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**Title:** The acute physiological responses to strongman training compared to traditional strength training

**Running head:** Acute physiological responses to strongman training

**Research performed at:** AUT University, Auckland, New Zealand

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## ABSTRACT

Strongman training has become an increasingly popular modality, but data on physiological responses are limited. This study sought to determine physiological responses to a strongman training session compared to a traditional 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 traditional 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 tire 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. Blood 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. 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.


**Key Words:** weight training; conditioning

## INTRODUCTION

Strongman training has become an increasingly popular modality used by practitioners for athletic development and general strength and conditioning. 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 (38). 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 (37, 38). Common strongman exercises include sled pulls, farmers walks, tire flips and overhead presses (41). 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 of an object from one location to the next (40). On 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 (1, 20, 36), heart rate (1, 20, 22) and oxygen consumption (1) 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 (12, 36). Likewise cortisol increases acutely after ST before falling below baseline levels at around three hours post ST (36).

Current research on physiological response to RST report increases in acute metabolic measures of blood lactate (7, 21, 34), heart rate (2, 11, 26) and oxygen consumption (11, 26, 31). RST has also been reported to induce large hormonal elevations with acute increases in testosterone (12, 29, 34) and cortisol (5, 14, 8). The reader is referred to a recent review on the physiology of strongman training in which direct comparsion between acute responses to strongman training sessions and traditional strength training sessions are elaborated (42).

While research by Ghigiarelli et al (12) 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 in regards to overall session profile. 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*

All participants acted as their own control in a crossover design in which participants 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 (23.6±7.5 years; 85.8±10.3 kg) volunteered to participate in this study. All participants had been regularly resistance training for at least the immediately previous two years, and a squat and deadlift strength of at least 1.0 and 1.2 times body mass respectively. Typical training frequency for the participants varied from 3-6 days of structured resistance training per week with between 6-10 repetitions for 2-4 sets for compound movements. Almost all participants were from a strength training facility where small group sessions were common, and training prescribed, hence recent training practices were very similar for all. 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. Participants were required to be between the ages of 18-45 and experienced 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. The study was granted Institutional ethical approval and all participants signed a voluntary informed consent form prior to participating.

****** Insert table 1 about here*****

*Procedure*

1RM Testing

Given participants were experienced strength trained individuals, maximal strength (1RM) for the RST exercises were determined by calculation (rep weight x number of reps x 0.3333) + rep weight) (8) based on very recent training load history.

Warm up

All sessions were supervised by a New Zealand Registered Exercise Professional (NZ REPs). 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 mask attached to a breath-by-breath gas analyser (Metalyzer 3Bsystem; CORTEX Biophysik GmbH, Leipzig, Germany) a heart-rate monitor (Polar™, Finland) before commencing the session (see figure 1).

**** Insert figure 1 about here****

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 2).

****Figure 2 about here****

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 3) 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. During familiarisation testing loads were adjusted so that set duration was always between 28 and 32 s duration.

****Figure 3 about here****

Strongman training session

The oxygen cart was positioned or wheeled alongside participants as they performed the exercises (see figures 4-5). The exercise order was sled drag, farmers walk, one arm dumbbell clean and press, and tire 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 in each hand for 24 m and dumbbell overhead at 30% of body weight for 10 repetitions. For the tire flip two sets of a sumo stance deadlift at approximately 50 and 75%1RM were used as a warm-up given only the full-sized tire was available. For the tire flip all participants performed one set of as many repetitions as they could in 30 s on a 220kg tractor tire (external diameter 150 cm, height on ground 80 cm). These percentages originated from pilot testing utilising four participants who performed sets of the strongman exercises at different percentages of bodyweight with the goal of ensuring sets would be approximately 30 s 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 4 about here****

For the sled drag (Figure 4) 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 not were permitted to come upright into a sprint position. The instruction issued was to go as fast as possible. The drag was continued for a timed 30 s period.

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, they then turned and picked up the handles again carrying them back to the start position. The instruction issued was to go as fast as possible. Partial repeats of this ‘lap’ were continued if needed until a 30 s set duration was met.

