The Acute Physiological Effects of Strongman Training

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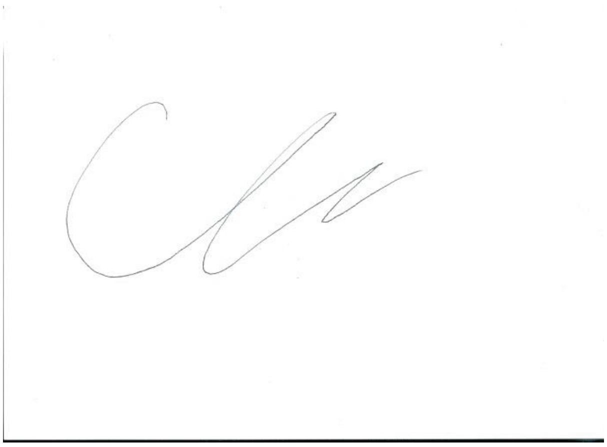
ATTESTATION OF AUTHORSHIP

“I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.”

Signed:

Colm Woulfe



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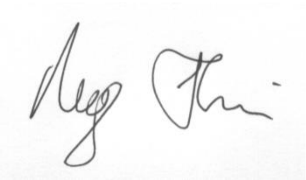

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Signed:

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ABSTRACT

Strongman training has become an increasingly popular modality used by practitioners for athletic development and general strength and conditioning, but data on physiological responses is limited. This thesis sought to quantify and compare a range of physiological responses to a strongman training session compared to a typical general strength training session.

Ten healthy males (23.6±7.5 years; 85.8±10.3 kg) with a minimum of two years of strength training experience, and a squat and deadlift strength of at least 1 and 1.2 times body mass respectively acted as their own control in a crossover design. Participants performed a strongman training session (ST), a strength/hypertrophy (RST) training session, and a resting session with seven days between each session. The ST consisted of sled drag, farmers walk, one arm dumbbell clean and press and tyre flip at loads eliciting approximately 30 seconds of effort per set. The RST consisted of squat, deadlift, bench press and power clean, performed with 75% of predicted one repetition maximum. Sessions were equated for approximate total and per set duration. Participants completed both sessions with a facemask on, attached to an oxygen analyser unit (Metalyzer 3B™, Cortex™, Germany). Analyses were conducted to determine differences in physiological responses within and between the two different protocols with significance set at $p \leq 0.025$ for lactate and testosterone and $p \leq 0.0125$ for heart rate, caloric expenditure and substrate utilisation.

Lactate and salivary testosterone were recorded immediately pre and post training sessions. Heart rate, caloric expenditure and substrate utilisation (fat and carbohydrate) were measured throughout the resting session, both training protocols and for 80 minutes post training sessions (STrecov and RSTrecov). No significant changes in testosterone occurred at any time point for either session. Lactate increased significantly immediately post both sessions (Pre ST 1.57 mmol/L, Post ST 7.53 mmol/L, Pre RST 2.01 mmol/L, Post RST 8.53 mmol/L). Heart rate, caloric expenditure and carbohydrate expenditure were all elevated significantly during ST and RST. Heart rate was significantly elevated compared to resting (67 bpm) in STrecov (96 bpm) and RSTrecov (99 bpm);

calorie and carbohydrate expenditure were not. Fat was significantly elevated only during RSTrecov.

These results indicate that when equated by training duration, ST represents an equivalent physiological stimulus on key parameters indicative of potential training induced adaptive responses to that produced by whole body RST. Such adaptations could conceivably include cardiovascular conditioning.

CHAPTER 1: INTRODUCTION

Purpose Statement

The purpose of this thesis was to consider and then build on the scientific knowledge surrounding the physiological responses to strongman training. To this end the intent was to investigate different metabolic and hormonal acute responses to strongman training, and compare and contrast these responses to that of traditional strength/hypertrophy gym training. Literature concerning the current known physiological responses to strongman training is critiqued, discussed and contrasted with the literature surrounding traditional strength/hypertrophy training with practical recommendations provided on how to implement strongman training into a training routine. The physiological responses to strongman and traditional strength/hypertrophy training are then investigated in an experimental repeated measures study, with recommendations provided based upon the results of the investigation.

Aim of Thesis

The aims of this research were as follows:

1. To review published literature on the acute physiological responses of strongman training and strength/hypertrophy training.
2. To investigate the acute physiological responses to two different training sessions; a strongman training session and a barbell strength/hypertrophy training session equated by approximate total set time.
3. To provide practical applications based upon the findings.

Study Limitations

1. Chapter Three uses a small sample size and is male only.
2. Testosterone and lactate were only taken pre and immediately post

Study Delimitations

1. Participation in the study was limited to strength trained males with a minimum of 1x bodyweight squat and 1.2x bodyweight deadlift

2. All testing was conducted in the same environment with the same temperature and humidity.

Significance of Thesis

This thesis examines the metabolic and hormonal responses to a strongman training session, which collectively may give a more detailed look at the physiological effects of training, along with giving insight into any associations between the metabolic and hormonal outcomes that may underlie chronic adaptations. This thesis provides exercise professionals with current scientific and evidence based information to better underpin conditioning practice. The findings of the thesis help enhance the knowledge of the strongman community and sport, these findings contribute to the awareness of the metabolic and hormonal changes that occur as a result of strongman training and strongman competitors could use this to better enhance their performance by optimising training protocols.

Thesis Outline

The main body of the thesis is presented through four chapters which include research and reviews at various stages of publication. Each chapter is therefore presented in the journal format and wording it was intended for. References are included as an overall reference list of the entire thesis at the end of the thesis.

Chapter two contains a review of literature currently in press with the Strength and Conditioning Journal on the physiological responses to strongman and strength/hypertrophy training.

Chapter three includes experimental research submitted to the Journal of Strength and Conditioning Research, examining the acute physiological responses to a strongman and strength/hypertrophy training session when equated for approximate total set time.

Chapter four provides an overall discussion of the findings from the presented research and some practical recommendations for strength and conditioners moving forward.

CHAPTER 2: LITERATURE REVIEW

The Physiology of Strongman Training

Abstract

This article aims to examine research surrounding the acute physiological responses to strongman training. To gain a greater understanding of the existing research to strongman training, acute physiological responses to strongman training are compared with that seen during common forms of gym based resistance training. Based upon the research some evidence based guidelines are recommended for strength and conditioners looking to implement strongman training into a training program.

The physiology of strongman training

Strongman exercises are becoming more prevalent in fitness centres and training facilities, likely owing to the novelty and competitive nature of the exercises. Despite this increased interest, current research on the physiological responses to strongman training has only examined acute responses, with much of this involving only a single exercise. The aim of this narrative review was to gain a better understanding of the existing research on strongman training by comparing physiological responses to strongman and weight training modalities.

Common Strongman Exercises

In a recent survey of 220 strength and conditioning coaches 88% reported using strongman implements in the training of their athletes. The strength and conditioning coaches surveyed trained athletes ranging from amateur (n=74), semi-professional (n=38) and professional level (n=108) and included coaches from organisations such as the National Football League (NFL), National Rugby League (NRL), Super Rugby, National Basketball League (NBL) and Major League Baseball (MLB) (61). In the survey strongman implements were defined as “any non-traditional implement integrated into strength and conditioning practice," main implements used were sleds, ropes, kettlebells, tyres, sandbags and farmers walk bars.

In strongman competitions the truck pull is a common event (54) and involves an athlete pulling a truck using a harness attachment connecting the athlete to the truck. The athlete faces the same direction they wish to pull towards with the truck attached behind them via a chest mounted harness, adopting the 4 point power position with both hands and feet on the ground they use lower body strength to take steps forward pulling the truck. While the truck pull is often used in strongman competitions it is impractical for athletes and coaches to implement a truck pull in regular training due to space requirements, thus a sled with a chest harness (see figure 1) or even a prowler is often used to simulate the truck.

Figure 1. Starting position of sled drag with chest pulling harness.

The farmers walk involves an athlete deadlifting two farmers bar handles (ostensibly, long dumbells with raised handles, see figures 2A & 2B) on either side of them, and then walking while carrying these loads, usually for a set time or distance with a set weight in competition settings. The farmers walk is believed to require high levels of grip strength, core strength and upper back strength (38) as well as the ability to walk quickly under substantial load (67).

Figure 2A. Start position of farmers walk.

Figure 2B. Middle position of farmers walk, walking with the weights.

The tyre flip involves athletes flipping large truck or tractor tyres. The athlete assumes a semi sumo deadlift position with his hands hooked under the edge of the tyre (see figure 3.A). In a neutral grip with palms facing each. This grip is preferred as it takes some strain off of the bicep tendon, but is dependent upon space under the tyre and at times a supinated position will be taken. The athlete will then lift upward, similar to the deadlift, then drive into the tyre extending the hips, knees and ankles (triple extension) to propel the tyre upwards and forwards (see figures 3B and 3C). The hands then rotate around from hip height to chest height to push the tyre over (see figure 3D).

Figure 3A. Start position of the tyre flip.

Figure 3B. Midway through a tyre flip.

Figure 3C. Point of tyre flip where an athlete can drive the tyre over completing the flip.

Figure 3D. End position of tyre flip where an athlete has completed flipping the tyre.

The overhead press is another very common strongman event (66); and is typically performed with a metal log, giant dumbbell or axle. Athletes are allowed to use any method of getting the object from ground to overhead and often employ a modified power clean movement for the clean portion, and a push press movement for the overhead press portion. While athletes are allowed to perform jerks or full cleans, the size and instability of the objects tends to favour a more controlled approach either in the form of a push press or strict press. For more in-depth description of the implements and lifting instructions readers are referred to Waller et al. (54).

Figure 4A. Start position of the strongman dumbbell clean & press.

Figure 4B. Mid rack position of the strongman dumbbell clean & press.

Figure 4C. End position of the strongman dumbbell clean & press.

While these exercises have been used for many years in strongman competition, for them to be applied effectively within strength and conditioning programs we need to have a deeper understanding of the underpinning physiological responses to these exercises. Long term training studies investigating the physiological effects of strongman exercises would give exercise professionals greater insight into how to strongman exercises may be best included in strength and conditioning programs. As there are currently no such long term training studies, we must look to relevant research that has examined the acute physiological responses to strongman training and compare that with what is currently known about traditional methods of resistance training.

Acute Physiological Responses

The American College of Sports Medicine (ACSM) released a position stand in 2011 with the goal of providing scientific evidence-based recommendations to health and fitness professionals in the development of individualised exercise prescriptions for apparently healthy adults of all ages. In this position stand the ACSM reports evidence based guidelines for the intensity and duration (using percentage of maximum heart rate, $V0_2$ max and rating of perceived exertion scales (RPE)) of exercise towards improvement of physical fitness and wellbeing.

Berning et al. (3) examined the metabolic demands of pushing and pulling a 1960kg motor vehicle. Six male strength athletes were required to attend three testing sessions. Sessions one and two were randomly assigned and entailed either pushing or pulling the 1960kg motor vehicle as fast as possible over a flat 400m course while heart rate and oxygen consumption were continuously recorded. Vertical jump was recorded immediately pre and post, and blood lactate levels were recorded immediately prior and 5 minutes post. Session three was a treadmill $V0_2$ max test. The push took 6.00 minutes on average to complete while the pull took 8.20 minutes on average. After the first 50m of the push/pull oxygen consumption averaged 44-49% of treadmill max while heart rates averaged 90-92% of HR max. It was observed that oxygen consumption and heart rate peaked within the first 100m of both the pushing/pulling and from that point on oxygen consumption and heart rate averaged 65% and 96% of treadmill maximum (50.3 $ml \cdot kg \cdot min^{-1}$, HR max 194 beats per minute) values respectively. Blood lactate values averaged 15.06mmol post pulling/pushing sessions, representing 131% of the treadmill $V0_2max$ test. Peak vertical jump also decreased from pre to post on average by 17%. Berning et al. (3) noted three key points; peak exertion was achieved quickly somewhere between 50m and 100m, the car push/pull is an extremely exhausting event with near maximal heart rates being maintained over several minutes, and this event is highly anaerobic with post car push/pull lactate scores 31% greater than observed following the maximal treadmill test. It was also noted that acute fatigue was substantial with vertical jump scores significantly decreasing and all subjects experiencing dizziness and nausea. Due to the extreme anaerobic energy output and level of fatigue involved, Berning et al. (3) recommended that the car push/pull should be considered an advanced form of training, and be carefully and sparingly incorporated into the overall training plan.

