatch, which is contraindicated for individuals with limited shoulder mobility. Falatic (2011) determined that the similar kettlebell snatch protocol, previously used by Schnettler et al., (2010), increased VO_2max over a 4 week period in female varsity soccer players using a 12 kg kettlebell, suggesting that further investigation is warranted to determine if kettlebell swing intervals increase VO_2max over time.

Conclusion

There were three main objectives to this study. The first was to determine the effects of increases in kettlebell mass on heart rate, blood lactate and ratings of perceived exertion during an interval kettlebell swing protocol. It was hypothesized that the physiological responses to kettlebell swing exercise would significantly increase as kettlebell mass (8, 12, & 16 kg) increased. The results of the analysis confirmed this as heart rate, blood lactate and RPE significantly increased as kettlebell mass increased. The second objective was to determine the effects of increasing swing cadence on the same physiological variables (heart rate, blood lactate and RPE) during an interval kettlebell swing protocol. As with kettlebell mass, increasing the swing cadence during each interval of the interval kettlebell swing protocol significantly increased all three dependent variables, supporting the hypothesis that increased swing cadence would significantly increase heart rate, blood lactate and RPE.

The final objective was to determine if there were any interaction effects of increasing both kettlebell mass and swing cadence on physiological response during an interval swing protocol. Heart rate and RPE did not see significant interaction effects between kettlebell mass and swing cadence; however, statistically significant interactions were found between KB mass and swing cadence for blood lactate. Upon further investigation, interaction effects were seen between the 8 and 12 kg kettlebell at all cadence levels and between the 8 and 10 SPI cadence level when using the 8 kg kettlebell. Blood lactate failed to significantly increase when increasing the kettlebell mass from 8 to 12 kilograms, regardless of the swing cadence used in the study, whereas significant increases were found between the 12 and 16 kg kettlebells, suggesting that anaerobic metabolism was not the predominant energy system used during the 8 and 12 kg kettlebell workloads. Also, blood lactate failed to increase between the 8 and 10 SPI cadence level only when using the 8 kg kettlebell.

Limitations

The current study recruited fitness facility users. Although the participants were experienced in kettlebell training, the sample may not have been homogenous with regards to their fitness levels and fitness backgrounds, creating the potential for large variations in the results of the study. Another limitation is that the current study utilized 5 minute rounds of the interval protocol. The minimum time required to transport lactate to the blood is about five minutes to determine a steady state for blood lactate (Gollnick, Bayly, & Hodgson, 1986). Similarly, the use of this relatively short interval protocol may have negatively impacted the results. Possibly, a longer duration round may have been needed as the blood lactate values may have been underestimated as the lactate in the muscles may not have been given enough time to reach a steady state in the blood stream.

Delimitations

The results of this study are delimited to only female participants between the ages of 18 and 48 years of age recruited from fitness facilities that offer kettlebell classes. Furthermore, the participants were experienced with kettlebell training, with a minimum of three months experience, and had previous instruction in proper kettlebell swing technique from a qualified RKC kettlebell instructor. The findings of the study are also delimited only to the kettlebell swing during an interval training protocol that utilizes 15 second work intervals followed by 15 seconds of rest. The results of this study cannot be generalized to other types of kettlebell swings (one arm or sport style swings, etc.), to other kettlebell exercises (the snatch, clean and press, etc.) or to other continuous or interval protocols with different interval durations. Furthermore, this study is only delimited to the kettlebell mass' (8, 12, & 16 kg) and swing cadences (8, 10, & 12 SPI) used.

Recommendations

Future studies should investigate comparisons between genders at static kettlebell swing workloads to determine if there are significant physiological differences. This will assist in developing mass recommendations based on physiological responses rather than gender alone. Furthermore, determining the physiological responses during different kettlebell styles, such as kettlebell sport or alternative styles may offer insight into developing training programs for these styles. Kettlebell sport utilizes a more energy efficient movement than does the 'hardstyle' used in this study, illustrated by a breathing pattern opposite that of the hardstyle. Determining the cadence and kettlebell mass that generates a physiological response within the aerobic-anaerobic transition zone during the kettlebell sport style would be extremely beneficial in determining training intensities for athletes in this power endurance sport. Also, determining the physiological response using other swing protocol formats (i.e., continuous vs. interval), may also be beneficial.