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 put the dumbbell overhead, standard technique being a two hand clean followed by a one arm push press, however some participants chose to snatch the dumbbell. Repetition cadence was self selected. Each repetition the dumbbell was returned to the floor and finished when participants had completed a timed 30 s set, typically approximately 10 repetitions to full extension (10±1.3 repetitions). Participants were permitted to alternate arms or complete all repetitions on one arm based on their personal preference.

****Figure 5 about here****

The tire flip (see figure 5) was performed for a single repetition at a time with maximum effort, and participants ran 180 degrees around the tire 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 tire up to chest height, their hands then transitioned from under the tire to a push position and they drove the tire forward completing the flip. The instruction was to complete as many flips as possible in 30 s.

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 recorded using a heart rate strap and watch (Polar™, Finland). Heart rate was recorded 15 s prior to every set and immediately post. Following the session heart rate was recorded every 30 s for 20 min; it was then recorded every 5 min for the next hour.

Energy expenditure & oxygen consumption

Energy expenditure and gas exchange was measured using breath-by-breath gas analysis which was calibrated at the start of every testing day. 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 gas analysis was used to determine minute ventilation, O2 consumption and CO2 production. Gas sampling allowed for estimation of fat and carbohydrate oxidation as well as energy expenditure using stoichiometric equations.

Data analysis

Descriptive statistics (mean ± SD) were calculated for all dependant variables that followed a normal distribution. The data were screened for normality using a histogram plot and Shapiro-Wilks test. 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 Wilcoxon 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 s while RST was 29±2 s. Session RPE was 13 for both ST and RST with no significant differences ($p = 0.103$) between sessions. Table 2 presents median values for the measured variables across all time points.

**** Table 2 about here****

Figures 6, 7, 8 and 9 present heart rate, caloric, fat and carbohydrate expenditure for the resting period (median of 30 min 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 min 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.

**** Insert Figure 6 about here*****

Heart rate, caloric, carbohydrate and fat expenditure were significantly greater for both ST and RST than resting.

**** Insert Figure 7 about here****

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.

**** Insert Figure 8 about here****

**** Insert Figure 9 about here****

**** Insert Figure 10 about here****

Figures 10 and 11 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.

**** Insert Figure 11 about here****

**DISCUSSION**

The aim of this study was to compare ST and RST that had been equated for approximate total set time and session duration for their respective acute physiological responses. 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 (40) 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. We conjecture that the acute physiological responses in our study may be indicative of the mechanisms underpinning the adaptations observed by Winwood et al (40).

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, (5, 12, 15, 28, 33, 34) some research has demonstrated testosterone can decrease following resistance training (3, 23). In the resistance training studies in which no acute increase in testosterone was reported, it has been speculated that lower volume training programs are responsible for the apparent insufficient stimulus (5, 15). 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 (5). 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 (15). 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) (10) 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 (18) 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 (20) found heart rates of 92% of maximum following 2 sets of 6 tire flips with 3 minutes rest between, while Berning et al (1) 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 (2) 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 (2) had shorter rest periods of 60-90 seconds.

Caloric expenditure in the present study is consistent with the findings of Falcone et al (9) who reported resistance exercise at 75% of 1RM to expend an average of 8.8 kcal/min when performed across six different exercises from a total session time of 30 minutes while we reported median values of 8.9 and 9.1 kcal/min for ST and RST respectively. Our findings on RST are similar to those of Ratamess et al., (26) who reported 8.2 kcal/min after sets (~37 s) of barbell back squats and 7.8 kcal/min after sets (~30 s) of deadlifts, both at 75 %1RM. 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 (9) for example reported treadmill running at 70% of max heart rate for 30 minutes to expend an average of 9.5 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 (16).

Fat expenditure has been found to be inversely correlated with exercise intensity (4); 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 (9), 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 (9). Carbohydrate expenditure has been shown to increase as exercise intensity increases (27). 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) (6). The EPOC represents the number of calories utilised above baseline following exercise, and the effect is greatest immediately following exercise and decreases with time (6). Researchers have demonstrated increases in energy expenditure and EPOC following resistance training (24). The present study reported an increase in EE following both ST and RST however they were not significantly different from resting. Research pertaining to EPOC and resistance training has demonstrated training volume (13), intensity (19) and rest intervals (17) 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 (30) and strength (31) 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 (30).