Table 1. Acute physiological responses to strongman and resistance training

Acute Physiological responses to Strongman activity									
Strongman Studies	**Activity**	**Participants**	**Time Point**	**Lactate**	**Heart rate**	**O2 consumption**	**Energy expenditure**	**Testosterone**	**Cortisol**
Berning et al (2007)	Car push and pull (with harness), 2 different sessions, 1960kg pushing for 400m, 1 maximal set	6 male strength trained athletes, squat 2-3x bodyweight	IPST(except lactate)	5 mins post- 15.6 mmol/L	186bpm (96% of treadmill max)	65% of max	N/A	N/A	N/A
Ghigiarelli et al (2013)	Chain drag, tyre flip, farmers walk, keg carry and atlas stone lift. 3 sets to muscular failure, 2 mins rest between sets, 3 mins rest between exercises.	16 strength trained men	IPST	N/A	N/A	N/A	N/A	H-136% ^ ST- 74% ^ XST- 54% ^	N/A
Keogh et al (2010)	Tyre flip. 2 sets of 6 flips with a 232-kg tyre 3 mins rest	5 strength trained athletes, 4 strongman experienced	2.5min PST	10.2mmol/L	179bpm (92% of age predicated max)	N/A	N/A	N/A	N/A
West et al (2013)	5 sets of 2 x20 m (30 s recovery between drags, 120 s recovery between sets) maximal backward sleddrags (loaded with 75% body mass)	11 strength trained males. Minimum 4 years strength training, 1rm backsquat 180±25kg	Baseline	1.7 mmol/L	N/A	N/A	N/A	158 pg/ml	3.4 pg/ml
			IPST	12 mmol/L	N/A	N/A	N/A	180 pg/ml	3.7 pg/ml
			15min PST	9 mmol/L	N/A	N/A	N/A	38 % ^ 217±49 pg/ml	54% ^ 5.2 pg/ml
Gym Based Studies									
Bloomer (2005)	30mins intermittent free weight squatting, 70% of 1RM to failure, 90-120secs rest between sets	10 healthy men, minimum 1.5x bodyweight squat	IPST	N/A	160bpm- 82% of age max	45% of max 20.22 ml/kg/min	20.93kj/min	N/A	N/A
Crewther et al (2008)	Machine squats- power 8sets of 6 reps @45%1RM 3min rest, hypertrophy 10sets of 10 reps @75% 1RM 2min rest, strength 6 sets of 4 reps @88%1RM	11 recreational active mean, training min 2 years, min twice per week.	IPST	N/A	N/A	N/A	N/A	H-sig ^ P- NC MS- NC	H-sig ^ P- NC MS- NC
Date et al (2013)	3 different volumes of power cleans. 3x3@3RM (LV). 3x6x80-85% of 3RM (MV). 3x9x70-75% of 3RM (HV) 2mins rest	10 male recreational athletes, minimum 1 year olympic weightlifting experience	IPST	LV- 4.03mmol/L MV-5.27mmol/L HV-7.43mmol/L	N/A	N/A	N/A	N/A	N/A
Garbutt et al (1994)	Circuit weight training. 3 cicuits of 9 exercises. 40%1RM- lowerbody exercises 15reps, upper 10reps. 30's rest between sets and exercises	10 healthy males, habitually active in sport & weight training	IPST	C1- 4.8 mmol/L C2- 6.9 mmol/L C3- 8.8 mmol/L	mean 69% of treadmill max C1- 122 bpm C2- 136 bpm C3- 149 bpm	mean 50% of max C1- 27.4ml/kg/min C2- 29.6ml/kg/min C3- 33.4ml/kg/min	N/A	N/A	N/A
Hakkinen & Pakarinen (1985)	Back squats Session A- 20 sets of 1 @1RM 3 mins rest, session B 10 sets of 10 @ 70% @1RM 3 mins rest	10 top level finish male strength athletes	IPST	N/A	N/A	N/A	N/A	A- NC B-sig ^	A- NC B- sig ^
Kelleher et al (2010)	Agonist-antagonist supersets (SS) & traditional (T) gym training. 6 exercises. 4 sets @10RM. Superset group has participants perform 1 superset before 1 mins rest.	10 Recreationally active young men, minimum 2 years weight training experience	IPST	SS- 11 mmol/L T- 7mmol/L	N/A	N/A	SS- 35 kj/min T- 26 kj/min	N/A	N/A
Schilling et al (2001)	2 groups Free weight squats - 3 sets of 10 @70% 1RM with 1 min rest, machine group- leg curl, leg extension, back extension -3 sets of 10 @70% 1RM with 1 min rest	6 males average training experience 9 years	5min post	N/A	N/A	N/A	N/A	FW- 12.5% ^ M-38% v	FW- 57% ^ M- 3% v
Schwab et al (1993)	Free weight squatting- 1 moderate load(MWL)- 4 sets of 6 reps @90-95% of 6RM. Session 2 Light weight (LWL)- 4 sets of 9-10 @60-65% of MWL	6 experienced weight lifters	IPST	N/A	N/A	N/A	N/A	MWL- 30.9% ^STST LWL- 26.6% ^STST	N/A

Table legend

STST= Serum testosterone, IPST= Immediately Post, C= Circuit, ^= Increase, ˅= Decrease, H=Hypertrophy training, ST= Strongman training, XST= Mixed strongman and gym training, M=Machine, FW= Free weights, P=Power training, MS= Strength training, NC= No change, SS= Superset, T= Traditional.

However the car push/pull performed in the study of Berning et al. (3) was for 400m, a much longer distance than the 20-30m the majority of strongman competitors use to train this event (65). The greater duration was likely a key contributing factor to the high lactate outputs and decreases in vertical jump performance seen immediately post exercise. Future research could also examine the physiological responses to the truck pull as performed with heavier loads and over much shorter distances to allow coaches and exercise professional's deeper insight into the physiological responses to strongman training.

The heart rates and oxygen consumption observed with the 400m car push/pull falls into the 'vigorous' training zone set by the ACSM, although after the first 50m oxygen consumption for the push/pull were 44% and 49% of $V0_2$ max respectively, levels that fall within the ACSM's moderate activity level range.

When comparing the results of the car push/pull with different modalities of resistance training we note that the car push/pull appears to be a more metabolically demanding exercise with higher heart rates achieved in a shorter period (96% HR max on average after 6-8 minutes of car push/pull) than the traditional forms of resistance training. Relevant resistance training studies reported mean heart rates of 69% of treadmill maximum (13) following circuit weight training performed for 17 minutes, and 82% of age predicted maximum heart rate (4) following 30 minutes of intermittent free weight squatting, placing them in the moderate and vigorous training zones respectively (12). The circuit training study also recorded an oxygen consumption of 50% of $V0_2$

max after 17 minutes, meaning it could be defined as a moderate activity level according to the ACSM's guidelines. The entire circuit weight training produced similar peak oxygen consumption rates to the first 50m of car push/pull. Despite 50m of car push/pull producing similar peak oxygen consumption levels and higher heart rates (90-92% of maximum after 50m) as the circuit weight training, the duration for the 50m car push/pull is likely to be under 1 minute (as the 400m took 6-8 minutes) while the average duration for 3 circuits to be completed was 17 minutes. It should be noted that the circuit weight training involved brief rest periods of up to 30 seconds between sets and exercises. Equated for time car push/pull appears to be more metabolically demanding than the circuit training used in the study. While loading would affect the magnitude of the metabolic demand placed upon the body, the car push/pull appears to produce metabolic responses deemed favourable for metabolic conditioning and circuit style training, and in practice is often performed for 20-30m on a sled or similar implement (65).

Keogh et al. (27) examined physiological and biomechanical aspects of the tyre flip, another common strongman event. Five resistance trained subjects who were experienced in the tyre flip performed 2 sets of 6 tyre flips with a 232kg tyre and 3 minutes of rest between sets. Heart rate and blood lactate were recorded across five time points throughout the session: immediately pre-set 1; immediately post set 1; immediately pre-set 2; immediately post set 2; and 2.5 minutes post set 2. High heart rates of 179 bpm (92% age predicted max) and lactate levels of 10.4 mmol/L were found at the conclusion of the second set of tyre flips. Keogh et al. (27) concluded from the results that the tyre flip appears to provide a relatively high degree of physiological stress, however in the future similar research would need to be conducted with larger sample sizes and athletes of varying degrees of experience to determine how factors such as training experience as well as exercise prescription factors such as relative loading, rest periods, numbers of sets and repetitions would influence this acute response.

When using the ACSM guidelines to categorise the tyre flip it falls into the vigorous training zone. Comparing the heart rate responses of the tyre flip to resistance training modalities of circuit weight training (13) and free weight squatting (4) it is observed that heart rate response to the tyre flip was greater. The tyre flip exercise is similar in nature in some ways to the power clean as there is little or no eccentric motion and a powerful triple extension is imperative to a successful lift. Lactate response to the power clean has been reported to be 7.4 mmol/L following 3 sets of 9 repetitions with 70-75% of 3RM and 2 minutes rest between sets (9). While the tyre flip produced a higher lactate output with less sets and repetitions it is difficult to compare due to the tyre being a set load and not individualised as a relative percentage of maximum.

Recent research performed by West et al. (56) examined the acute metabolic, hormonal, biochemical and neuromuscular responses to a backward sled drag training session. West et al. (56) had 11 strength trained males with an average back squat of 180kg and 4 years of weight training experience perform 5 sets of 2x20m reverse sled drags with 75% of their bodyweight on an indoor running surface. Participants were instructed to drag the sled 20 meters as fast as possible, rest for 30 seconds then drag the sled back, this was counted as 1 set and participants performed 5 sets with 120 seconds of rest between sets. Hormonal measures assessed included salivary testosterone and cortisol, with metabolic measures including blood lactate and creatine kinase, and neuromuscular responses were measured through countermovement jumps (CMJ). Participants performed a dynamic warm-up, followed by 3 CMJ on a force platform. Baseline measures through saliva and blood were then collected 15 minutes later. Following blood and saliva collection participants began the sled drag workout. Upon completion of the sled workout participants performed 3 CMJ before saliva and blood collection. Participants then rested before the CMJ and blood/saliva collection was repeated at 15 minutes, 1 hour, 3 hour and 24 hours post sled drag. West et al. (56) observed CMJ to significantly decrease after sled dragging and remain significantly below baseline until recovering at 3 and 24 hours post sled drag. No changes in creatine kinase were seen at any time point post sled dragging. Blood lactate increased to 12.4 mmol/L immediately post sled drag training and remained elevated at 9.0 mmol/L 15 minutes post. Blood lactate remained elevated at 1 hour post sled drag with 3.8 mmol/L before returning to baseline levels of 1.7 mmol/L at 3 and 24 hours post sled drag. Testosterone peaked 15 minutes post sled drag before decreasing below baseline at the 3 hour time point, with a further peak seen at 24 hours post. Cortisol concentrations tended to increase at 15 minutes post sled drag before declining at 1 hour post. Three hours post cortisol declined below baseline and at 24 hours post cortisol returned to baseline levels.