The current study has shown that the physiological responses elicited by the kettlebell swing are sufficient for increasing cardiovascular capacity. Helgerud et al., (2007) determined that a 20 minute 15:15 second interval treadmill running protocol at 90 to 95% of heart rate max significantly increased VO_2max by 5.5% and stroke volume by 10% over 8 weeks. The current study revealed that heart rate responded between 90 to 95% of HRmax at a cadence of 12 SPI using a 16 kg kettlebell. The 12 kg kettlebell came very close with a response of 89% of HRmax and was still above the anaerobic threshold. Therefore, it can be suggested that using a 20 minute 15:15 interval swing protocol as used in the current study at a cadence of 12 SPI with either a 12 or 16 kg kettlebell for 8 weeks would increase cardiovascular capacity and stroke volume.

Falatic (2011), using a 20 minute 15:15 interval kettlebell snatch protocol using a 12 kg kettlebell in female NCAA soccer athletes at an overspeed eccentric pace, 3 times per week for 8 weeks significantly increased cardiovascular capacity by 6% ($p < 0.008$). Future studies should investigate the effects of the current kettlebell swing protocol for 20 minutes, 3 days per week for 8 weeks to determine if the kettlebell swing would result in a significant increase in cardiovascular capacity and stroke volume.

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Appendix A

Recruitment Letter and Consent Form

September, 2012

Dear prospective participant,

I would like to extend an invitation to participate in a research study being conducted by me, Corey Wesley, a graduate student in the School of Kinesiology at Lakehead University School of Kinesiology, supervised by Dr. Derek Kivi. You are being asked to participate because you have had a minimum of 3 months experience with kettlebell training and have been instructed in the proper technique of the kettlebell swing from a qualified kettlebell instructor.

The purpose of this study is to determine the effect of different kettlebell mass and kettlebell swing cadence levels on heart rate response, lactate accumulation and ratings of perceived exertion. Prior to the first session, you will be required to sign the attached consent form and Physical Activity Readiness Questionnaire (PAR-Q), and pass a movement clearance test. If you fail to pass the PAR-Q form and the movement clearance tests, you will not be able to participate in the study.

All participants will be asked to attend 3 individual test sessions which will be approximately 60-75 minutes each in duration, held 48 hours apart. On each testing day, your resting heart rate and your maximal heart rate will be determined based on an age predicted equation; and you will be required to wear a Polar RS 400 Heart Rate Monitor and chest strap for each session. You will also be required to provide blood samples using a LactatePro Blood Lactate Analyzer to determine the accumulation of lactate in your blood stream during each stage of testing. Prior to each session, your height and body mass will be measured, and a baseline lactate sample will be taken. This will involve a small prick at the end of your finger, with a drop of blood being drawn. You will then warm up for a total of 10 minutes, consisting of 5 minutes on a cycle ergometer at a pace of 60 revolutions per minute, followed by a 5 minute specific kettlebell dynamic stretching routine that is common to kettlebell training. You will then be given the opportunity to practice the two arm kettlebell swing for 1 minute. Testing will start five minutes after the warm up is complete.

Each of the three testing sessions will consist of three 5 minute rounds. Each round will be comprised of 10 intervals of 15 seconds of the two arm kettlebell swing, followed by 15 seconds rest between intervals, for a total of 5 minutes. You will then be given a 10 minute recovery period between rounds. For each 5 minute round, you will randomly use a different mass kettlebell. The kettlebell mass's used for each round will be 8, 12 and 16 kilograms. The three individual testing sessions will utilize one of three different kettlebell swing cadence levels.

During data collection, your heart rate will be recorded directly into the Polar RS 400 Heart Rate Monitor, and a blood sample will be taken immediately after the completion of each of the 3 rounds for each session for blood lactate analysis. Upon completion of each of the three rounds at each testing session, you will also be required to record your perceived intensity level for each testing protocol on a Rating of Perceived Exertion scale of 6-20. When the testing session has been completed, you will cool down with static stretching for 5 minutes.

The day of each testing session, you will be required not eat a substantial meal within 4 hours before the test, abstain from alcohol 24 hours before the test, abstain from coffee, tea, or other caffeine sources for at least 1 hour before the test and not to train or do high intensity physical work on the day of the testing. If any of the above guidelines have not been adhered to on the day of testing, you will be asked to return on another day.

Potential risks of participating in this study include, but are not limited to, elevated heart rate, minor sprains and/or strains, shortness of breath, and the possibility of contusions. Given that the testing is of high intensity, you may experience muscle soreness in the days following the test. There will be a minimum of 48 hours in between testing sessions.

Participation in this study is completely voluntary; you have the right to withdraw at any time without penalty, and all information will be strictly confidential, at no time will you be required to verbalize your results to the other participants present. Only the researchers will have access to the recorded data and personal information, and no identifiable characteristics will be used in the final report. Data will be securely stored at Lakehead University in Dr. Kivi's office, for a period of 5 years. Your results from this study will be available to you upon request following the completion of the study. If you have any questions please feel free to contact me at 631-5361 or at cwesley1@lakeheadu.ca. This research has been approved by the Lakehead University Research Ethics Board. If you have any questions related to the ethics of the research and would like to speak to someone outside of the research team, please contact Sue Wright at the Research Ethics Board at 343-8283 or swright@lakeheadu.ca.