Researchers have theorised fat oxidation is enhanced during recovery from resistance exercise to spare available carbohydrate for glycogen resynthesis, and to replenish muscle glycogen fat expenditure must be enhanced (25). 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 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. 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 (10). ST or RST can be used to increase energy expenditure and in turn the energy deficit necessary for weight loss (16).

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**Figure Legends**

**Figure 1.** Schematic timeline of data collection

**Figure 2.** Position of oxygen cart in relation to participant

**Figure 3.** Powerclean with oxygen cart

**Figure 4.** The sled drag with oxygen cart

**Figure 5.** Tire flip with oxygen cart

**Figure 6**: Median heart rate response for Resting, ST, STrecov, RST, and RSTrecov

**Figure 7:** Median caloric expenditure for Resting, ST, STrecov, RST and RSTrecov

**Figure 8:** Median fat expenditure for Resting, ST, STrecov, RST and RSTrecov

**Figure 9:** Median carbohydrate expenditure for Resting, ST, STrecov, RST and RSTrecov

**Figure 10:** Median testosterone response pre- to post-session for ST and RST protocols

**Figure 11:** Median lactate response pre- to post-session for ST and RST protocols

## Table Legends

**Table 1.** Participant characteristics (mean ± SD)

**Table 2.** Acute physiological responses (median ± interquartile range)

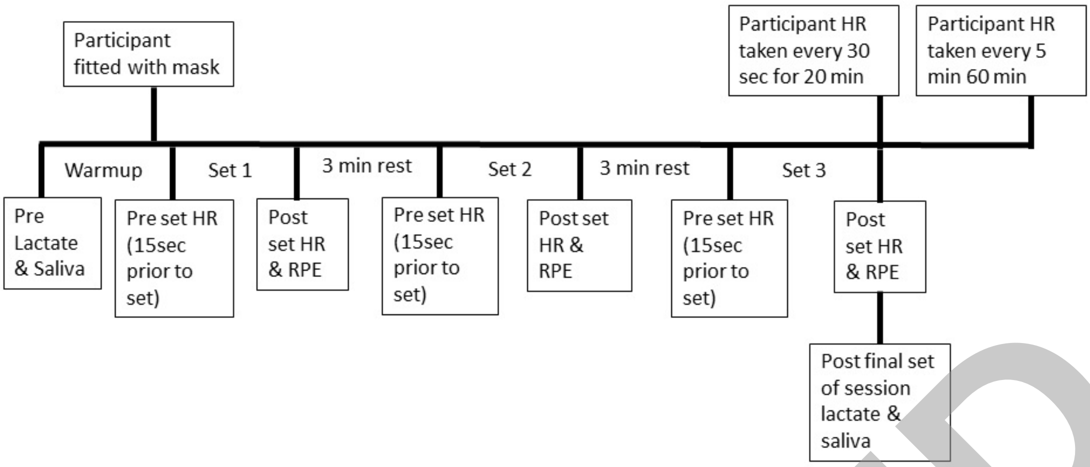
**Table 1. Participant characteristics (mean±SD)**