The lack of any significant sled drag-induced increase in creatine kinase was interpreted by West et al. (56) to indicate no significant muscle damage incurred from the sled drag session. A possible mechanism for this lack of muscle damage was the lack of use of stretch shortening cycle (eccentric followed by concentric) in the contractions required to pull the sled as a reverse sled drag is primarily concentric muscle action. With CMJ height returning to baseline at 3 hours post it was conjectured that full recovery of neuromuscular function had occurred within this time, a result consistent with the lack of muscle damage, as assessed via creatine kinase. The increase in testosterone was attributed to the increase in lactate with the metabolic component to the session being an important stimulus for testosterone secretion; this was confirmed with the correlation (r =0.67) between the change scores of testosterone and lactate (56). The increase of testosterone at 24 hours was said to be a rebound effect to aid in recovery (70). Cortisol was shown to be related to the changes in lactate with the rise in cortisol suggested to reflect the metabolic demand placed upon the body (70). Overall the increases in lactate, testosterone and cortisol post sled drag were said to be indicative of a positive training stressor.

A limitation of the study was the lack of a control group to show the changes in hormonal markers were due to the sled drag and not natural diurnal variation. Likewise, the measurement times lasted only up to 24 hours post-exercise may have been inadequate as changes in creatine kinase may take longer than 24 hours to peak (34, 37, 50). Therefore, the lack of any significant change in creatine kinase within this timeframe and the resulting interpretation of no muscle damage may have reflected this limitation (22, 23).

Eccentric muscle actions have been linked to muscle damage and an increase in creatine kinase levels (40). This is consistent with other research showing creatine kinase levels were much lower following concentric only exercise compared to eccentric only exercise (40). Similar lactate responses were observed between the sled drag exercise and a reciprocal superset workout involving a total of 12 supersets opposed to 5 sets of the sled drag. West et al. (56) reported cortisol levels increased by 54% 15 minutes post sled drag training session, before returning to baseline levels at 60 minutes post training and decreasing by 52% at 3 hours post. Similar results to the sled drag session were reported by Schilling et al. (46) who reported a 57% increase in cortisol five minutes post a free weight squat session, consisting of 3 sets of 10 repetitions at 70% of 1RM with 1 minute rest between sets. Other studies reported significant increases in cortisol levels (7, 18) , but only from the hypertrophy training groups. The hypertrophy protocol implemented by Crewther et al. (7) involved 10 sets of 10 repetitions at 75% of 1RM with half the sets performed on the supine squat and half on the smith machine squat, participants were given 2 minutes rest between sets. The hypertrophy protocol reported by Hakkinen and Pakarinen (18) was performed for 10 sets of 10 repetitions at 70% of 1RM with 3 minutes rest between sets on the free weight squat. It is possible that strongman training shares many similarities with common hypertrophy protocols regarding the duration of sets which could be the reason for similar increases in cortisol to those of the hypertrophy training methods.

Ghigiarelli et al. (14) examined the acute salivary testosterone responses of two novel strongman training protocols compared to a common hypertrophy resistance training protocol. Sixteen male participants, who acted as their own control, completed three different protocols designed to match total volume, rest period and intensity between the protocols. The protocols were hypertrophic (H), a strongman (ST) and mixed involving both strongman exercises and traditional gym exercises (XST). All protocols were performed to muscular failure with a 2 minutes rest between sets and a 3 minute rest between exercises. The H protocol consisted of the squat, leg press, bench press and seated row performed for 3 sets of 10 reps to failure at 75% of 1RM. Unlike earlier studies, the ST protocol consisted of multiple exercises including the tyre flip, chain drag, farmers walk, keg carry and atlas stone lift. The XST session included the tyre flip, back squat, chain drag, bench press and stone lift in that order, exercises were loaded at 75% of 1RM performed for 10 repetitions. Each protocol was performed with a week of rest in-between to account for the changes in diurnal variation. Salivary testosterone was recorded immediately pre, immediately post, and 30 minutes post each protocol. The H protocol induced testosterone increases of 137%

immediately post, the ST protocol a 70%, and the XST protocol a 54% increase immediately post however there were no significant differences between groups.

Ghigiarelli et al. (14) concluded that strongman training appears to be an effective tool for increasing endogenous testosterone response in a similar pattern to that of recognised hypertrophic protocols. This increase in testosterone has been speculated to facilitate the growth response and increase in muscle protein synthesis (31). While this position has recently been challenged (57-59), Ghigiarelli et al. (14) suggested that there is a larger body of research supporting the former (21, 32, 44, 47, 52, 53). A viable reason for the large increases in testosterone when compared to the other research (7, 18, 46, 49) is that the total volume of work performed and muscle mass used was higher than the majority of other studies, with subjects performing five exercises for 3 sets to muscular failure. Research has shown a relationship between volume and testosterone response (15).

Practical applications

The following practical applications provided are given based upon existing research. It is acknowledged that the vast majority of existing studies in the field of strongman training is on acute responses with a lone study on short term training (63). For more in depth practical applications, strongman training would need to be researched with the use of training studies, examining the chronic effects over a period of months to years. Despite the limitations of the research we can provide recommendations based upon the acute responses (see table 2).

Practical applications					
Physiological goal	Exercise	Sets	Reps	Load/Difficulty	Rest
Muscle Hypertrophy(1,31,35,36)	Strongman Lifts (eg tyre, log, dumbell press ect)	3-4	8-12	70-85% 1RM	60-120 seconds
	Strongman Moving events (farmers walk, truck pull, sled drag ect)	3-4	20-50 meters	15-17 BORG RPE scale (20 point)	60-120 seconds
Metabolic conditioning (28,56)	Strongman Moving events (farmers walk, truck pull, sled drag ect)	3-4	minimum of 30 seconds	15+ on BORG RPE scale (20 point)	minimum of 30 seconds
General conditioning (12)	Strongman Moving events (farmers walk, truck pull, sled drag ect)	5	60 seconds- 5 different exercises	15+ on BORG RPE scale (20 point)	60 seconds

Table 2. Evidence based practical applications for strongman training.

Traditional gym training methods are well established for the hypertrophy training block (1, 31, 35, 36). Recently strongman training was compared to traditional resistance training using exercises matched for biomechanical similarity and equal loading (63). Between group differences indicated small positive changes in muscle mass in the strongman group compared to the traditional group indicating strongman training may be a viable modality of training for the hypertrophy block of training (63). Large time under tension have been shown to have favourable effects on increasing muscle hypertrophy (39). For increasing muscle hypertrophy researchers recommend sets of 8-12 repetitions with loads of 70-85% of 1RM performed for 3-4 sets (1, 31, 35, 36). Sets with these parameters generally last 25-40 seconds, somewhat comparable to strongman events which generally range from 30-60 seconds with loads that require the athlete to work for similar durations. These durations of 30-60 seconds are commonly utilised by competitive strongman athletes when performing 20-50m sets of farmers carries and 30 meter truck pulls (65). Strength and conditioning coaches often use sleds, farmers walks and tyre flips in the training prescription for non-strongman athletes, making use of these implements to train metabolic conditioning, explosive strength/power and muscle endurance (61). Due to the horizontal nature of the exercises it is problematic to prescribe based on 1RM percentage as these exercises are often performed for a set horizontal distance and the resistance force may also be influenced by the friction force, especially for events like the truck or sled pull.

Strongman exercises also require multiple large muscle groups to contract simultaneously; exercises such as the farmers carry or yoke walk require powerful co-contraction of multiple muscle groups including core, upper body and lower body musculature (38). Multiple large muscle groups contracting simultaneously has been shown to be a great stimulus for the metabolic and hormonal responses believed important for muscle hypertrophy (21).

Based upon the above research, strength and conditioners looking to prescribe strongman exercises with the intent of increasing muscular hypertrophy should implement exercises such as the sled drag and farmers walk, with each set lasting 30-45 seconds for 3-4 sets with 90-120 seconds of rest, and loads that allow the athlete to complete at least 30 seconds of an exercise before muscular failure (see table 2).

Research on strongman exercises also shows large metabolic and cardiovascular responses, indicating it could be used for both metabolic and cardiovascular conditioning. Coaches looking to implement strongman exercises as a means of developing metabolic conditioning should look at prescribing exercises such as the tyre flip, sled drag and truck pull/sled drag for sets of a minimum of 30 seconds as this has been reported to produce lactate levels ranging from 10-16 mmol/L (28, 56) (see table 2). Training adaptations to lactate levels of this magnitude may cause adaptations in lactate production, clearance mechanisms and tolerance levels that may lead to an improvement in performance (26). Coaches looking to implement longer sets of strongman exercises may wish to split the duration between different exercises to cover a larger amount of musculature as the metabolic conditioning will be exclusive to active muscle groups.

Strongman exercises can also effectively be used as general conditioning exercises. Research has shown heart rate and oxygen consumption levels ranging from moderate to near maximal on the ACSM’s intensity chart when performing strongman exercises (3). According to the ACSM, those looking to increase their general fitness should perform 30-60 minutes of moderate intensity exercise per day, or 20-60 minutes of vigorous activity. Based upon the ACSMs guidelines we recommend coaches implement strongman exercises such as sled drags, tyre flips and car pushes for sets of 1-2 minutes in a circuit format with the total time equating to 20-30 minutes. An example of this could be 5 different exercises performed for 1 minute each for 5 rounds with 1 minutes rest in between. Care would need to be taken to prescribe a load that the individual is capable of performing for the full minute (see table 2). Coaches should also be aware that this form of training is likely to have a large metabolic component to it, and that optimal recovery strategies should be in place.

Strength and conditioners could also use strongman training as a means of training multiple qualities at a single time. This would help with training efficiency and allow coaches to spend more time on other qualities. An example of this may be in the sport specific training phase where skill work is being performed in much higher volumes. In the sport specific phase a coach could use strongman training in a circuit format to maintain an athlete’s anaerobic conditioning and strength in a single session, as opposed to having to train the two qualities separately. Sled pulls may be particularly useful exercise in this in-season context due to their reduced creatine kinase levels and quicker anaerobic power recovery times (56), acknowledging that their muscular action and contraction types are not completely specific to all athletic activities. Furthermore it has been speculated that strongman training may lead to greater adherence to resistance training programs due to the novelty and challenging nature of the exercises, often allowing athletes to train outdoors (67).

Strongman training also has its limitations. Winwood et al. (64) performed a retrospective survey of 213 strongman competitors looking at injury epidemiology. Winwood et al. (64) observed that strongman athletes were 1.9 times more likely to sustain an injury when performing strongman implement training compared to traditional training when matched to training exposure. Furthermore as many strongman exercises require such high levels of core stability much of the injury risk may be on the lower back (38). Due to these risks significant coaching is required by strength and conditioning coaches looking to implement strongman training into their athletes programs and it is imperative that they take the time to coach their athletes in proper technique and monitor them closely. It should also be noted that to date there has been no specific research on strongman training for females.

Another issue of strongman training is the greater challenge in precisely quantifying and altering training load for a number of individuals within the same session (2). Quantifying training load is most difficult for horizontal pulling and pushing exercises such as heavy sled pulls and prowler pushes because of the coefficients of friction (static and dynamic) between the resistance and ground would need to be measured. Other exercises such as tyre flips, keg carries and stone lifting can present problems as the loads may be too heavy or too light to apply sufficient loading for some of your athletes. However, other exercises such as yoke walks, farmers walks, sled pulls and prowler pushes can quite quickly have their loads changed by adding or removing plates.

Strength and conditioners employing tyre flips, keg carries and stone lifts would be wise to have access to a range of different sized implements to ensure movement competency is adhered to with lighter loads on strongman implements before progressing their athletes onto heavier implements much like they would when coaching athletes with a barbell squat or power clean.

