Journal of Strength and Conditioning Research Publish Ahead of Print
DOI: 10.1519/JSC.0000000000000885

Comparison of the effects of seated, supine and walking inter-set rest strategies upon work rate.

Running Head: Effects of seated, supine and walking rest on work rate

Research conducted at The University of Utah Human Performance Lab
No internal or external funding was provided for the completion of this study

Kristen A. Ouellette: The University of Utah Human, College of Health, Exercise and Sport Science Department
1165 Douglas Street
Salt Lake City, UT 84105
Phone: (860)966-1520
Email: KOuellette25@gmail.com

Timothy A. Brusseau: The University of Utah, College of Health, Exercise and Sport Science Department

Lance E. Davidson: Brigham Young University, Department of Exercise Science

Candus Ford: The University of Utah, College of Health, Exercise and Sport Science Department

Disa L. Hatfield: The University of Rhode Island, College of Human Science and Services, Department of Kinesiology

Janet M. Shaw: The University of Utah, College of Health, Exercise and Sport Science Department

Patricia A. Eisenman: The University of Utah, College of Health, Exercise and Sport Science
Department

ABSTRACT

The idea that an upright posture should be maintained during the inter-set rest periods of training sessions is pervasive. The primary aim of this study was to determine differences in work rate associated with three inter-set rest strategies. Male and female members of the CrossFit™ community (male n = 5, female n = 10) were recruited to perform a strenuous training session designed to enhance work-capacity that involved both cardiovascular and muscular endurance exercises. The training session was repeated on three separate occasions to evaluate three inter-set rest strategies which included lying supine on the floor, sitting on a flat bench, and walking on a treadmill (0.67 meters • second^{-1}). Work rate was calculated for each training session by summing session joules of work and dividing by the time to complete the training session (joules of work • second^{-1}). Data were also collected during the inter-set rest periods (heart rate, respiratory rate and volume of oxygen consumed) and were used to explain why one rest strategy may positively impact work rate compared to another. Statistical analyses revealed significant differences ($p \leq 0.05$) between the passive and active rest strategies, with the passive strategies allowing for improved work rate (supine = 62.77$\pm$7.32, seated = 63.66$\pm$8.37 and walking = 60.61$\pm$6.42 average joules of work • second^{-1}). Results also suggest that the passive strategies resulted in superior heart rate, respiratory rate and oxygen consumption recovery. In conclusion, work rate and physiological recovery were enhanced when supine and seated inter-set rest strategies were employed compared to walking inter-set rest.

Key Words: rest strategy, active rest, passive rest, work rate, work-capacity, CrossFit™

INTRODUCTION

Many coaches believe that when an athlete places their hands on their knees and allows their torso, head and shoulders to drop during competition or training that they are physically exhausted and mentally defeated. Therefore the admonition to maintain an upright or standing posture (and often some type of movement) during inter-set rest between training and conditioning sets has become common and stems from anecdotal evidence concerning acceptable body position to enhance recovery and appear less fatigued.

While much research has focused on the assignment of inter-set rest periods to enhance physical performance and physiological recovery, the emphasis has been on determination of the optimal duration of the inter-set rest period and whether or not the inter-set rest should be active or passive. Little research has been done to examine the influence of body posture assumed during the inter-set rest and no research exists regarding the manipulation of inter-set rest to specifically enhance an athlete's work rate, defined as the amount of physical work that can be done per unit of time. Therefore, the primary aim of this investigation was to determine if resting in a position such as lying supine or sitting passively would result in reduced work rate (lower performance) in comparison to remaining upright and walking slowly (the rest method that is most commonly utilized).

The impact that the length of the inter-set rest period has on training session volume (sets • repetitions • intensity) has been evaluated extensively during traditional strength and hypertrophic resistance training sessions. Reports consistently demonstrate that longer inter-set rest periods equate to increased training volume due to that fact that longer rest allows for more complete local substrate repletion (12, 21, 27, 33, 36-39). When the goal of training is strength or power development, longer inter-set rest periods (at least 2 minutes) are typically recommended, so that lifting load and quality can remain high (1). A longitudinal study by de Salles supports the implementation of lengthier inter-set rest periods, 5 versus 3 or 1 minute(s), over a 16 week mesocycle to result in larger strength gains (12). When the goal of training is muscular hypertrophy, shorter rest periods coupled with moderate loads and high training volumes are recommended in order to create the necessary muscular stress and hormonal environment conducive to muscle protein synthesis (20). While the literature provides guidance for structuring the duration of inter-set rest periods for increases in training volume, optimal hormonal response, and recovery, none of the aforementioned studies systematically examined the influence of the study participant's body posture during the inter-set rest periods. Further, no studies have reported on inter-set rest strategies during training sessions designed specifically designed to enhance an athlete's work capacity, or, the amount of work they are capable of performing in a given time period.