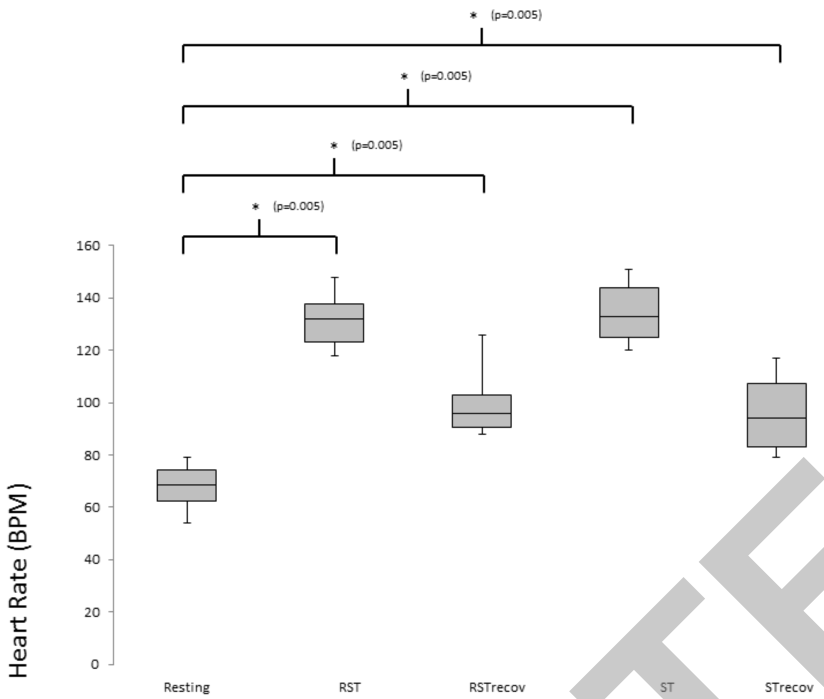
| | n | Age (years) | Weight (kg) | Squat (kg) | Squat (% of bodyweight) | Deadlift (kg) | Deadlift (% of bodyweight) |
|---|---|---|---|---|---|---|---|
| Men | 10 | 24±7 | 86±10 | 140±29 | 163±34 | 163±37 | 191±45 |

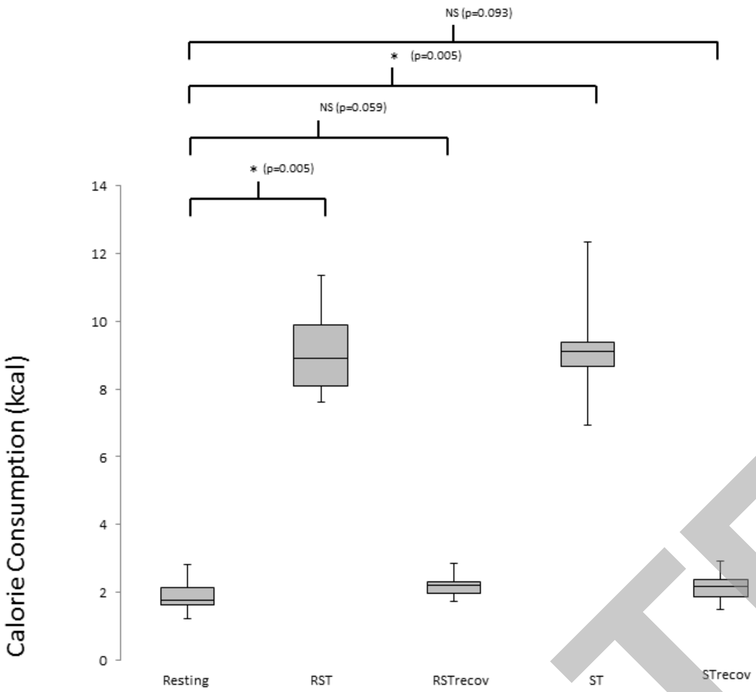
**Table 2. Acute physiological responses (median±interquartile range)**