CHAPTER 3: STRONGMAN VERSUS STRENGTH/HYPERTROPHY RESISTANCE TRAINING ACUTE PHYSIOLOGICAL EFFECTS

Abstract

Strongman training has become an increasingly popular modality, but data on physiological responses is limited. This study sought to determine physiological responses to a strongman training session compared to a common strength exercises training session. Ten healthy males (23.6±7.5 years, 85.8±10.3 kg) volunteered in a crossover design where all participants performed a strongman training session (ST), a common strength exercise training session (RST), and a resting session within seven days apart. The ST consisted of sled drag, farmers walk, one arm dumbbell clean and press, and tyre flip at loads eliciting approximately 30 seconds of near maximal effort per set. The RST consisted of squat, deadlift, bench press and power clean, progressing to 75% of 1RM. Sessions were equated for approximate total set duration. Lactate and salivary testosterone were recorded immediately pre and post training sessions. Heart rate, caloric expenditure and substrate utilisation were measured throughout the resting session, both training protocols and for 80 minutes post training sessions. Analyses were conducted to determine differences in physiological responses within and between protocols ($p \leq 0.025$ and $p \leq 0.0125$). No significant changes in testosterone occurred at any time point for either session. Lactate increased significantly immediately post both sessions. Heart rate, caloric expenditure and substrate utilisation were all elevated significantly during ST and RST. Heart rate and fat expenditure were significantly elevated compared to resting in both sessions' recovery periods; calorie and carbohydrate expenditure were not. Compared to RST, ST represents an equivalent physiological stimulus on key parameters indicative of potential training induced adaptive responses. Such adaptations could conceivably include cardiovascular conditioning.

Introduction

Strongman training has become an increasingly popular modality used by practitioners for athletic development, general strength and conditioning, anaerobic conditioning and fat loss. In a recent survey of strength and conditioning coaches, 88% (n=220) reported using strongman equipment in the training of their athletes and 81% reported good to excellent results from using strongman training (61). Strongman training and competition involve large multi-joint movements that share similar kinematic profiles to common strength training exercises (RST) such as the squat and deadlift (60, 62). Common strongman exercises include sled pulls, farmers walks, tyre flips and overhead presses (65). A key difference between strongman exercises and RST is that strongman exercises are often performed in a horizontal plane and involve a moving component where an athlete performs carries, pushes or pulls an object from one location to the next (63). At a physiological level this may elicit unique metabolic and hormonal responses to those of RST.

Current research pertaining to strongman training (either of one exercise or a training session) report acute increases in metabolic outputs across a variety of different measures. Blood lactate (3, 27, 56), heart rate (3, 27, 33) and oxygen consumption (3) increased following a session involving a single strongman type exercise. Research investigating hormone levels and strongman training (ST) has shown an increase in acute hormonal levels of testosterone following a ST session training (14, 56). No studies to date have examined the calorie, carbohydrate or fat expenditure of ST.

Current research on physiological response to RST report increases in acute metabolic measures of blood lactate (9, 30, 55), heart rate (4, 13) and oxygen consumption (13, 48). Research has also reported RST to induce large hormonal elevations with acute increases in testosterone (14, 47, 51) and cortisol (7, 17, 46).

While Ghigiarelli et al (14) has examined the testosterone response to an entire ST session and compared it with that of hypertrophy training, no research has collectively examined the metabolic and hormonal effects of ST and compared it directly to RST. Therefore the aim of this study was to examine the acute metabolic and hormonal response to ST and compare it with RST.

This information on ST could be used to give exercise professionals a deeper insight into the physiological mechanisms involved in strongman and its potential adaptations in performance and body composition.

Methods

Experimental approach to the problem

Ten participants acted as their own control in a crossover design in which they performed both a strongman training session (ST) and a traditional strength exercise (RST) training session within seven days apart. Five participants performed ST first and five performed RST first, and sessions were equated for approximate total set duration. Testing was conducted at the same time each day and participants were required to perform each session with identical pre-session routines such as nutrition, exercise and sleep. Variables of interest included salivary testosterone, blood lactate, heart rate, and calorie, fat and carbohydrate expenditure. Analyses were conducted to determine differences in physiological responses within and between the two different protocols.

Subjects

Ten healthy males (23±7 years; 85±10 kg) volunteered to participate in this study. All had a minimum of two years of strength training experience, and a squat and deadlift strength of at least 1.0 and 1.2 times body mass respectively (see table 3). Participants were required to be between the ages of 18-45 and familiar with the squat, bench, deadlift and power clean exercises. Participants had no existing injuries that could be aggravated by doing the ST and RST sessions and were not taking any performance enhancing drugs. Training frequency for the participants varied from 3-6 days of weight training per week with repetition ranges varying between 6-10 repetitions for 2-4 sets for compound movements. No participants had professional strongman competition experience but two participants had competed in a novice strongman competition. All participants were familiar with and had performed the strongman exercises in their own training. The study was granted Institutional ethical approval and all participants signed a voluntary informed consent form prior to participating.

Table 3. Participant characteristics (mean ± standard deviation)

	n	Age (years)	Weight (kgs)	Squat (kgs)	Squat (% of bodyweight)	Deadlift (kgs)	Deadlift (% of bodyweight)
Men	10	24±7	86±10	140±29	163±34	163±37	191±45

Procedure

Warm up

All sessions were supervised by a New Zealand Registered Exercise Professional who had three years of competitive strongman experience. All sessions were conducted within the institutional strength laboratory. For both sessions, participants first conducted a warm-up consisting of 5 minutes on a stationary bike (Life Fitness, New Zealand) at self-selected intensities with the aim of getting heart rate to 110-120 beats per minute followed by 3 minutes of dynamic stretching involving leg swings, arm swings, walking lunges and squats with minimal added load. Participants were then fitted with a breath-by-breath gas analyser (Metalyzer 3Bsystem; CORTEX Biophysik GmbH, Leipzig, Germany) a heart-rate monitor (Polar^{TM}, Finland) before commencing the session (see figure 5).

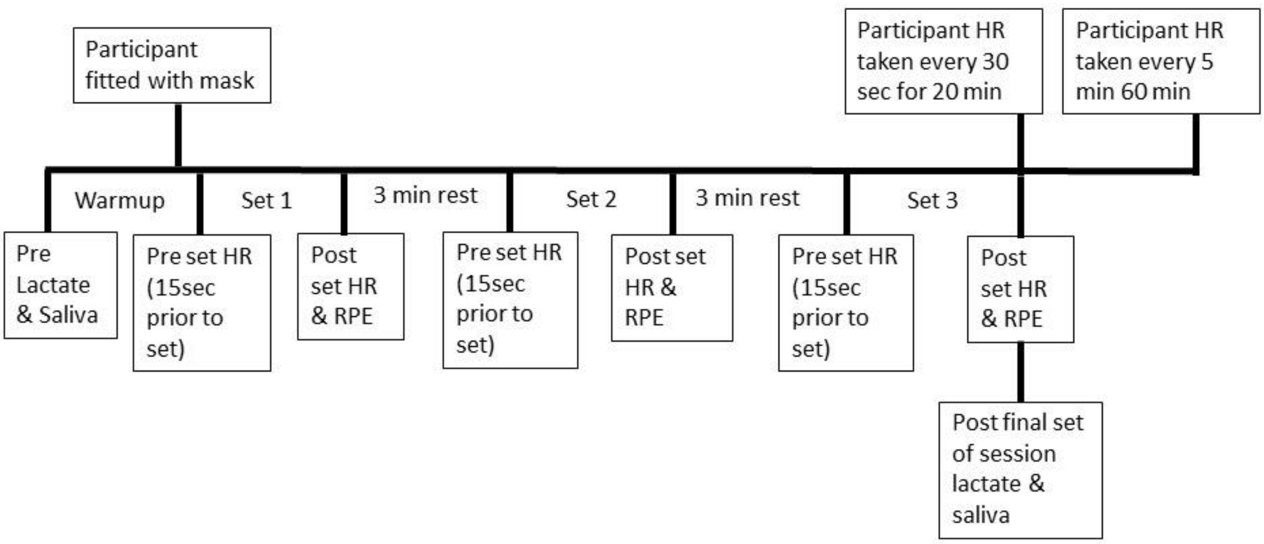

Figure 5. Schematic timeline of data collection

1RM Testing

Participants were experienced strength trained individuals. Maximal strength (1RM) for the RST exercises were determined by calculation (rep weight x number of reps x0.3333) + rep weight) (10) based on self-reported very recent training load history.

Traditional strength exercise training session

Participants performed the squat, deadlift, bench press and power clean in that order with a 3 minute passive rest interval between sets and exercises. Participants were required to perform two warm up sets at 50% and 75% of the working set which was at 75% of their predicted one repetition maximum load, for 10 repetitions. Participants were instructed to complete the repetitions at a self-selected pace. Sets at this intensity and duration typically involved approximately 30 seconds of total time per set. Participants were fitted with the oxygen facemask and cart which was positioned in a way to allow the unrestricted exercise performance (see figure 6).

Figure 6. Position of oxygen cart in relation to participant.

For the squat, participants were required to remove the bar from the racks with the bar positioned across the middle of the trapezius and squat down until the bottom of the thigh was parallel with the ground. For the deadlift the participants were required to lift the bar from the floor and the bar had to touch the ground between every rep, the 'touch and go' protocol was permitted but excessive bouncing was not. In the bench press participants were required to lower the bar down until it touched their chest and then press it up to full arm extension. The power clean (see figure 7) exercise required participants to pull the bar from the ground to their clavicle using a triple extension motion, a touch and go protocol was permitted with no excessive bouncing.

Figure 7. Power clean with oxygen cart.

Strongman training session

The oxygen cart was positioned or wheeled alongside participants as they performed the exercises (see figures 8 and 9). The exercise order was sled drag, farmers walk, one arm dumbbell clean and press, and tyre flip. Participants were required to perform two warm up sets of 50% and 75% of the working set, the working set for sled drag was 200% of bodyweight for 12 m, farmers walk 80% of bodyweight (each arm) for 24 m and dumbbell overhead at 30% of body weight for 10 repetitions. For the tyre flip all participants performed one set of as many repetitions as they could in 30 seconds on a 220kg tractor tyre (external diameter 150 cm, height on ground 80 cm) as scaling tyre resistance to each individual proved unfeasible given the time and budget restraints. These percentages originated from pilot testing utilising three participants who performed sets of the strongman exercises at different percentages of bodyweight with the goal of ensuring sets would be approximately 30 seconds in duration, in an effort to approximately equate the two session protocols. There was 3 minutes passive rest between all sets and exercises. In all sets participants were instructed to perform at a self-selected pace but with maximum effort.

Figure 8. The sled drag with oxygen cart.

For the sled drag (Figure 8) participants were attached to a harness with the sled positioned behind them. They started in the four point power position and took steps forward, instructed to stay low for the whole set (within hand touching distance of the ground) and were not permitted to come upright into a sprint position (28). For the farmers walk participants deadlifted a pair of farmers handles (length 1300 mm, handle width 30 mm) off the floor and taking short steps walked 12 m before placing the farmers bars back down, participants then turned and picked up the handles again carrying them back to the start position (29). For the dumbbell overhead participants were permitted to get the dumbbell overhead anyway they chose to and were allowed two hands to clean the dumbbell but only one hand to press the dumbbell overhead, standard technique being a two hand clean followed by a one arm push. However some participants chose to snatch the dumbbell. Each repetition the dumbbell was returned to the floor and finished when participants had completed 10 repetitions to full overhead extension, participants were permitted to alternate arms or complete all repetitions on one arm based on their personal preference.

Figure 9. Tyre flip with oxygen cart.

The tyre flip (see figure 9) was performed for a single repetition at a time, and participants ran 180 degrees around the tyre to flip it back to the starting position. Each flip the participant assumed a deep squat position leaning their chest into the tire with their hands hooked underneath the tire. Participants performed triple extension of the ankles, knees and hips bringing the tyre up to chest height, their hands then transitioned from under the tyre to a push position and they drove the tyre forward completing the flip (27).

Testing

Salivary testosterone

Participants were instructed to abstain from brushing their teeth or drinking hot liquid for 30-60 minutes prior to testing. All saliva collections were made with participants seated, leaning forward, and with their heads tilted down. Participants were instructed to swallow in order to empty their mouth of saliva before an unstimulated whole saliva sample was collected into a sterile bijou tube (7 ml-capacity with screw top, Labserve, Auckland, NZ). Care was taken to allow saliva to dribble into the collection vial with minimal orofacial movement. Samples were frozen and stored at -80 °C until analysis. The salivary testosterone concentrations were determined using commercially available ELISA kits (Salimetrics, State College, PA, USA). The sensitivity of the kits were <1.9 pg/ml (salivary testosterone). The mean intra-assay coefficients of variation was 2.7%.