Thank you,

Corey Wesley, MSc (c), CK, RKC, CPT,

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Effects of Varying Kettlebell Sizes on Heart Rate, Blood Lactate, and Ratings of Perceived Exertion in Experienced Kettlebell Users

I, ____ (PLEASE PRINT), consent to participate in this study. I am aware that the purpose is to measure the effects of using different kettlebell masses and cadence levels in experienced kettlebell users, using the two arm kettlebell swing, on heart rate response, lactate accumulation and ratings of perceived exertion.

I understand that I will be required to attend three 60-75 minute sessions on 3 separate dates. Prior to the first session, I will be required to sign and complete a consent form and a Par-Q, and successfully pass a movement clearance test in order to participate in the study.

I understand that I will be required to perform 15 second intervals of the two arm kettlebell swing, for 3 five minute rounds with a 1 to 1 work to rest ratio of 15 seconds. A 10 minute recovery period between rounds will be given. The cadence will be predetermined for each kettlebell session. A different size kettlebell will be use during each of the three stages of each testing session.

I understand that I will complete a 10 warm-up including dynamic stretching before the testing, a cool down following the testing, and will wear a heart rate monitor with a chest strap. I will also be required to offer blood samples using a LactatePro blood lactate analyzer. I am aware that height, body mass, and age will be recorded.

I understand that on the day of testing, I will be required to not eat a substantial meal 4 hours before the test, abstain from alcohol 24 hours before the test, abstain from coffee, tea, or other caffeine sources for 1 hour before the test and do not train or do high intensity physical work on the day of the testing. If any of the above guidelines have not been adhered to on the day of testing, I understand I will be asked to return on another day.

I understand that participation in this study is entirely voluntary, and I am able to withdraw from this study at any time without penalty. I understand that all information that I provide will remain confidential. Data will be securely stored in Dr. Kivi's office SB1026, School of Kinesiology, Lakehead University for a period of 5 years.

I have been informed of the tests that I am required to perform and I am aware that with all physical activity and sports, some risk of injury exists. I understand that risks in participating in this study may include, but are not limited to; elevated heart rate, sprains, strains, contusions and muscle soreness. I accept all of these risks by participating in this study.

____

Signature of Participant   Date

Appendix B

Data Collection Sheet

Data Collection Sheet

Date ____________________________ **Name:** __________________________

Age: _____ **Height (cm)** _____________ **Weight (kg):** ____________________

Max Heart Rate: (205.8 – 0.685 x age) __________________**(bpm)**

Movement Clearance Test: **PASS** **FAIL**

Consent Form Signed: **YES** **NO**

Physical Activity Readiness Questionnaire: **PASS** **FAIL**

Pre Blood Pressure

Session 1 _____/_____ **Session 2** _____/_____ **Session 3** _____/_____

5 Minute Supine on Floor

Resting Heart Rate (bpm)

Session 1 __________ **Session 2**__________ **Session 3**__________

Resting Lactate (mmol/l)

Session 1 __________ **Session 2**__________ **Session 3**__________

Post Protocol

Post Protocol Heart Rate (bpm)

Session 1 __________ **Session 2**__________ **Session 3**__________

Post Protocol Blood Pressure

Session 1 _____/_____ **Session 2** _____/_____ **Session 3** _____/_____

Kettlebell Swing Protocol 1- 8 SPI

Lactate Accumulation
Stage 1 (8 KG) ___________(mmol)
Stage 2 (12 KG) ___________(mmol)
Stage 3 (16 KG) ___________(mmol)
Average Heart Rate
Stage 1 ____ (bpm)_______(%MHR)
Stage 2 ____ (bpm)_______(%MHR)
Stage 3 ____ (bpm)_______(%MHR)
RPE
Stage 1 ___________
Stage 2 ___________
Stage 3 ___________

Kettlebell Swing Protocol 2 – 10 SPI

Lactate Accumulation
Stage 1 (8 KG) ___________(mmol)
Stage 2 (12 KG) ___________(mmol)
Stage 3 (16 KG) ___________(mmol)
Average Heart Rate
Stage 1 ____ (bpm)_______(%MHR)
Stage 2 ____ (bpm)_______(%MHR)
Stage 3 ____ (bpm)_______(%MHR)
RPE
Stage 1 ___________
Stage 2 ___________
Stage 3 ___________