In addition to the consistent research about the optimization of inter-set rest period duration, it has been equally well established that active rest strategies are superior to passive rest when the goal is lactate removal (3, 4, 8, 11, 16, 34, 35). However, studies comparing the effects of active and passive inter-set rest upon performance are inconsistent, perhaps due to the fact that many different protocols, exercise types (swimming, cycling, resistance training), performance measures and subjects with vastly different training experience have been tested; thus producing variable results (2, 5-7, 10, 17, 22, 23, 31, 32). Some studies support the idea that active inter-set rest allows for improved performance (performance defined as enhanced anaerobic power or higher lifting volume) when compared to passive inter-set rest (2, 7, 10, 17), while others show the opposite relationship (9, 13-15, 29-32), or no difference (22, 23). Therefore, further objective studies are necessary to determine the impact of body posture, active and passive inter-set rest upon training session work rate.

For research on the impact of inter-set rest strategies upon training session work rate to be of maximum value to the coach, information regarding body posture during the inter-set rest period is needed. Given the information provided by previous research, our research builds upon the use of inter-set rest periods that are of sufficient duration (2-5 minutes instead of 45-60 seconds) to elicit high training volumes and enhanced recovery (27, 36-39). Finally, testing was done on subjects who were specifically trained and prepared for the challenges of the associated protocol so that the outcomes may be applicable to skilled athletes. Therefore, the primary purpose of this study was to objectively evaluate the impact of three inter-set rest strategies on training session work rate. Of secondary interest was the determination of which inter-set rest strategy was most strongly associated with physiological markers of recovery.

Based on previous research of a similar nature, we hypothesized that seated and supine inter-set rest would allow subjects to produce more work per unit of time and to have more complete recovery of their heart rate, respiratory rate and oxygen consumption within the training sessions (13-15, 29, 30). Providing insight into the connection between specific inter-set rest strategies and work rate will supply strength and conditioning coaches with a rationale to allow or disallow their athletes to rest seated or supine during strength and conditioning training sessions designed to elicit high work rates.

METHODS

Experimental Approach to the Problem

Data collection occurred over a period of four weeks. During week 1, pre-testing occurred. The order of testing was: body composition, maximal strength and peak oxygen consumption assessment. Maximal strength was assessed in order to help with selection of a proper load for the training sessions. During weeks 2, 3 and 4 subjects reported to the laboratory once per week, on the same day of the week, and completed a standardized training session developed by O'Shea (25) to improve work capacity.

During the training sessions, the loads used and the length of the inter-set rest periods were held constant across weeks 2-4, however, the inter-set rest strategy was modified to include either supine, seated or walking strategies. Therefore, the inter-set rest strategy served as the primary independent variable in this study. The order of rest strategies was randomly assigned to the subjects in a manner such that all possible orders were represented equally. Work rate was calculated for each training session and served as the primary dependent variable in this study. Finally, physiological markers of recovery, including heart rate, respiratory rate and oxygen consumption, were measured during all inter-set rest periods to provide information on the extent of recovery associated with each rest strategy.

Subjects

Fifteen subjects were recruited from the CrossFit™ community in Salt Lake County, Utah. Characteristics of the subjects are presented in Table 1. Subjects all reported being free of injury, illness, and performance enhancing drugs. Subjects all had a minimum of 6 months of CrossFit™ training, prior strength training, and intense cardiovascular training experience which was confirmed by gym membership and coach recommendation. Prior to testing, the University of Utah IRB approved all methodology, subjects provided written consent and were given the physical activity readiness questionnaire (PAR-Q). Subjects were required to demonstrate proper exercise form for all of the included lifts and were removed from the study if they could not execute the training exercises without coaching cues. Before testing, subjects completed a dietary recall for the day before and the day of testing. A photocopy was made of the dietary record and subjects were asked to replicate their eating prior to each training session. Finally, subjects were allowed to continue their regularly scheduled CrossFit™ training for the duration of the study except for the days assigned for data collection. While subjects were encouraged to attend training sessions in a rested and hydrated state, neither of these was specifically examined. During training sessions, subjects were allowed to drink water; however, the amount of water consumed was minimal due to the collection of oxygen consumption during rest periods.