Lactate

Whole blood was taken via fingertip puncture using a spring loadable lancet (Safe-T-Pro Plus, Germany), blood was taken and measured immediately using a Lactate Pro™ (Lactate pro, Arkray, Japan) lactate analysis unit.

Heart rate

Heart rate was observed in real time using a heart rate strap and watch (Polar™, Finland) with results typed into a spreadsheet. Heart rate was recorded 15 seconds prior to every set and immediately post. Following the session heart rate was recorded every 30 seconds for 20 minutes; it was then recorded every 5 minutes for the next hour.

Energy expenditure & oxygen consumption

Energy expenditure and gas exchange was measured using breath-by-breath gas analysis. The mask was fitted to the participants after the standardized warm-up and remained on and recording data for each session and 80 minutes post workout during a passive post-session recovery data collection period termed STrecov and RSTrecov for post ST and RST respectively. Immediately post session participants were allowed to lift the mask up to expel saliva for the second saliva reading and have a brief drink of water before refitting the mask and commencing the STrecov or RSTrecov data collection phase. The metabolic cart was calibrated at the start of each day of testing.

Rating of Perceived Exertion

Participants were instructed to rate their perceived exertion (RPE) for each set by pointing at their corresponding rating on a 6-20 BORG scale in the rest period immediately following their sets. All RPE readings were then used to create a mean RPE for each session.

Data analysis

The data was screened for normal distribution using a histogram plot and Shapiro-Wilks test. Descriptive statistics (mean ± SD) were calculated for all dependant variables that followed a normal distribution. Normally distributed data was analysed using a paired samples T-test with significance set of $p \leq 0.05$. Data that did not follow a normal distribution was analysed using the Wilcoxin signed rank test and is presented using the median, upper and lower quartiles, minimum and maximum values. To avoid type I and type II errors due to multiple pairwise comparisons, the alpha level was adjusted to $p \leq 0.025$ when two comparisons were conducted, and $p \leq 0.0125$ when four pairwise comparisons were made. All statistical analyses were performed using SPSS software (version 22, SPSS Inc, Chicago, IL).

Results

There were no significant differences ($p = 0.742$) in set times between protocols; mean set time for ST was 29±4 seconds while RST was 29±2 seconds. Session RPE was 13 for both ST and RST with no significant differences ($p = 0.103$) between sessions. Table 4 presents median values for the measured variables across all time points.

Table 4. Median results of physiological measures

Measure	Resting	IPRE ST	IPRE RST	IMPST ST	IMPST RST	ST	RST	STrecov	RSTrecov
Heart Rate (BPM)	69±12	---	---	167±14*	170±7*	133±19*	132±15*	94±24*	96±12*
Calories (kcal/min)	1.75±0.49	---	---	---	---	8.91±1.82*	9.12±0.70*	2.20±0.35	2.18±0.49
Fat (g/min)	0.07±0.02	---	---	---	---	0.14±0.09	0.11±0.08	0.13±0.04	0.14±0.09*
CHO (g/min)	0.34±0.17	---	---	---	---	1.98±0.47*	1.94±0.45*	0.25±0.12	0.26±0.14
Lactate (mmol/L)	---	1.60±0.45	2.05±1.58	6.30±4.58*	8.60±2.18*	---	---	---	---
Testosterone (pg/ml)	---	243±62	280±108	237±158	189±90	---	---	---	---

Table Legend.

Table legend: *= p value was ≤ 0.025 when two comparisons were conducted, and p ≤ 0.0125 when four pairwise comparisons were made., Resting= median value from 30 minute resting session, ST= Median value of entire strongman training session, STrecov= median value of 80 minute recovery period post strongman training, RST= Median value of entire strength/hypertrophy training session, RSTrecov= median value of 80 minute recovery period post RST, CHO= Carbohydrate, IPRE ST= Immediately pre strongman session, IPRE RST= Immediately pre strength/hypertrophy session, IMPST ST= Immediately post ST, IMPST RST= Immediately post RST, BPM= beats per minute

Figures 10, 11, 12 and 13 present heart rate, caloric, fat and carbohydrate expenditure for the resting period (median of 30 minutes passive rest on a separate day), ST and RST (median of the whole training session from the first work set to the last work set including rest periods between sets), and STrecov and RSTrecov (median for the 80 minutes passive recovery period immediately post the training sessions). Presented are the median, upper and lower quartiles and minimum and maximum values for each variable. Also presented are p-values for comparison within and between sessions.

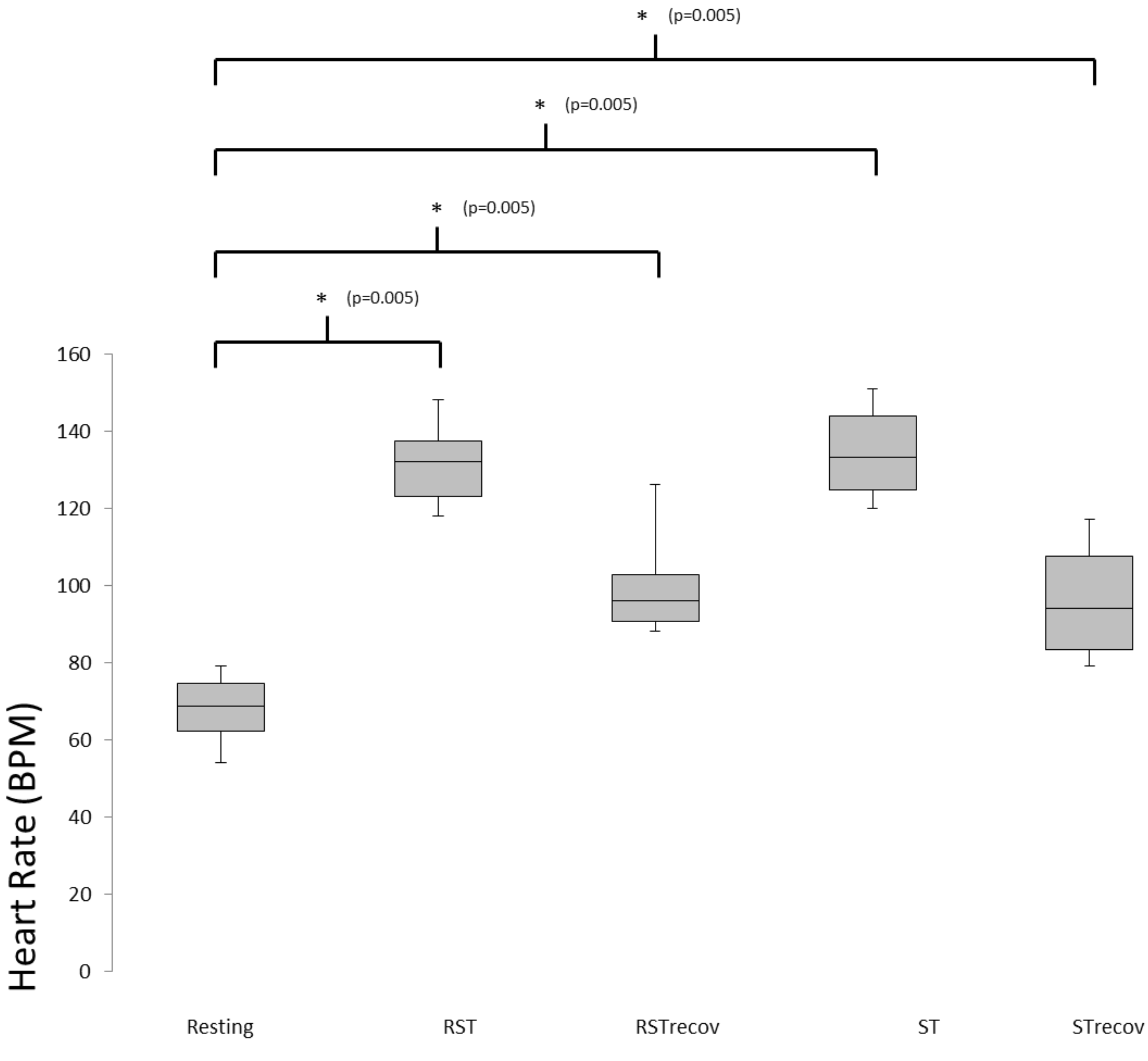

Figure 10: Median heart rate response for Resting, ST, STrecov, RST, and RSTrecov

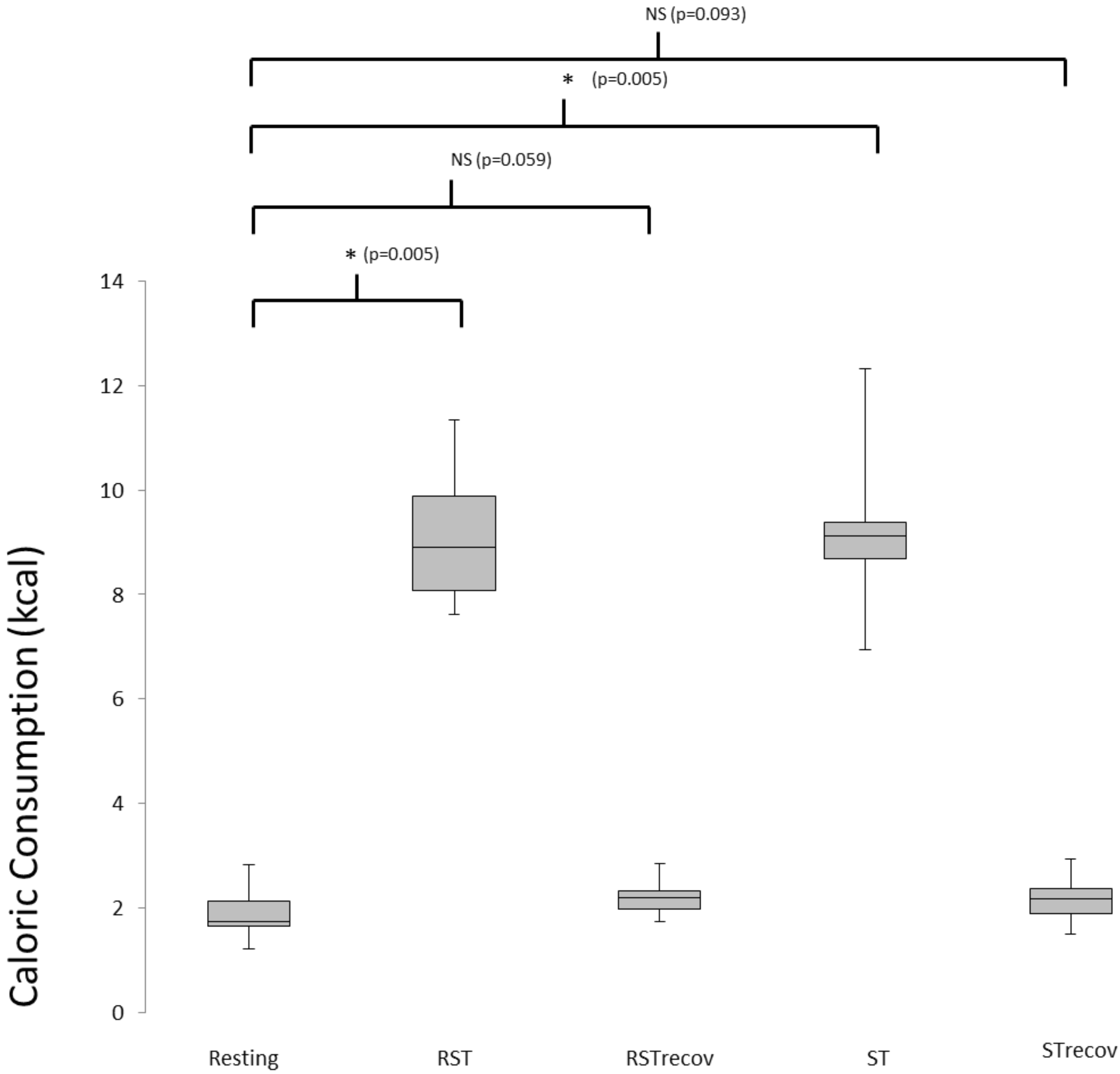

Figure 11: Median caloric expenditure for Resting, ST, STrecov, RST and RSTrecov

Heart rate, caloric, carbohydrate and fat expenditure were significantly greater for both ST and RST than resting. Heart rate was significantly higher in both STrecov and RSTrecov than resting. Calorie and carbohydrate expenditure were not significantly different in STrecov and RSTrecov compared to resting. Fat expenditure was significantly greater in RSTrecov when compared to resting while STrecov not significantly different to resting.