Kettlebell Swing Protocol 3 – 12 SPI

Lactate Accumulation
Stage 1 (8 KG) ___________(mmol)
Stage 2 (12 KG) ___________(mmol)
Stage 3 (16 KG) ___________(mmol)
Average Heart Rate
Stage 1 ____ (bpm)_______(%MHR)
Stage 2 ____ (bpm)_______(%MHR)
Stage 3 ____ (bpm)_______(%MHR)
RPE
Stage 1 ___________
Stage 2 ___________
Stage 3 ___________

HEART RATE (BPM) - 8 SPI

DATE: ______________________

NAME: ______________________

	8 KG	*12 KG*	*16 KG*
1	________	________	________
2	________	________	________
3	________	________	________
4	________	________	________
5	________	________	________

HEART RATE (BPM) - 10 SPI

DATE: ______________________

NAME: ______________________

	8 KG	*12 KG*	*16 KG*
1	________	________	________
2	________	________	________
3	________	________	________
4	________	________	________
5	________	________	________

HEART RATE (BPM) - 12 SPI

DATE: ____________________________

NAME: ___________________________

	8 KG	*12 KG*	*16 KG*
1	________	________	________
2	________	________	________
3	________	________	________
4	________	________	________
5	________	________	________

Appendix C

Blood Lactate Sampling Procedure

Blood Lactate Sampling Procedure

The testing protocol will be supervised by the graduate student researcher, who will have completed the training workshop "Blood Samples for Lactate Measurement – Procedures and Safety" conducted by Dr. Kivi prior to testing. The workshop training consists of the potential hazards associated with the testing procedures, necessary precautions to prevent exposure to infectious agents, necessary precautions to prevent the release of contained material, and emergency response in the event of an unplanned release.

The researchers and study particiapnts will be required to clean their hands with disinfecting gel before they enter and exit the lab.

Methods

The lab will be conducted in the Exercise Physiology Laboratory (SB 1025). Informed consent will be obtained, and a Physical Activity Readiness Questionnaire (Par-Q) will be completed. The protocol followed in this lab will be approved by the School of Kinesiology Risk Management Committee prior to testing.

The procedures for taking blood samples are as follows:

Equipment

-Lactate measurement device with test strips
-Latex gloves, lab coat
-Lancets
-Disinfecting wipe
-Sterile gauze pad
-Biohazard waste disposal container
-Sharps container

Sampling Procedures

1. Prior to testing, hands will be thoroughly washed with soap and hot water, and two pairs of latex gloves will be put on. Investigators will also be wearing a lab coat.

2. Prior to collecting the sample, the area where the blood sample will be taken (fingertip) will be disinfected using the disinfecting wipe and dried with the sterile gauze pad. The used wipe and pad will then be put into the biohazard waste disposal container.

3. The skin will be pierced with a single-use lancet (on the fingertip), and a small drop of blood will accumulate on the surface of the skin. This drop of blood will be wiped with a sterile gauze pad. The lancet will be put into the sharps container, and the pad will be put into the biohazard waste disposal container.

4. A second small drop of blood will accumulate on the surface of the skin. The test strip, connected to the Lactate measurement device, will be touched to the blood drop and a small sample will be taken. After the sample has been taken, the participant will be given a sterile gauze pad to hold on the fingertip to prevent blood from dripping. The lactate measurement device will scan the blood sample, and the blood lactate value will be displayed in 60 seconds.

5. After the blood lactate value has been displayed, the test strip will be removed from the lactate measurement device using a sterile gauze pad and put into the biohazard waste disposal container. A new test strip will be put into the device in preparation for the next blood sample.

Steps 2-5 will be repeated for each blood sample taken.

6. At the completion of the testing one participant, the investigators will remove the top pair of latex gloves and put them into the biohazard waste disposal container and put on a new second pair of gloves. At the completion of the testing session, the gloves will be removed and the hands will be washed using soap and hot water.

Appendix D

Physical Activity Readiness Questionnaire (PAR-Q) Form

Physical Activity Readiness Questionnaire - PAR-Q (revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
☐	☐	**1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
☐	☐	**2. Do you feel pain in your chest when you do physical activity?**
☐	☐	**3. In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	**4. Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	**5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	**6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	**7. Do you know of any other reason why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ________________________________

SIGNATURE ________________________________ DATE ________________________________

SIGNATURE OF PARENT ________________________________ WITNESS ________________________________
or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

Appendix E

Movement Clearance Test

The following tests, as presented by Cook & Jones (2010, p. 10-14), are intended to reveal pain. If they do provoke pain anywhere, the participants will not be allowed to participate in the kettlebell study. A positive test on any of the clearance tests is reason for referral to the appropriate healthcare professional. Three clearance tests will be performed, the spine flexion, spine extension and shoulder impingement tests.