[Table 1 about here]

Procedures

Pre-Testing

Anthropometric Measurements

On the first testing day the subject's height was measured using a stadiometer, their body composition (weight and volume) was assessed via Bod Pod (Concord, CA) air displacement plethysmography (19) and the Siri equation was used to calculate body fat percentage (28).

Strength Testing

After the anthropometric testing, a 5 minute self-selected warm-up period was allowed before 3 repetition maximum (3RM) testing began. 3RM testing was performed in accordance with the guidelines from the National Strength and Conditioning Association. The NSCA 3RM testing guidelines outline proper inter-set rest length and load increases (1). The thruster exercise was assessed first, followed by the conventional deadlift. For the thruster, subjects were required to squat until the top of their thigh was parallel to the floor, and then using the momentum of the front squat, they were instructed to press the barbell overhead and fully extend the knees and hips in one fluid motion. During the conventional deadlift, subjects started with their feet approximately hip width apart and their hands just outside of their shins. The deadlift was deemed complete if they were able to smoothly lift the bar from the floor to a fully standing position with their hips extended into the bar. During the deadlift a flat back had to be maintained throughout the lift and participants were allowed to use either a pronated or alternating grip on the barbell. For further lift descriptions see Murphy (24).

Lactate Threshold and Peak Oxygen Consumption Testing

Ten minutes after 3RM testing, subjects were fitted with a Polar heart rate monitor (Lake Success, NY) and underwent combined lactate threshold and peak oxygen consumption (VO2 peak) testing on a RacerMate Velotron Dynafit Pro cycle ergometer (Seattle, WA). Testing was conducted using the same incremental protocol for all those involved. Subjects began cycling at 100 watts and the resistance was increased every 3 minutes to elicit an increase of 25 watts. The electronically braked ergometer allows the subject to choose their desired cadence and adjusts the resistance to maintain the proper power output. Lactate measurements were taken during the final 30 seconds of each stage using a Lactate Pro Analyzer (Quesnel, BC). The Lactate Pro Analyzer requires a small drop of blood, which was obtained by piercing the fingertip with a spring loaded lancet. The fingertip was cleaned with alcohol, dried and the first drop of blood wiped away before collecting the test drop. Once a blood lactate of 4 mmol/dL was detected, subjects began the VO2 peak portion of testing. Workload was increased by 25 watts, every 60s until VO2 peak was reached. A Hans-Rudolph (Shawnee, KS) headpiece, nose clips and mouthpiece were worn throughout the entire lactate and VO2 peak testing protocol in the event that lactate threshold and VO2 peak occurred at similar workloads. VO2 peak was assessed via open-circuit indirect calorimetry (Parvo Medics TrueMax 2400 System, Sandy, UT). Finally, subjects were allowed a 5 minute recovery period before familiarization with the cycling protocol that was to be used during the training sessions which involved 2 minutes of all-out cycling at a resistance level consistent with 5% of body weight.

Training Session Days

Over the next 3 weeks, subjects completed 3 training sessions. The training session was an interval weight training protocol developed by O'Shea (25). The purpose of the training session is to improve work-capacity (work performed per unit of time) or power/strength endurance.

On training session days, subjects were outfitted with a Polar heart rate monitor and began by resting for 5 minutes using the required strategy (supine, seated or walking) for that day. Heart rate (HR) and ventilatory data such as respiratory rate (RR) and oxygen consumption (VO2) were collected during this initial rest period to familiarize subjects with the proper body posture. Subjects were then allowed a ten minute, self-selected, warm-up period. Following the warm-up, subjects began the training session employing 1 of the 3 possible rest strategies.