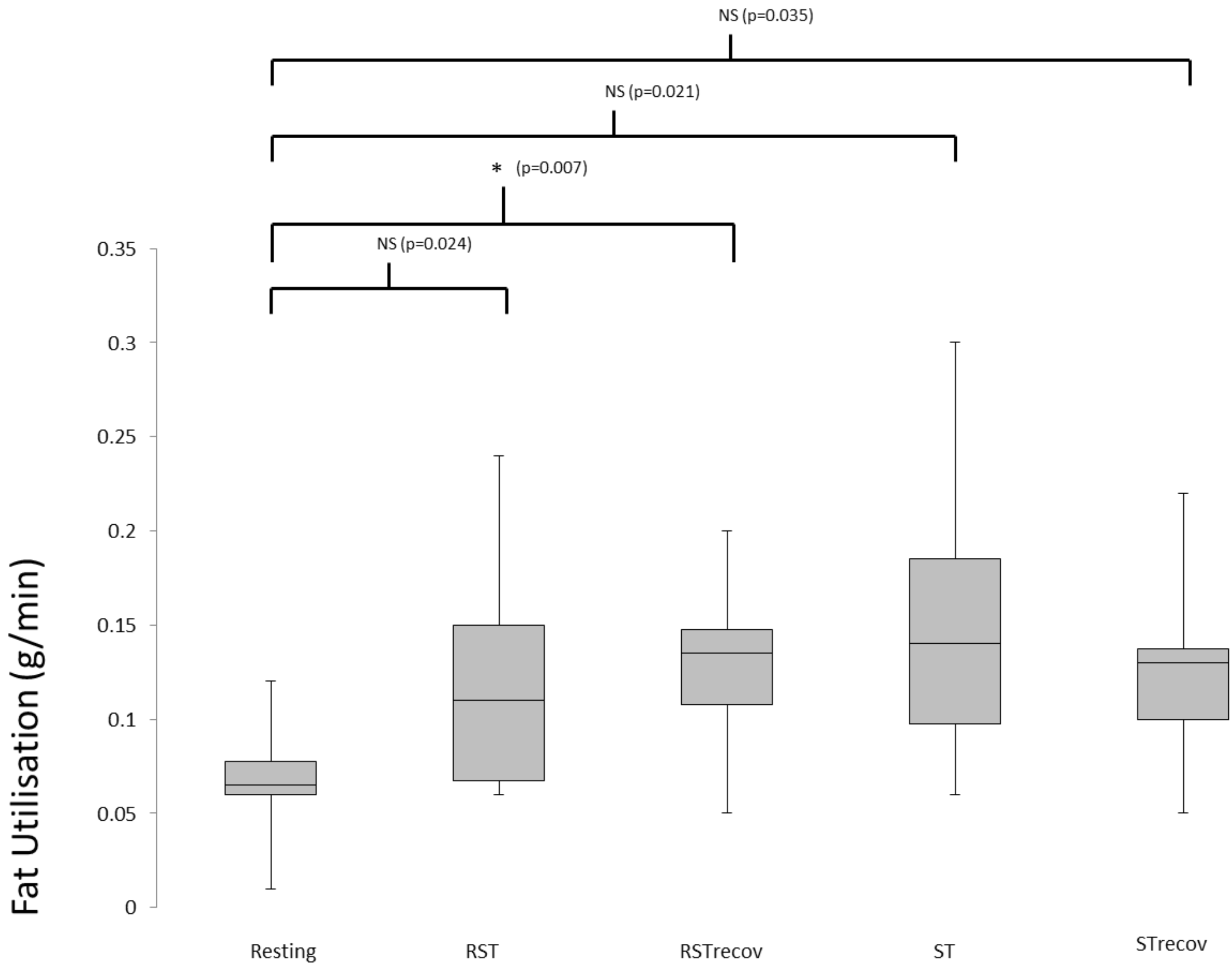

Figure 12: Median fat expenditure for Resting, ST, STrecov, RST and RSTrecov

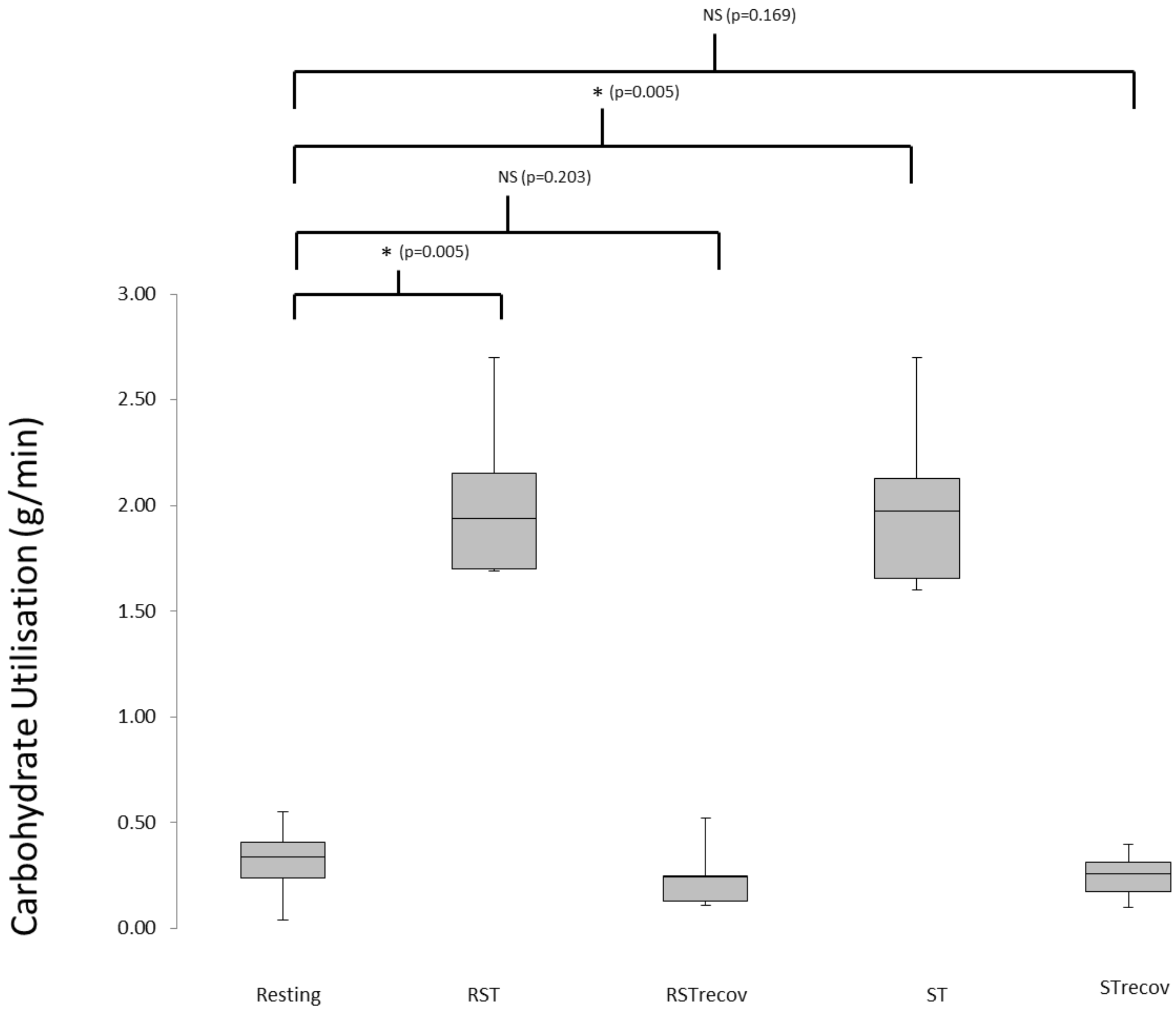

Figure 13: Median carbohydrate expenditure for Resting, ST, STrecov, RST and RSTrecov

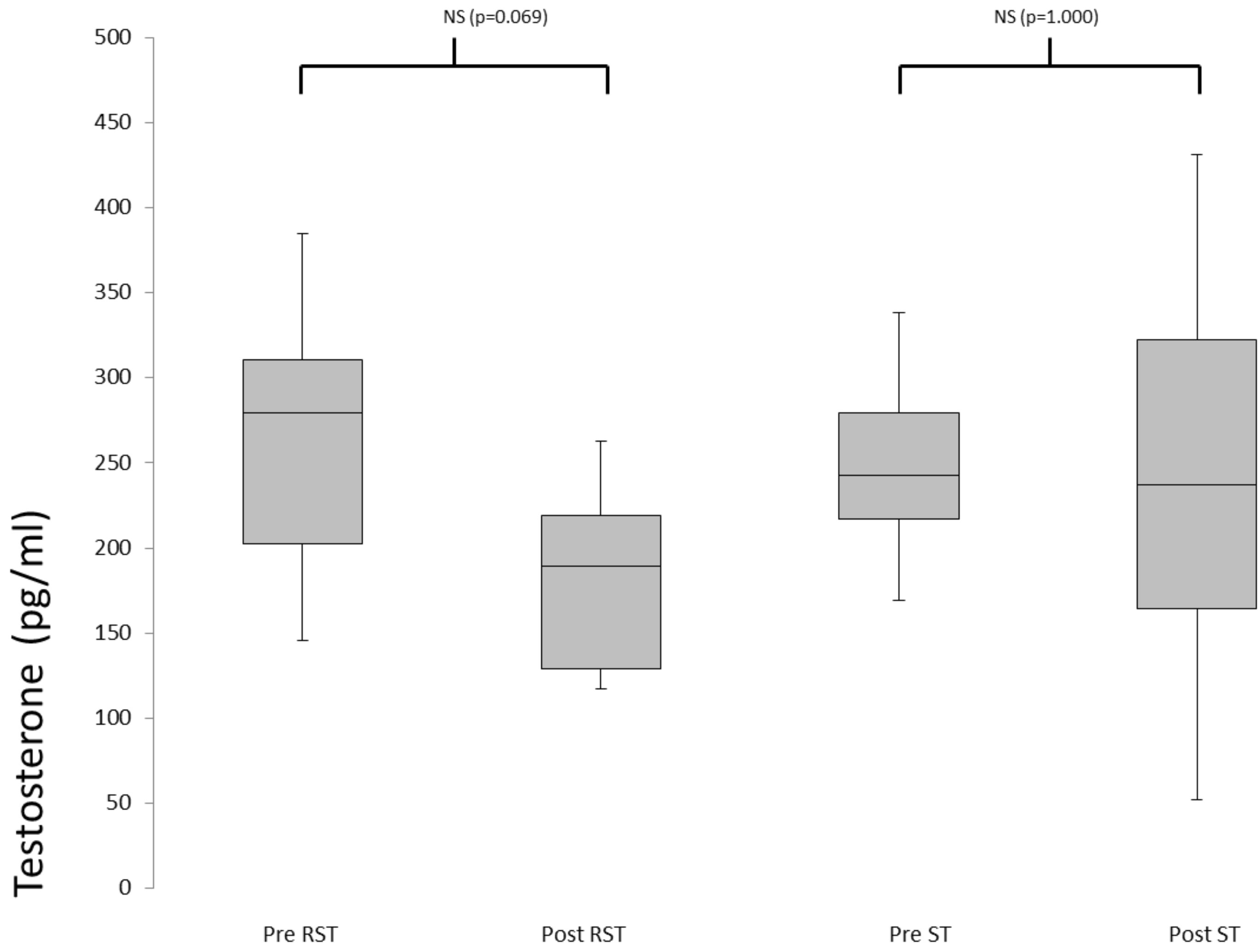

Figure 14: Median testosterone response pre- to post-session for ST and RST protocols

Figures 14 and 15 present testosterone and lactate responses to the two different protocols from pre to immediately post session. Presented are the median, upper and lower quartiles, and minimum and maximum values with associated p-value for within and between group differences. Lactate increased significantly from pre to post ST and RST but testosterone did not.