Test 1: Spine Flexion

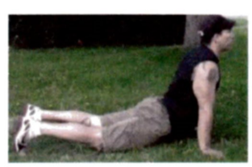
Goal: To place the spine and body into flexion to see if pain is present.

Description:

Start in a Tall Kneeling Position with the feet pointed behind you so the tops of your feet are on the ground.
Bring your hips to your heels, fold forward at the waist, and place your hands on the ground in front of you (arms straight). Continue to fold until your abdomen is against your thighs and your forehead is on the ground.
This move will fully flex the knees, hips, spine and shoulders and extend the ankles. If pain is noted in any of these areas, it is considered a positive test.

Test 2: Spine Extension

Goal: To place the spine and body into extension to see if pain is present.



Description:

Start prone (lying on stomach) with the body flat and hands underneath the shoulders.
Press the upper body off the ground until the elbows are straight.
Attempt to keep the hips on the ground, but if they lift off, keep the thighs relaxed and continue until elbows are straight.
If pain is noted in the spine (especially the lower back), arms and hips, it is considered a positive

test.

Test 3: Shoulder Impingement

Goal: To determine if pain is present while placing the shoulder in an adducted, internally rotated and flexed position.

Description:

Stand with your feet together and reach across to place one hand (palm) on the opposite shoulder.
Keeping the palm down and hinging at the wrist, lift the elbow as high as you can without losing contact with the palm.
Does this cause pain or pinching?
Repeat on the other side.
If this test does provoke pain, please seek referral to the appropriate medical professional.

Appendix F

Kettlebell Specific Warm Up

Kettlebell Specific Warm Up

The Kettlebell Specific Warm Up consisted of 9 different dynamic exercises for a total of 5 minutes. The dynamic warm up included dynamic stretches proposed by Tsatsouline (2006), patterning drills proposed by Cook & Jones (2010), and other common movements that are similar to the movements involved in the testing protocol. The specific dynamic movements were performed for 30 seconds each, consecutively moving on to the next movement for a total of 5 minutes including transition time between exercises. The movements involved in the warm-up included; the kettlebell around the body (right & left), the pump stretch, the pry stretch, face the wall squat, glutes to wall drill, kettlebell deadlift, two handed kettlebell swing, the 'halo', and the Goblet Squat Bootstrapper. The participants were then given 1 minute to practice the two hand swing using the testing mass for 1 minute. Testing began 5 minutes after completion of the warm up.

Exercise Descriptions

Around the Body

Goal: To prepare the body for an external resistance

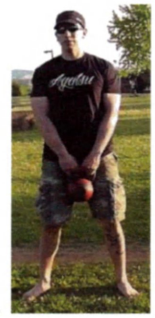
Description:

Circle the kettlebell in the transverse plane around the body with straight arms
Switching from hand to hand anterior and posterior to the body
For a total of 20 seconds in each direction


2.

3.

4.

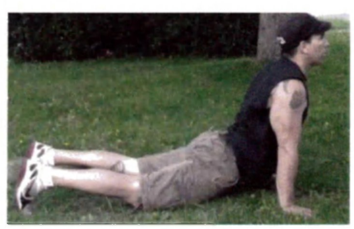
5.


The Pump Stretch

Goal: To warm up to hip flexors, lower back, erector spinea and shoulders.

Description:

Assume a high hips position; your hands shoulder width apart and your feet a little wider (Picture 1).
Keeping your elbows locked, shift your weight forward and drop your hips, until your arms are straight and support most of your weight. (Picture 2)
Tense your gluteal muscles and push your hips forward as far as you can.
Now shift your hips side to side and turn a few times. Try to loosen up the muscles on the top of your thighs. “Pry”. (Pictures 3 & 4).
Keeping your elbows locked; push yourself back into the starting position.
Push your hips as far back as possible and bring your chest as low to the deck as you can. (Pictures 5 & 6).


2.

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4.


5. 

6. 

Face the wall Squat

Goal: A drill for developing the back and hip flexibility needed for pulling and squatting

Description:

Facing the wall, stand 1 to 3 inches away from the wall with your feet a little wider than your shoulders and slightly turned out, your arms hanging free.
Keeping your feet planted, squat down as low as you can.

2. 

3. 

Key points

The inside edges of feet may not come up as you squat down
The knees cannot "frog" outwards on the way down.

The Halo

Goal: Promotes shoulder mobility and loosens up the rotator cuff muscles.