During part 1 of the training session, subjects used 80% of the 3RM thruster value to perform 10 repetitions of the thruster exercise. The thruster exercise was followed with 2 minutes of all-out effort rowing at a resistance level of 6. Rowing took place on a Concept 2D model rower, with a PM3 monitor (Morrisville, VT). Subjects were blinded to rowing output during all tests. Subjects then rested for 2 minutes, during which HR, RR and VO2 data were continuously collected via Parvo Medics TrueMax 2400 System Metabolic Cart (Sandy, UT). After the third set of the above mentioned exercise combination, 5 minutes of rest was taken. The 2 and 5 minute rest periods align with O'Shea's protocol, with the 5 minute period allowed for extra rest before part 2 of the training session. Heart rate, RR and VO2 data were again continuously collected during the rest period.

Part 2 of the training session included 8 repetitions of the deadlift (at 80% of 3RM), followed by 2 minutes of all-out cycling at a resistance level consistent with 5% of the subject's body weight. A rest period of 2 minutes was taken after each of the first two sets of exercise and a 5 minute rest period was taken after the third set. Data collection was the same as during part 1 of the training session. A visual diagram of the protocol may be seen in figure 1. The goal of each session was to complete the training session in as little time as possible, without compromising exercise form. Subjects were encouraged to work as hard and fast as possible without feeling hurried or as if they would be hurt or collapse as a result of their effort.

[Figure 1 about here]

Rest Position Descriptions

Supine rest was taken with the subject lying on a foam mat on the floor with the legs and arms extended and flat against the floor. Researchers assisted the subjects to position their nose clip and mouth piece so that subjects could lie down quickly and would not have to be hindered by positioning the equipment. Supine rest was chosen as it would allow the majority of the musculature to fully relax during rest periods and potentially enhance recovery.

Seated rest was taken with the subject seated comfortably on a standard exercise bench with their feet on the floor, elbows resting on the thighs just above the knees and the torso slightly angled forward. Again, researchers assisted subjects with the equipment as soon as they sat down. Seated rest was chosen because exercise benches are often available to athletes, making it a viable and practical choice as a rest strategy.

Rest via slow walking took place on a research grade Quinton Q-Stress TM55 treadmill (Waukesha, WI) set to 0.67 meters • second^{-1}. The mouthpiece was suspended next to the treadmill so that subjects could easily position the equipment and begin walking. Researchers were nearby to assist with equipment at all times. The slow walking strategy was chosen because athletes may be encouraged to remain standing and moving slowly during rest periods, to maintain venous return and possibly improve blood lactate removal. This may be the most common rest strategy used by athletes.

Finally, masking tape was placed on the floor to mark where all of the testing equipment was to be placed each week. Marking the placement of the bike, rower, barbells, foam mat for supine rest and bench for seated rest improved consistency between testing sessions. Consequently, subjects moved the same distance between pieces of equipment during each training session.

Work Rate Calculation

Data were calculated for each individual under each condition (supine, seated and walking) by summing the joules of work produced during the cycling and rowing portions of the training session and dividing this value by the total time (in seconds) taken to complete the training session. The resultant work rate value was presented as joules of work•second^{-1}. Quantification of work for the thrusters and conventional deadlifts was not calculated, as all subjects completed all repetitions, making this a constant value across training sessions for each subject. Presumably, more fatigue equated to slower lifting, more breaks and slower movement between exercises, which adequately captured how each rest strategy impacted work rate, due to the fact that this was a timed session.

Recovery Measures Calculation

Heart rate, RR and VO2 were averaged every 15 seconds during data collection. Area under the curve was calculated for each marker of physiological recovery (HR, RR and VO2) and summed across all rest periods for each training session (supine, seated and walking). For example, a subject in the supine training session spent a total of 18 minutes resting between their sets, during which recovery data were collected (Figure 1). Heart rate area under the curve was calculated by summing all of the 15 second averaged HR values that were recorded each rest period

Statistical Analyses

The SPSS statistical software program version 20 was used for statistical comparisons. A repeated measures (RM) ANOVA with post-hoc comparisons was run to determine the differences in work rate as a function of supine, seated or walking rest strategy. Data were screened for outliers, multivariate normality and sphericity before proceeding with

RM ANOVA. The data were normal and free of outliers and thus linear statistics were appropriate.

Bivariate correlations were used to assess the relationships between the markers of physiological recovery (area under the curve for HR, RR and VO2) associated with each rest strategy to safeguard against multi-collinearity. A MANOVA, followed by discriminant function analysis (DFA) was used to determine if differences were apparent between the markers of physiological recovery by rest strategy, and if so, which recovery variables (HR, RR or VO2) best differentiated the three rest strategies. Significance was set at $p \leq 0.05$ for all statistics.