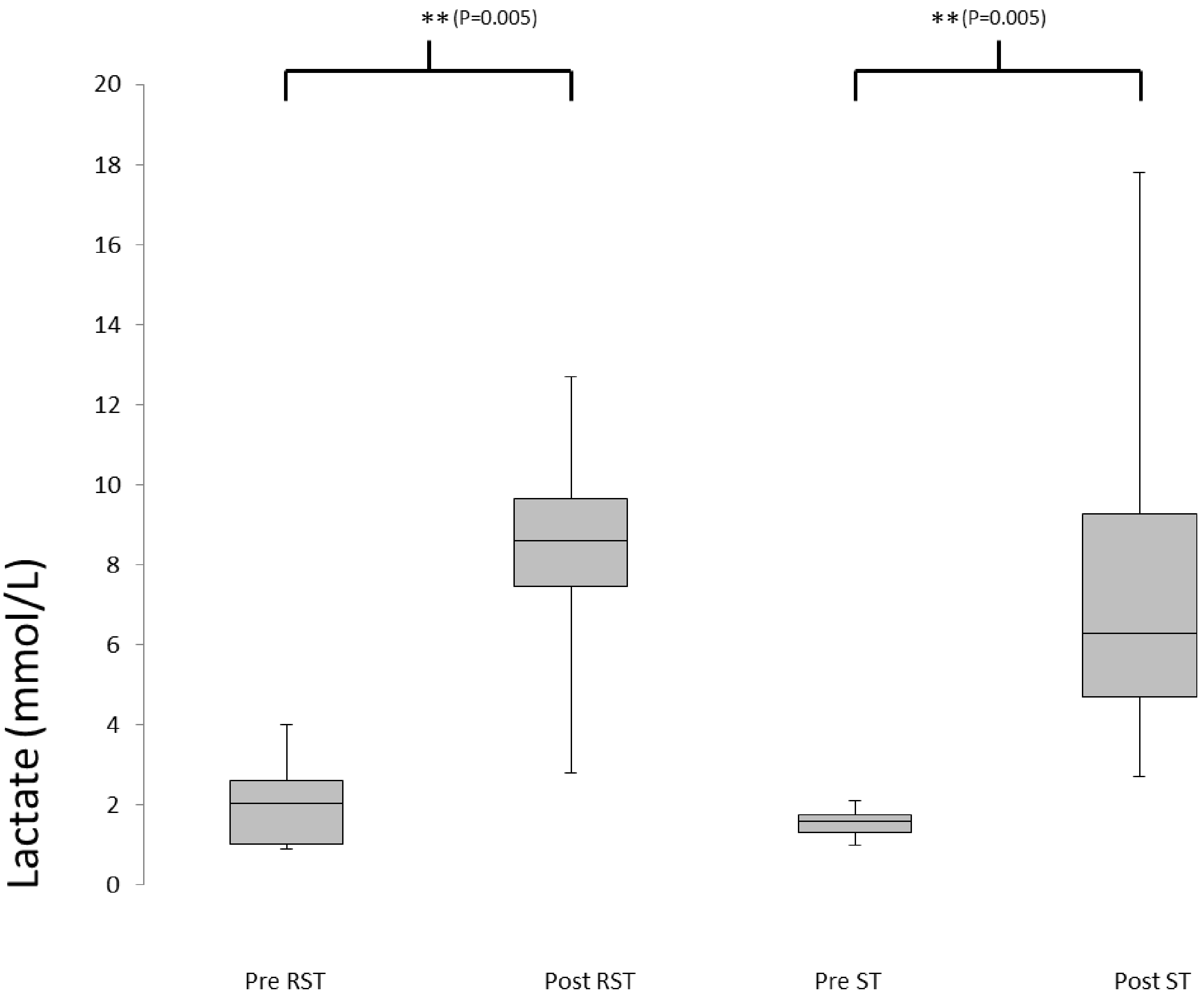

Figure 15: Median lactate response pre- to post-session for ST and RST protocols

DISCUSSION

The aim of this study was to compare the acute metabolic and hormonal response to ST and RST training sessions that were equated for approximate total set time and session duration. The present study was the first to examine collectively the metabolic and hormonal response to ST and compare it with RST training. We found that ST and RST type training produced similar acute metabolic and hormonal responses. Winwood et al (63) investigated the long term training effects of strongman exercises on aspects of muscular function and performance and compared it with traditional training. No significant differences on the changes in muscular performance measures between the strongman training group and the traditional training group were found. While the Winwood et al (63) study was a training intervention, we could speculate that the acute physiological responses in our study may be indicative of the mechanisms underpinning the adaptations observed by Winwood et al (63).

It was surprising to see that neither group in our study experienced a significant acute increase in testosterone at any time point analysed. While the majority of research has found testosterone rises acutely following resistance exercise and strongman training, (7, 14, 18, 46, 49, 56) some research has demonstrated testosterone can decrease following resistance training (5, 41). In the resistance training studies in which no acute increase in testosterone was reported, it has been speculated that such programs may have lacked sufficient volume of exercise (7, 18). It is therefore possible that the protocols used in our study did not provide sufficient volume to induce a significant increase in testosterone levels. Our study utilised two warm up sets and one working set at 75% of 1RM for 10 repetitions over 4 different exercises with 3 minutes rest between exercises equating to 40 total working repetitions at 75% of 1RM. Previous research reported testosterone to increase using a hypertrophy protocol which equated to 100 working repetitions at 75% of 1RM (10 sets of 10 repetitions, 2 minutes rest between sets), while a power protocol and strength protocol did not evoke any changes in testosterone with volumes of 48 repetitions at 45% of 1RM (8 sets of 6 repetitions, 3 minutes rest between sets) and 24 repetitions at 88% of 1RM (6 sets of 4 repetitions, 4 minutes rest between sets) for power and strength respectively (7). Other research also demonstrated an increase in testosterone using 100 working repetitions at 70% of 1RM (10 sets of 10 repetitions, 3 minutes rest between sets) while their second loading scheme of 20 repetitions at 100% of 1RM with 3 minutes rest experienced no change (18). While our loading scheme was similar in intensity to loading schemes which produced significant increases in testosterone, it appears to lack the volume used in the studies reporting significant increases, further supporting the influence of training volume on the acute testosterone response.

Median heart rates (69% max heart rate for both protocols) reported in the present study fell within the moderate range defined by the ACSM (between 64-76% of heart rate max) (12) indicating that both protocols could provide the stimulus required to achieve a positive adaptation in cardiovascular conditioning. This is consistent with the findings of Hrubeniuk et al (24) where resistance training was reported to be a sufficient method of reaching the aerobic component of the physical activity guidelines and a suitable alternative to traditional aerobic training methods. Keogh et al (27) found heart rates of 92% of maximum following 2 sets of 6 tyre flips with 3 minutes rest between, while Berning et al (3) reported a mean heart rate of 96% of maximum following 400 m of car push and pull. Comparatively, we found slightly lower heart rates following the final set of each exercise (81-83% heart rate max) likely due to the difference in our loads selected in order to equate the two training modalities. Bloomer et al (4) reported heart rates of 82% of maximum following 30 minutes of intermittent free weight squatting, slightly higher than the median heart rate of 69% of max in the present study, however the protocol used by Bloomer et al (4) had shorter rest periods of 60-90 seconds.

The present study is reported median caloric expenditure of 8.9 and 9.1 kcal/min for ST and RST respectively. Consistent with the findings of Falcone et al (11) who reported resistance exercise at 75% of 1RM to expend an average of 8.83 kcal/min when performed across six different exercises from a total session time of 30 minutes. These findings, and ours, demonstrate the relative equivalency in total energy expenditure of resistance training sessions utilising large muscle group compound exercises with cardiovascular conditioning exercises such as treadmill running. Falcone et al (11) for example reported treadmill running at 70% of max heart rate for 30 minutes to expend an average of 9.48 kcal/min, very similar to our findings. Hence, our findings provide support for the inclusion of either ST or RST in programmes designed to elicit the calorie expenditure considered necessary to support objectives such as weight loss (19).

Fat expenditure has been found to be inversely correlated with exercise intensity (6); the present study observed fat expenditure was not significantly elevated during either ST or RST. RST performed for sets and repetitions in our study is considered a form of high intensity exercise (11), these findings support such a view and suggest that ST may be considered high intensity. Carbohydrate expenditure was significantly elevated during both ST and RST when compared to resting, this is consistent with other research on high intensity exercise which has demonstrated it is primarily fuelled by glycogen (11). Carbohydrate expenditure has been shown to increase as exercise intensity increases (45). Large increases in carbohydrate expenditure demonstrate the high intensity nature of ST and RST.

In the recovery period post exercise the oxygen consumption is commonly termed the excess post-exercise oxygen consumption (EPOC) (8). The EPOC represents the number of calories utilised above baseline following exercise, and the effect is greatest immediately following exercise and decreases with time (8). Researchers have demonstrated increases in energy expenditure and EPOC following resistance training (42). The present study reported no significant difference between ST, RST and resting. Research pertaining to EPOC and resistance training has demonstrated training volume (16), intensity (25) and rest intervals (20) to have the largest effect on the magnitude of the EPOC. In our study rest periods and loads were chosen as they fell within the recommended guidelines to increase both hypertrophy (47) and strength (47) and could be approximated in both ST and RST. The lack of significant differences in EPOC between ST, RST and baseline is likely due to a combination of insufficient volume, intensity and rest intervals that were too long to elevate EPOC greatly. While our study has demonstrated no significant differences between STrecov and RSTrecov compared to baseline, greater volumes and intensities would likely affect the magnitude of the EPOC. Rest times could also be shortened to 60-90 seconds while still keeping within the hypertrophy training recommendations (47).

Researchers have theorised fat oxidation is enhanced during recovery from resistance exercise to spare available carbohydrate for glycogen resynthesis. To replenish muscle glycogen fat expenditure must be enhanced (43). Our findings support this theory for RST, as in RSTrecov fat was significantly elevated while carbohydrate was not, however in STrecov neither fat or carbohydrate expenditure were significantly elevated.

In conclusion, the results of the present study indicate the acute physiological responses to ST and RST do not differ significantly when performed for the same total set duration.

Practical applications

This study supports the view that ST can be effective at evoking similar acute physiological responses to those of RST. Our findings may have practical implications for exercise prescription for both general population and athletes. Practitioners looking to prescribe exercise programs can arguably expect similar metabolic adaptations given the observed similarities in session response between the two protocols we examined. Both ST or RST could elicit cardiovascular adaptations in addition to the expected metabolic adaptations commonly associated with resistance training, given heart rates for both protocols fell within the moderate level as defined by the ACSM (12). Either ST or RST can be used to increase energy expenditure and in turn contribute to the energy deficit required for weight loss (19).

CHAPTER 4: GENERAL DISCUSSION AND PRACTICAL APPLICATIONS

Preface:

This chapter is an overview of the findings of the thesis in the context of practical applications. The aim is to enhance the current understanding of the acute physiological responses to strongman training so that exercises professionals may have greater insight into how to appropriately program ST into a training plan. Recommendations for future research will also be provided for researchers wishing to further examine ST in the future.