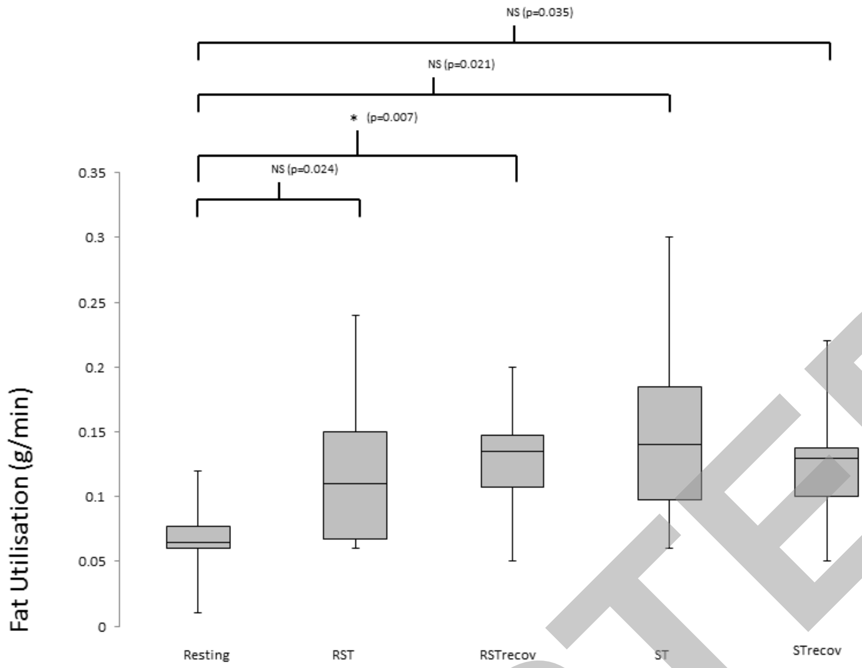
| Measure | Resting | IPRE ST | IPRE RST | IMPST ST | IMPST RST | ST | RST | STrecov | RSTrecov |
|---|---|---|---|---|---|---|---|---|---|
| Heart Rate (BPM) | 69±12 | --- | --- | 167±14* | 170±7* | 133±19* | 132±15* | 94±24* | 96±12* |
| Calories (kcal/min) | 1.75±0.49 | --- | --- | --- | --- | 8.91±1.82* | 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 | --- | --- | --- | --- |

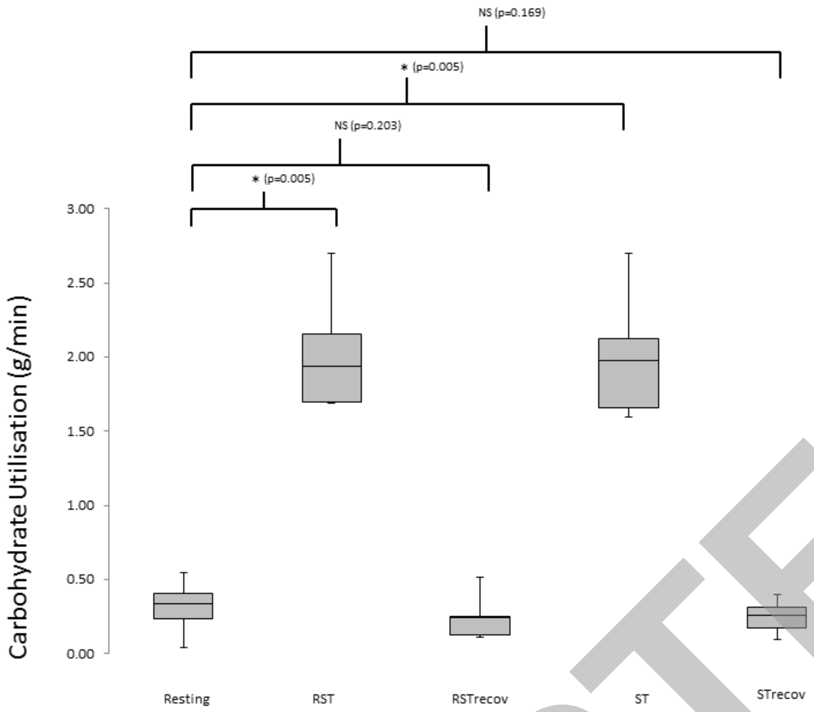
Table legend: *= a significant difference was found compared to resting, Resting= median value from 30 minute resting session, ST= Median value of entire strongman training session, STrecov= median value of 80 minute recovery period post strongman training, RST= Median value of entire strength/hypertrophy 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