RESULTS

Work rate mean and SD by rest strategy are presented in figure 2. Results of the RM ANOVA showed a significant difference between the three rest strategies when work rate, measured as joules of work•second^{-1}, was compared across training sessions ($p \leq 0.05$). Post-hoc comparisons were made between training sessions involving supine and walking trials, and seated and walking trials (Table 2). Results indicate that a significantly higher work rate was achieved during the seated and supine trials compared to the walking trial; supine and walking significantly differ ($p \leq 0.05$), seated and walking significantly differ ($p \leq 0.05$).

[Figure 2 about here]

[Table 2 about here]

Bivariate Pearson correlations within each rest strategy between the markers of physiological recovery ranged from .26-.66, indicating levels of correlation that are moderate and therefore, not collinear and as such all variables were retained for analyses. Visual comparison of physiological recovery data for HR and VO2 during the 2 and 5 minute rest periods can be seen in figures 3-6. MANOVA showed significant group differences between recovery variables by rest strategy ($F=1148.37$, $df=3$, $p \leq 0.05$). Discriminant function analysis revealed two functions, the first explaining 98.5% of variance, canonical $R^2 = .57$ and the second explaining 1.5% of variance, canonical $R^2 = .09$. Together, these functions significantly differentiated the rest strategies, $\Lambda = .60$, $X^2(6) = 16.42$, $p = .01$, but removal of the first function indicated that the second function did not differentiate the groups, $\Lambda = .99$, $X^2(2) = .30$, $p > 0.05$. The correlation between the outcomes and discriminant functions showed that HR and VO2 loaded highly on function 1 (.90 and .82 respectively) and lower on function 2 (-.39 and .37 respectively), while RR loaded evenly across the two functions (.58 and .70). Function 1 has been named oxygen delivery. These results, paired with the discriminant function plot indicate that the oxygen delivery function discriminated the supine and seated trials from the walking trial.

[Figures 3, 4, 5 and 6 about here]

DISCUSSION

The primary finding in the current study was that when subjects assumed a supine posture or sat quietly on a bench during their inter-set rest periods, they were able to produce significantly higher work rates (greater joules of work•second^{-1}) than when they walked slowly during the inter-set rest periods (Table 2 and Figure 2). It is quite common for sport and strength and conditioning coaches to require athletes to remain standing and lightly active between sets of lifting or conditioning exercises. To our knowledge, there are no clear performance or psychological benefits derived from this practice in healthy and fit athletes. Based on our findings, it may in fact be detrimental to work rate to continue moving during inter-set rest periods during multi-modal, work-capacity style training sessions such as the interval weight training protocol.

It has been proposed that the length of inter-set rest may be individualized by assigning a recovery HR, instead of the traditional method of assigning an inter-set rest period (26). Under the premise that an optimal recovery point exists, our analyses were done to determine if superior recovery, defined as greater reductions in HR, RR and VO2 during rest periods (Figures 4-7), was associated with any of the rest strategies (supine, seated or walking rest). Discriminant function analysis results showed that HR and VO2 were the primary variables that differentiated our conditions and therefore, HR and VO2 may indeed be acceptable indicators of recovery as they were lower as a result of supine and seated inter-set rest. Simply put, higher work rates and lower recovery HR and VO2 values were observed during the training sessions that employed supine and seated rest compared to the training session that utilized the slow walking rest strategy.

No apparent difference was observed between the supine and seated conditions, suggesting that passive rest, be it supine or seated, is equally effective for enhancing work rate.

Work rate and recovery findings are in agreement with previous research that has tested short duration cycling (6 x 4 second sprints, set 25 seconds apart). Spencer et al., revealed that active rest lead to greater performance decrements over 6 maximal cycling sprints; 7.4 ± 2.2% decrement in peak power with active rest, compared to 5.6 ± 1.5% decrement with passive rest (29). A follow-up study utilizing the same methods, but testing passive, low intensity active and medium intensity active rest produced the same results, with data trending that demonstrated performance decrements became greater as inter-set rest became more intense (30). Both investigations attributed the reduced fatigue indices associated with passive rest to greater phosphocreatine (PCr) replenishment, which they confirmed by muscle biopsy (29). Spencer showed significant negative correlations between percent of PCr replenishment and percent decrement in cycling power. Discriminant function analysis regarding the recovery data from the training sessions in the current study indicated that HR and VO2 differentiated between the passive (supine and seated) and active (walking) rest strategies. Since PCr resynthesis is an oxidative process, training session markers of physiological recovery agree with Spencer's assertion that passive rest may improve PCr resynthesis compared to active rest and this may impact subsequent work rate.