Literature on ST (either of one exercise or a training session) has observed acute increases in metabolic outputs across a variety of different measures. Blood lactate (3, 27, 56), heart rate (3, 27, 33) and oxygen consumption (3) increased following a session involving a single strongman exercise. Likewise this thesis demonstrated a significant increase in post strongman training session blood lactate, significant increases in heart rate during and in the recovery period post strongman session, and significant increase in energy and carbohydrate expenditure throughout the training session.

Literature examining testosterone levels and ST has demonstrated that a full ST session utilising multiple strongman exercises can acutely increase testosterone significantly, to that of the same level as a strength/hypertrophy training session (14). Research has also demonstrated an increase in acute testosterone following a training sessional involving only a single strongman exercise the reverse sled drag (56). In contrast, this thesis did not find a significant increase in testosterone levels at any time point for either training approach. This may have been due to insufficient volume to evoke a response from all participants, with Ghigiarelli (14) implementing a strongman session with fifteen working sets, opposed to the present studies four working sets.

Recommendations

- Strongman training can be used as a form of metabolic conditioning; exercises such as the sled drag, farmers walk, and tyre flip can be used for multiple sets of approximately 30 seconds in duration.
- Provided proper coaching and loading progression strongman training can be used for experienced strength trained males as a way of performing functional strengthening exercises, while also training the aerobic system. Provides enough stimulus to meet the requirements for general health as set by the ACSM
- Strongman training can be used in the place of barbell strength/hypertrophy work as it may provide variety to an athlete while still providing very similar acute physiological responses. It is recommended that the ST exercises should be performed for similar durations to the barbell exercises they are replacing.

While more research on ST continues to emerge, there is a need for greater uniformity across studies. A popular aspect of ST is the novelty and variety of different pieces of training equipment, this can be a problem for researchers as there is no industry standard when performing the lifts. Often there are variations among ST equipment. This variation may influence the acute and chronic physiological effects observed in different research studies. Researchers moving forward should strive to use standardised pieces of strongman equipment, or when not possible report all known dimensions of the equipment.

Future research could also examine additional metabolic and hormonal markers such as creatine kinase and cortisol. While this research had an 80 minute recovery period it would be interesting to see testosterone and lactate levels following the 80 minutes and further to examine if there are any differences between ST and RST.

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APPENDICES

APPENDIX 1- ETHICS APPROVAL

A U T E C
S E C R E T A R I A T

20 March 2014

Nigel Harris
Faculty of Health and Environmental Sciences

Dear Nigel

Re Ethics Application: **14/17 The metabolic and hormonal responses to strongman training.**

Thank you for providing evidence as requested, which satisfies the points raised by the AUT University Ethics Committee (AUTEC).

Your ethics application has been approved for three years until 19 March 2017.

As part of the ethics approval process, you are required to submit the following to AUTEC:

- A brief annual progress report using form EA2, which is available online through http://www.aut.ac.nz/researchethics. When necessary this form may also be used to request an extension of the approval at least one month prior to its expiry on 19 March 2017;
- A brief report on the status of the project using form EA3, which is available online through http://www.aut.ac.nz/researchethics. This report is to be submitted either when the approval expires on 19 March 2017 or on completion of the project.

It is a condition of approval that AUTEC is notified of any adverse events or if the research does not commence. AUTEC approval needs to be sought for any alteration to the research, including any alteration of or addition to any documents that are provided to participants. You are responsible for ensuring that research undertaken under this approval occurs within the parameters outlined in the approved application.

AUTEC grants ethical approval only. If you require management approval from an institution or organisation for your research, then you will need to obtain this.

To enable us to provide you with efficient service, please use the application number and study title in all correspondence with us. If you have any enquiries about this application, or anything else, please do contact us at ethics@aut.ac.nz.

All the very best with your research,

Kate O'Connor
Executive Secretary
Auckland University of Technology Ethics Committee

Cc: Colm Woulfe cjwoulfe@hotmail.com; Matthew Wood; Justin Keogh; Deb Fletcher, Sunesh Singh

APPENDIX 2: PARTICIPANT INFORMATION SHEET

Participant Information Sheet

Date Information Sheet Produced:

20/09/2013

Project Title

The Metabolic and Hormonal responses to strongman training.

An Invitation

You are hereby invited to participate in a research project designed to examine the metabolic and hormonal effects of strongman training. The data collected during this research project will be used to contribute toward my (Colm Woulfe) Masters in Sport & Exercise.

If you accept this invitation to a participate in the project, you do so voluntarily and may at any stage withdraw yourself or any information that you have provided for this project at any time prior to completion of data collection - without being disadvantaged in any way. Any publicised results will at no time mention your name or corresponding personal details.

What is the purpose of this research?

This project will collect data for use in a study examining the metabolic and hormonal effects of strongman training. The data collected will contribute toward Colm Woulfe's Masters (Thesis) and may also be utilised in a published journal following its acceptance by Auckland University of Technology as a Master's Thesis.

The project specifically aims to examine the metabolic and hormonal effects of a strongman training session when compared to a traditional strength training session.

How was I identified and why am I being invited to participate in this research?

You have been identified as being a healthy male with a minimum of two years of strength training experience, and a squat and deadlift strength of at least 1 and 1.2x body mass respectively, between the ages 18-45.

Please note that your results and/or participation may need to be excluded if you are unable to consistently train and/or if injury disallows you to safely participate in the testing sessions over the course of the project.

What will happen in this research?

The project will involve attendance of three different days, two testing days of approximately 3 hours, and one familiarisation session of 1 hour.

The two testing days will involve a 1 hour training session including the warm up, and 80 mins of EPOC recording where u will be required to be at rest.

In the familiarisation session you will be informed of the technique required for the following testing sessions, and will be informed of the procedures that will happen on the day. Baseline EPOC readings will also be taken which will help acclimatise you the wearing the device we use for gas exchange.

You will need to perform both a strongman training session, and a strength training session with 7 days in between. The order of the sessions will be randomly decided and you will be notified of which training session you will perform first in your familiarisation session.

For both testing sessions you will be required to give saliva samples immediately before the training, and after the training ends. A small finger prick will also be done before and after training to take a small amount of blood for lactate readings. Each training session will also require you to wear a face mask device called the metamax unit, which allows us to measure your gas exchange throughout the workouts.

The workouts are as follows, each workout is preceded by a dynamic warmup

Strongman workout-

Sled drag- 3 sets (2 warm up sets, 1 work set at prescribed load)- 15m- load at 2x bodyweight

Farmers walk- 3 sets(2 warm up sets, 1 work set at prescribed load)- 30m- load at 80% of bodyweight

Dumbell clean and press- 3 sets- (2 warm up sets, 1 work set at prescribed load) load-30% bodyweight

Tyre Flip- 1 set of 30 seconds with a 220kg tyre (remember half the tyre weight is in contact with ground)

Strength Workout-

Squat 3 sets (2 warm up sets, 1 work set at prescribed load) @75% of 1RM x10 reps

Deadlift 3 sets (2 warm up sets, 1 work set at prescribed load) @75% of 1RM x10 reps

Bench Press 3 sets (2 warm up sets, 1 work set at prescribed load) @75% of 1RM x10 reps

Power clean 3 sets (2 warm up sets, 1 work set at prescribed load) @75% of 1RM x10 reps

The data will only be used for the purpose of the study.

What are the discomforts and risks?

There are no greater risks than those involved in performing a strongman training session and a traditional strength training session. All care will be taken to minimise all risks involved in performing the training sessions and there will be no additional risk than what is involved in a strongman or strength training session.

The design of the projects has occurred with specific attention to both minimising the time it takes to gather data (i.e. to do the tests) and the fatigue which could be caused by maximally testing. We have allowed large rest periods to reduce fatigue but not interrupt your training session.

How will these discomforts and risks be alleviated?

The discomforts will not be anything more than is required of a strongman or strength training session.

Risk will be alleviated by having at least one person with a first aid certificate on the premises. Staff experienced with lifting technique will also be on hand to assist with spotting and coaching cues to ensure safe technique guidelines are adhered to.

What are the benefits?

Benefits to coaches and athlete's

While different aspects of strongman training have been investigated independently in the past, research collectively examining the metabolic and hormonal effects of strongman training compared to regular gym based strength training could be used to give exercise professionals a deeper insight into the physiological mechanisms involved in strongman and its potential adaptations in performance and body composition. Research looking at the metabolic and hormonal effects of a strongman training session collectively may give a more detailed look at the physiological effects of training, along with giving insight into any associations between the metabolic and hormonal outcomes that may underlie chronic adaptations. Exercise professionals could use this information to better underpin conditioning practice.

Benefits to the researcher

The data collected during this project will contribute towards a Thesis to be submitted for Masters qualification by the researcher Colm Woulfe.

What compensation is available for injury or negligence?

In the unlikely event of a physical injury as a result of your participation in this study, rehabilitation and compensation for injury by accident may be available from the Accident Compensation Corporation, providing the incident details satisfy the requirements of the law and the Corporation's regulations.

How will my privacy be protected?

Following the completion of both testing sessions, you will be provided a small summary report and a simple explanation of the results within 1 week of the last day of testing. In published reports of the results no individuals data will be able to be identified.

What are the costs of participating in this research?

There is absolutely no cost to being involved in the project or in obtaining your individual results following the project other than your time. Your time (1x 1 hour session and 2 x3 hour sessions separated by 7 days) will be required. Remembering that each training session will be strenuous.

What opportunity do I have to consider this invitation?

From the 1st to the 14th of July. So take the time to consider and ask questions of the researcher during this time. Following this data collection will begin and continue for the next 6-8 weeks.

How do I agree to participate in this research?

If you agree to participate in this project, please sign the consent form attached to this information sheet. If there is none attached contact Colm Woulfe (details below) to obtain one.

Will I receive feedback on the results of this research?

A final written report will be distributed to you to benefit the development and planning of future training sessions. As with published data no individual's results will be able to be identified in the final report. Finally any published papers on this topic will be available from the researcher at any stage also.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, **Dr Nigel Harris, PhD, Senior Lecturer, School of Sport and Recreation, Email-** nigel.harris@aut.ac.nz **PHONE +64 9 921 9999 extn 7301.**

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Kate O'Connor, *ethics@aut.ac.nz* , 921 9999 ext 6038.

Whom do I contact for further information about this research?

Researcher Contact Details:

Colm Woulfe

Email hgk4652@aut.ac.nz

Mob: 021-1301589

Project Supervisor Contact Details:

Dr Nigel Harris, PhD, Senior Lecturer, School of Sport and Recreation, Email- nigel.harris@aut.ac.nz
PHONE +64 9 921 9999 extn 7301.

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Approved by the Auckland University of Technology Ethics Committee on *type the date final ethics approval was granted*, AUTEC Reference number *type the reference number*.

APPENDIX 3: CONSENT FORM

Consent Form

Project title: The Metabolic and Hormonal responses to strongman training.

Project Supervisor: Dr. Nigel Harris

Researcher: Colm Woulfe

- ○ I have read and understood the information provided about this research project in the Information Sheet dated 26/10/2013
- ○ I have had an opportunity to ask questions and to have them answered.
- ○ I understand that I may withdraw myself or any information that I have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.
- ○ I am not suffering from heart disease, high blood pressure, any respiratory condition (mild asthma excluded), any illness or injury that impairs my physical performance, or any injury that will prevent me from adequetly performing the training sessions.
- ○ I agree to provide saliva samples and blood for lactate testing.
- ○ I agree to take part in this research.
- ○ I wish to receive a copy of the report from the research (please tick one): Yes○ No○
- ○ I wish to have my saliva samples returned to me in accordance with right 7 (9) of the *Code of Health and Disability Services Consumers' Rights* (please tick one): Yes○ No○

Participant's signature: ....

Participant's name: ....

Participant's Contact Details (if appropriate):

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Date:

Approved by the Auckland University of Technology Ethics Committee on 20th March 2014 AUTEC Reference number 14/17

APPENDIX 4: RPE SCALE

Borg Rating of Perceived Exertion

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