Description:

Hold a kettlebell upside down by its horns and slowly move it around your head.
Work up to progressively tighter circles.
Keep your gluteal muscles tight to protect your back.

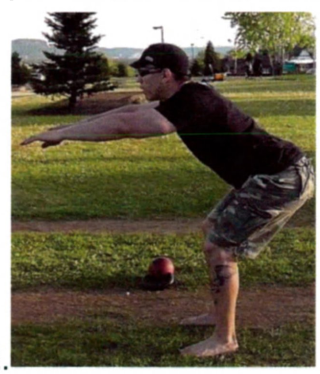

2. 
3. 
4. 
5. 

Glutes to Wall Drill

Goal: Motor learning drill to develop the hip hinge required for the kettlebell swing

Description:

Stand backside facing wall, 1 foot length from the wall with a shoulder width stance (picture 1)
Reach back with gluteal muscles (buttocks) and touch the wall (picture 2)
If you are successful, move the feet away 1 inch and try again
Repeat, each time moving forward, until you find the furthest point from the wall where you can successfully touch the wall without falling backward.
At this point you can practice the hip hinge, initially using the arms as a counter balance by reaching forward.
Inhale on the way back to touch the wall, exhale at the top as you tighten the gluteals and core, creating a straight line from the ears to the ankles. (picture 3)

1. 
2. 
3. 

Key Points

The hips reach back first and stay high
The chest will tilt forward as the hips reach back
Don't confuse an upright back with a flat back
Don't squat and lower the hips

Touch the Wall KB Deadlift

Goal: Transition from un-weighted to weighted patterning of the Hip Hinge

Description:

Assume the same stance you found during the first two touch the wall drills
Place the kettlebell between the heels or slightly behind them. (Picture 1).
Adjust your stance as wide as necessary to accommodate the kettlebell, but not wider.
Keeping the arms glued to the ribs, reach back with the hip to touch the wall while grasping the kettlebell at the bottom position. Don't forget to inhale. (Picture 2).
Keeping the spinal alignment and arms against the ribs, return to the top position by pushing the feet into the ground and extending the hips until the body forms a straight line at the top. This should be accompanied by a forced exhale with tight gluteals and abdominals at the top. (Picture 3).
Inhale again and return the kettlebell to the ground, keeping the arms against the ribs and the spine perfect. Release the kettlebell and stand up. (Picture 4).

1. 
2. 
3. 
4. 

Key Points

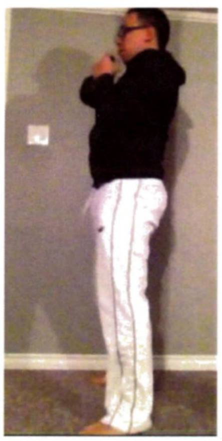
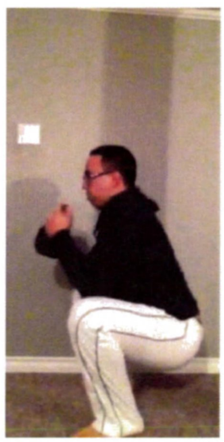
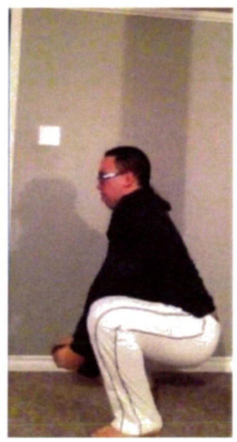
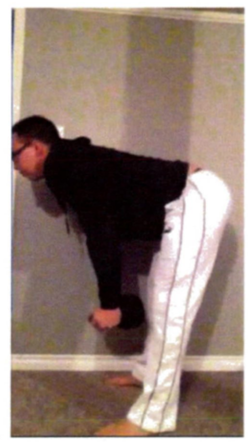
If you must elevate the kettlebell to adjust to your mobility ability, place it on the appropriate surface to ensure perfect form and lower as your mobility improves.
Keep the same spine alignment learned with the dowel rod on the back.
Keep the arms glued against the ribs.
Push your feet into the ground to start the movement and do not lead with the shoulders.
Remember to incorporate proper breathing.

Goblet Squat Bootstrapper

Goal: To warm up the hip flexors, glutes, semitendinosus, biceps femoris and quadriceps

Description:

In standing position bring kettlebell to chest level with elbows tight against the ribcage and the elbows fully flexed (Picture 1).
Initiate movement with hip flexors, pulling down into a deep squat position (Picture 2).
Remaining in deep squat position, extend elbows down and lower kettlebell between the legs (Picture 3).
Keeping kettlebell in place, raise hips up as legs straighten out, ensuring spine remains in a neutral position (Picture 4).
Repeat in opposite direction until back in standing position.