Work rate findings from this study are also in agreement with research that has tested slightly longer duration, physically exhausting protocols. Castagna et al. recruited young basketball athletes to complete 10 x 30 meter shuttle runs interspersed with 30 seconds of passive rest, or active rest; running at 50% of maximal aerobic speed (9). Results showed that fatigue indices were significantly different ($p \leq 0.05$) between the active and passive conditions (3.39 $\pm$ 2.3 and 5.05 $\pm$ 2.4 respectively) and on average athletes were able to run faster when rest was passive rather than active (6.17 $\pm$ 0.10 and 6.32 $\pm$ 0.10 seconds per sprint shuttle respectively). Dupont employed a protocol where subjects ran as many 15, set-distance sprints as possible interspersed with 15 seconds of active or passive rest (14). Time to exhaustion between the conditions was significantly different ($p \leq 0.05$), 745 $\pm$ 171 seconds during the passive rest condition and 445 $\pm$ 79 seconds compared to the active rest condition. Dupont suggests the difference in performance may be explained by the fact that active rest increases energy demand and may result in less oxygen being available for the reloading of myoglobin and subsequent resynthesis of PCr (14, 18). A second investigation showed that passive rest allowed for significant attenuation of oxyhemoglobin decrements, suggesting that passive rest allowed for greater oxygen delivery, increased myoglobin reoxygenation and superior PCr resynthesis (15). It is possible that the supine and seated inter-set rest strategies reduced energy demands more than the walking inter-set rest strategy and therefore, may have been responsible for improvements in PCr resynthesis and subsequent work rate.

Discriminant function analysis revealed a function (oxygen delivery), consisting of HR and VO2, differentiated between the passive (supine and seated) and active (walking) rest conditions. The idea that HR and VO2 may be used to indicate physiological recovery provides coaches with a simple and objective method to determine if athletes are adequately recovered before proceeding with their workout. Of the two, HR would certainly be the more practical method for monitoring recovery than VO2. The optimal restorative HR has not yet been determined and very well may be different depending on the type of exercise being performed. However, our results show that on average, HR was restored to 162% of resting HR after 2 minutes and 154% of resting HR after 5 minutes of passive (seated or supine) rest compared to 190% of resting HR after 2 minutes and 180% of resting HR after 5 minutes of active (walking) rest.

The current study has demonstrated that seated or supine rest may allow for superior training session work rates (4.22% greater joules of work●second^{-1} than walking rest) and also enhanced physiological recovery. The use of upright, active or walking rest may not be optimal for training sessions that are directed at the improvement of work rate and work-capacity. Therefore, strength coaches may allow athletes to passively rest (seated or supine) in order to augment recovery during exceptionally taxing, mixed modal, work-capacity training sessions. Strength coaches may also opt for more objective measures of recovery (heart rate for example) to determine if an athlete is fully recovered between sets.

PRACTICAL APPLICATION

The use of high intensity, multi-modal, work-capacity style strength and conditioning regimens has gained popularity and appears beneficial for training the specific work-capacity, strength, and power endurance requirements of populations such as active military and fire personnel, as well as various athletes. During sessions such as the IWT and those designed to create similar metabolic and muscular demands and ultimately improve work-capacity, allowing athletes to lie supine or sit during their inter-set rest periods may enhance work rate and recovery. Therefore, if strength and conditioning coaches are seeking to optimize work rate, allowing athletes too passively rest (seated or supine) may allow for acute increases in work rate and perhaps long term improvements in work-capacity. However, further longitudinal investigations would be necessary to determine the long-term implications of seated or supine rest upon work-capacity.

Heart rate may also offer a practical and inexpensive way to monitor physiological recovery. More work should be done however, to determine appropriate HR recovery levels that are consistent with work rate (improvements in possible joules of work•second^{-1}) enhancement.