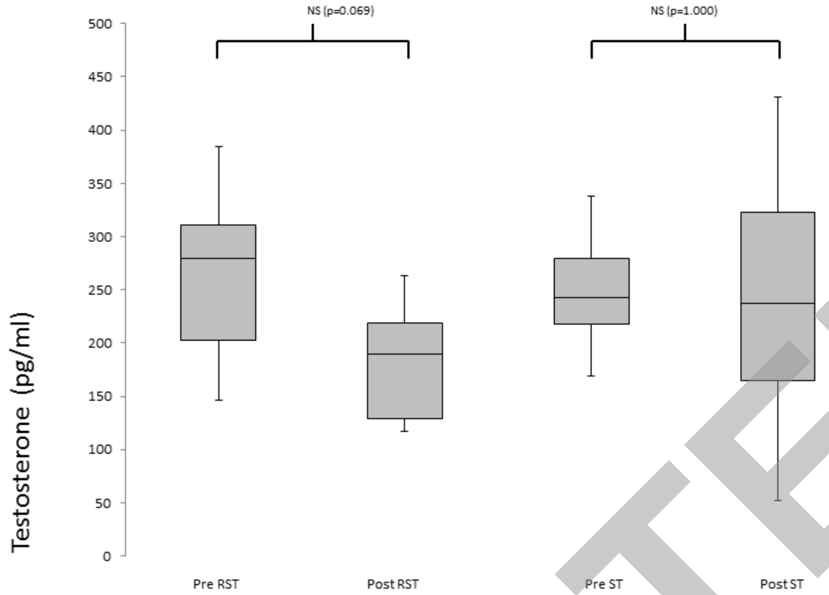

Participant fitted with mask
Participant HR taken every 30 sec for 20 min
Participant HR taken every 5 min 60 min
Warmup
Set 1
3 min rest
Set 2
3 min rest
Set 3
Pre Lactate & Saliva
Pre set HR (15sec prior to set)
Post set HR & RPE
Pre set HR (15sec prior to set)
Post set HR & RPE
Pre set HR (15sec prior to set)
Post set HR & RPE
Post final set of session lactate & saliva

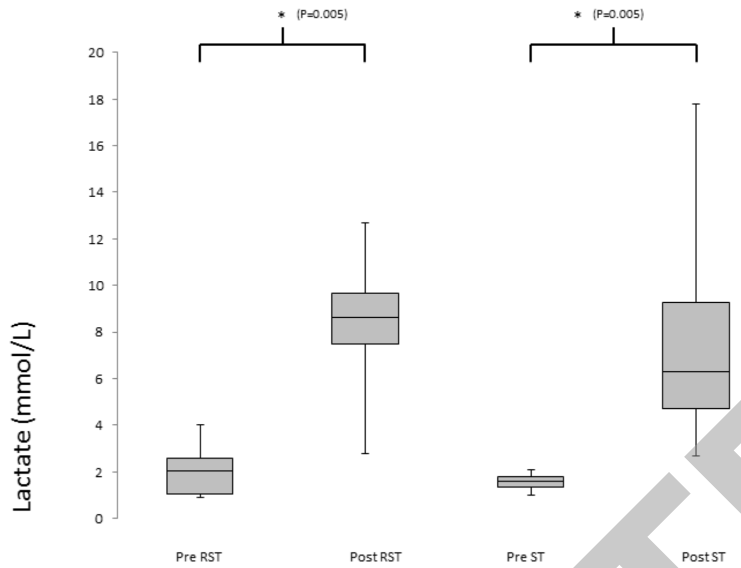

* (p=0.005)
* (p=0.005)
* (p=0.005)
* (p=0.005)
Heart Rate (BPM)
160
140
120
100
80
60
40
20
0
Resting
RST
RSTrecov
ST
STrecov


NS (p=0.093)
* (p=0.005)
NS (p=0.059)
* (p=0.005)
Calorie Consumption (kcal)
14
12
10
8
6
4
2
0
Resting
RST
RSTrecov
ST
STrecov


NS (p=0.035)
NS (p=0.021)
* (p=0.007)
NS (p=0.024)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Fat Utilisation (g/min)
Resting
RST
RSTrecov
ST
STrecov


NS (p=0.169)
* (p=0.005)
NS (p=0.203)
* (p=0.005)
Carbohydrate Utilisation (g/min)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Resting
RST
RSTrecov
ST
STrecov


NS (p=0.069)
NS (p=1.000)
Testosterone (pg/ml)
500
450
400
350
300
250
200
150
100
50
0
Pre RST
Post RST
Pre ST
Post ST



* (P=0.005)
* (P=0.005)
Lactate (mmol/L)
20
18
16
14
12
10
8
6
4
2
0
Pre RST
Post RST
Pre ST
Post ST