1. 
2. 
3. 
4. 

Appendix G

Borg Ratings of Perceived Exertion Scale

Borg Rating of Perceived Exertion (RPE) Scale

Instructions

Please rate your perception of exertion. This should reflect how heavy and strenuous the testing protocol feels to you.

Look at the rating scale below and gage how strenuous the protocol felt to you. The scale ranges from 6 to 20, where 6 means "no exertion at all" and 20 means "maximal exertion." Choose the number that best describes your level of exertion.

9 corresponds to "very light" exercise.

13 on the scale is "somewhat hard" exercise.

17 "very hard" is very strenuous.

19 on the scale is an extremely strenuous exercise level. For most people this is the most strenuous exercise they have ever experienced.

Ratings of Perceived Exertion (Please circle one)

The Borg Scale

6	**No exertion at all**
7	**Extremely light**
8	
9	**Very Light**
10	
11	**Light**
12	
13	**Somewhat Hard**
14	
15	**Hard (Heavy)**
16	
17	**Very Hard**
18	
19	**Extremely Hard**
20	**Maximal exertion**

Appendix H

Raw Data

Table 6

Participant Heart Rate Values for Each Cadence and Mass

Participant	C1M1	C1M2	C1M3	C2M1	C2M2	C2M3	C3M1	C3M2	C3M3
1	131	132	140	135	139	144	159	175	175
2	144	152	160	157	169	175	161	171	178
3	136	139	149	143	157	170	158	167	180
4	116	125	137	141	153	160	168	175	174
5	107	110	121	112	115	127	147	153	158
6	101	112	125	115	128	140	150	161	170
7	109	121	135	113	134	146	143	161	163
8	129	150	159	151	164	169	159	176	181
9	148	157	161	152	158	159	170	173	177
10	118	129	145	112	127	135	137	152	171
11	110	130	144	125	151	158	156	167	183
12	130	144	147	129	139	148	154	161	169
13	143	160	174	150	165	169	166	180	180
14	122	130	142	133	141	156	155	170	178
15	115	132	138	111	123	142	126	142	154
16	132	153	158	143	152	162	169	172	187
17	151	159	165	152	159	167	179	182	177
18	98	105	114	108	113	124	122	130	146

C1= 8 SPI; C2 = 10 SPI; C3 = 12 SPI; M1 = 8 kg; M2 = 12 kg; M3= 16 kg.

Table 7

Heart Rate (bpm) Descriptive Statistics

Cadence/Mass	Mean ± SD (bpm)	Range	Min – Max Value
C1M1	124 ± 16	53	98 – 151
C1M2	135 ± 17	56	105 – 160
C1M3	145 ± 16	60	114 – 174
C2M1	132 ± 17	49	108 – 157
C2M2	143 ± 17	56	113 – 167
C2M3	153 ± 15	51	124 – 175
C3M1	154 ± 15	57	122 – 179
C3M2	165 ± 14	52	130 - 182
C3M3	172 ± 11	41	146 – 187

Values are presented as mean ± SD. C1= 8 SPI, C2 = 10 SPI, C3 = 12 SPI, M1 = 8 kg, M2 = 12 kg, M3= 16 kg

Table 8

Participant Blood Lactate Values (mmol/l) for Each Cadence and Mass

Participant	R	C1M1	C1M2	C1M3	C2M1	C2M2	C2M3	C3M1	C3M2	C3M3
1	1.3	1.8	1.4	2.3	1.6	2.0	2.9	1.6	4.0	5.6
2	1.1	2.1	1.9	3.3	1.7	3.8	4.9	2.1	3.1	4.7
3	0.8	4.0	3.2	4.3	3.4	4.6	7.2	5.7	7.6	9.0
4	1.6	1.9	1.6	2.7	2.7	3.0	5.1	6.0	6.0	8.3
5	0.9	1.0	1.0	2.2	0.9	1.2	2.2	2.1	4.6	6.6
6	0.9	0.8	0.8	1.2	0.9	1.0	2.6	3.3	3.2	4.6
7	0.9	1.9	1.1	1.9	1.2	2.1	2.3	1.8	3.7	4.6
8	2.2	3.3	4.7	5.9	6.0	6.1	9.2	8.1	8.9	16.7
9	1.4	1.7	2.7	3.6	2.6	3.1	4.4	6.7	6.9	9.9
10	1.1	1.0	1.6	2.4	1.0	2.1	n/a	1.7	3.3	5.8
11	0.8	1.2	3.6	1.4	1.8	2.0	2.8	2.6	4.0	6.7
12	1.3	1.3	3.0	2.7	1.0	1.6	2.2	2.0	2.6	3.6
13	1.4	1.7	3.1	5.7	1.6	3.7	5.0	3.0	6.3	6.7
14	1.0	2.6	1.9	2.4	2.7	2.9	3.9	3.2	5.2	8.6
15	1.0	1.2	1.7	3.1	1.8	2.8	4.2	2.6	4.0	5.0
16	0.8	0.9	0.8	2.4	2.3	2.8	3.4	2.9	3.3	6.1
17	1.0	0.8	1.3	3.0	1.0	1.3	3.7	8.6	11.0	8.7
18	0.8	0.8	1.0	1.3	1.4	1.2	1.6	1.3	1.3	3.2