REFERENCES

1. *The Essentials of Strength and Conditioning.* Champaign, IL: Human Kinetics, 2008.
2. Ahmaidi S, Granier P, Taoutaou Z, Mercier J, Dubouchaud H, and Prefaut C. Effects of active recovery on plasma lactate and anaerobic power following repeated intensive exercise. *Med Sci Sports Exerc* 28: 450-456, 1996.
3. Bangsbo J, Graham T, Johansen L, and Saltin B. Muscle lactate metabolism in recovery from intense exhaustive exercise: impact of light exercise. *J Appl Physiol* 77: 1890-1895, 1994.
4. Belcastro AN and Bonen A. Lactic acid removal rates during controlled and uncontrolled recovery exercise. *J Appl Physiol* 39: 932-936, 1975.
5. Bogdanis GC, Nevill ME, Boobis LH, Lakomy HK, and Nevill AM. Recovery of power output and muscle metabolites following 30 s of maximal sprint cycling in man. *J Physiol* 482 (Pt 2): 467-480, 1995.
6. Bogdanis GC, Nevill ME, Lakomy HK, and Boobis LH. Power output and muscle metabolism during and following recovery from 10 and 20 s of maximal sprint exercise in humans. *Acta Physiol Scand* 163: 261-272, 1998.
7. Bogdanis GC, Nevill ME, Lakomy HK, Graham CM, and Louis G. Effects of active recovery on power output during repeated maximal sprint cycling. *Eur J Appl Physiol Occup Physiol* 74: 461-469, 1996.
8. Bonen A and Belcastro AN. Comparison of self-selected recovery methods on lactic acid removal rates. *Med Sci Sports* 8: 176-178, 1976.
9. Castagna C, Abt G, Manzi V, Annino G, Padua E, and D'Ottavio S. Effect of recovery mode on repeated sprint ability in young basketball players. *The Journal of Strength & Conditioning Research* 22: 923-929, 2008.
10. Corder K, Jeffrey A. Potteiger, Karen L. Nau, Stephen F. Figoni, Scott L. Hershberger. Effects of Active and Passive Recovery Conditions on Blood Lactate, Rating of Perceived Exertion, and Performance During Resistance Exercise. *Journal of Strength and Conditioning Research* 14: 151-156, 2000.
11. Davies CT, Knibbs AV, and Musgrove J. The rate of lactic acid removal in relation to different baselines of recovery exercise. *Int Z Angew Physiol* 28: 155-161, 1970.
12. de Salles BF, Simão R, Miranda H, Bottaro M, Fontana F, and Willardson JM. Strength increases in upper and lower body are larger with longer inter-set rest intervals in trained men. *Journal of Science and Medicine in Sport* 13: 429-433, 2010.
13. Dorado C, Sanchis-Moysi J, and Calbet JAL. Effects of recovery mode on performance, O2 uptake, and O2 deficit during high-intensity intermittent exercise. *Canadian journal of applied physiology* 29: 227-244, 2004.
14. Dupont G, Blondel N, and Berthoin S. Performance for short intermittent runs: active recovery vs. passive recovery. *European journal of applied physiology* 89: 548-554, 2003.
15. Dupont G, Moalla W, Guinhouya C, Ahmaidi S, and Berthoin S. Passive versus active recovery during high-intensity intermittent exercises. *Medicine and science in sports and exercise* 36: 302-308, 2004.