R = Resting Blood Lactate; C1= 8 SPI; C2 = 10 SPI; C3 = 12 SPI; M1 = 8 kg; M2 = 12 kg; M3= 16 kg.

Table 9

Blood Lactate (mmol/l) Descriptive Statistics

Cadence/Mass	Mean ± SD (mmol/l)	Range	Min – Max Value
C1M1	1.7 ± 0.9	3.2	0.8 – 4.0
C1M2	2.0 ± 1.1	3.9	0.8 – 4.7
C1M3	2.9 ± 1.3	4.7	1.2 – 5.9
C2M1	2.0 ± 1.2	5.1	0.9 – 6.0
C2M2	2.6 ± 1.3	5.1	1.0 – 6.1
C2M3	4.0 ± 1.9	7.6	1.6 – 9.2
C3M1	3.6 ± 2.3	7.3	1.3 – 8.6
C3M2	4.9 ± 2.4	9.7	1.3 - 11
C3M3	6.9 ± 3.1	13.5	3.2 – 16.7

Values are presented as mean ± SD.
C1= 8 SPI, C2 = 10 SPI, C3 = 12 SPI, M1 = 8 kg, M2 = 12 kg, M3= 16 kg

Table 10

Participant RPE Values for Each Cadence and Mass

Participant	C1M1	C1M2	C1M3	C2M1	C2M2	C2M3	C3M1	C3M2	C3M3
1	7	9	13	10	12	13	11	13	16
2	9	10	11	11	13	16	12	15	18
3	10	13	14	10	14	17	13	16	19
4	8	12	13	11	1	14	15	17	18
5	7	11	13	6	11	13	11	13	17
6	7	8	10	8	10	12	10	12	14
7	7	12	13	6	11	13	11	13	15
8	9	12	14	12	14	15	15	17	17
9	11	12	14	12	13	15	14	16	17
10	7	9	11	8	10	13	11	14	17
11	7	11	13	8	12	14	14	17	18
12	10	13	14	11	13	15	14	16	18
13	10	12	14	7	9	15	14	17	18
14	6	7	13	9	12	14	11	13	15
15	10	13	15	10	13	15	13	16	18
16	7	11	12	7	11	13	11	13	17
17	7	9	11	11	12	13	14	16	17
18	7	9	13	7	12	14	11	16	19

C1= 8 SPI; C2 = 10 SPI; C3 = 12 SPI; M1 = 8 kg; M2 = 12 kg; M3= 16 kg.

Table 11

RPE Descriptive Statistics

Cadence/Mass	Mean ± SD (RPE)	Range	Min – Max Value
C1M1	8.1 ± 1.5	5	6 – 11
C1M2	10.7 ± 1.8	6	7 – 13
C1M3	12.8 ± 1.3	5	10 – 15
C2M1	9.1 ± 2	6	6 – 12
C2M2	11.9 ± 1.4	5	9 – 14
C2M3	14.1 ± 1.3	5	12 -17
C3M1	12.5 ± 1.7	5	10 -15
C3M2	15 ± 1.7	5	12 - 17
C3M3	17.1 ± 1.4	5	14 - 19

Values are presented as mean ± SD.
C1= 8 SPI, C2 = 10 SPI, C3 = 12 SPI, M1 = 8 kg, M2 = 12 kg, M3= 16 kg

Table 12

Percentage of Maximal Heart Rate

Cadence/Mass	8 kg		12 kg		16 kg	
	HRmax%	HRR%	HRmax%	HRR%	HRmax%	HRR%
8 SPI	67 ± 9	50 ± 11	73 ± 9	59 ± 12	78 ± 8	67 ± 11
10 SPI	71 ± 9	57 ± 11	76 ± 9	66 ± 12	83 ± 7	73 ± 10
12 SPI	83 ± 8	75 ± 11	89 ± 7	84 ± 9	93 ± 5	89 ± 6

Values are measured as a percentage of age predicted heart rate maximum and percentage of heart rate reserve