16. Gisolfi C, Robinson S, and Turrell E. Effects of aerobic work performed during recovery from exhausting work. *Journal of Applied Physiology* 21: 1767-1772, 1966.
17. Hannie PQ, Garry R. Hunter, Tamas Kekes-Szabo, Christal Nicholson, Peggy C. Harrison. The Effects of Recovery on Force Production, Blood Lactate, and Work Performed During Bench Press Exercise. *Journal of Strength and Conditioning Research* 9: 8-12, 1995.
18. Haseler LJ, Hogan MC, and Richardson RS. Skeletal muscle phosphocreatine recovery in exercise-trained humans is dependent on O2availability. *Journal of Applied Physiology* 86: 2013-2018, 1999.
19. Heyward VH and Wagner DR. *Applied body composition assessment.* Champaign, IL: Human Kinetics, 2004.
20. Kraemer WJ and Ratamess NA. Hormonal responses and adaptations to resistance exercise and training. *Sports Medicine* 35: 339-361, 2005.
21. Matuszak ME, Fry AC, Weiss LW, Ireland TR, and McKnight MM. Effect of rest interval length on repeated 1 repetition maximum back squats. *J Strength Cond Res* 17: 634-637, 2003.
22. McAinch AJ, Febbraio MA, Parkin JM, Zhao S, Tangalakis K, Stojanovska L, and Carey MF. Effect of active versus passive recovery on metabolism and performance during subsequent exercise. *Int J Sport Nutr Exerc Metab* 14: 185-196, 2004.
23. Mohamad NI, Cronin JB, and Nosaka KK. The effect of aerobic exercise during the interset rest periods on kinematics, kinetics, and lactate clearance of two resistance loading schemes. *J Strength Cond Res* 26: 73-79, 2012.
24. Murphy TJ. *Inside the Box: How CrossFit Shredded the Rules, Stripped Down the Gym, and Rebuilt My Body.* VeloPress, 2012.
25. O'Shea P. *Quantum Strength Fitness II.* Corvallis, Oregon: The Oregon Center for Applied Athletic Strength Training and Conditioning, 1995.
26. Piirainen JM, Tanskanen M, Nissila J, Kaarela J, Vaarala A, Sippola N, and Linnamo V. Effects of a heart rate-based recovery period on hormonal, neuromuscular, and aerobic performance responses during 7 weeks of strength training in men. *J Strength Cond Res* 25: 2265-2273, 2011.
27. Senna G, Willardson JM, de Salles BF, Scudese E, Carneiro F, Palma A, and Simao R. The effect of rest interval length on multi and single-joint exercise performance and perceived exertion. *J Strength Cond Res* 25: 3157-3162, 2011.
28. Siri WE. Body composition from fluid spaces and density: analysis of methods. *Techniques for measuring body composition*: 223-244, 1961.
29. Spencer M, Bishop D, Dawson B, Goodman C, and Duffield R. Metabolism and performance in repeated cycle sprints: active versus passive recovery. *Medicine and science in sports and exercise* 38: 1492, 2006.
30. Spencer M, Dawson B, Goodman C, Dascombe B, and Bishop D. Performance and metabolism in repeated sprint exercise: effect of recovery intensity. *European journal of applied physiology* 103: 545-552, 2008.

31. Toubekis AG, Adam GV, Douda HT, Antoniou PD, Douroundos, II, and Tokmakidis SP. Repeated sprint swimming performance after low- or high-intensity active and passive recoveries. *J Strength Cond Res* 25: 109-116, 2011.
32. Toubekis AG, Douda HT, and Tokmakidis SP. Influence of different rest intervals during active or passive recovery on repeated sprint swimming performance. *Eur J Appl Physiol* 93: 694-700, 2005.
33. Weir JP, Wagner LL, and Housh TJ. The effect of rest interval length on repeated maximal bench presses. *The Journal of Strength & Conditioning Research* 8: 58, 1994.
34. Weltman A, Stamford BA, and Fulco C. Recovery from maximal effort exercise: lactate disappearance and subsequent performance. *J Appl Physiol* 47: 677-682, 1979.
35. Weltman A, Stamford BA, Moffatt RJ, and Katch VL. Exercise recovery, lactate removal, and subsequent high intensity exercise performance. *Res Q* 48: 786-796, 1977.
36. Willardson JM and Burkett LN. A comparison of 3 different rest intervals on the exercise volume completed during a workout. *J Strength Cond Res* 19: 23-26, 2005.
37. Willardson JM and Burkett LN. The effect of rest interval length on bench press performance with heavy vs. light loads. *J Strength Cond Res* 20: 396-399, 2006.
38. Willardson JM and Burkett LN. The effect of rest interval length on the sustainability of squat and bench press repetitions. *J Strength Cond Res* 20: 400-403, 2006.
39. Willardson JM and Burkett LN. The effect of different rest intervals between sets on volume components and strength gains. *J Strength Cond Res* 22: 146-152, 2008.

ACKNOWLEDGEMENTS

The authors thank Tommy and Bobbie Jo Hackenbruck and members of Ute CrossFit for their efforts and professionalism. The authors also thank Traci Thompson of Peak Health and Fitness for her support, assistance in lab preparation and equipment use. Finally, special thanks to Dr. Barry Shultz for his guidance regarding selection of appropriate statistical analyses. This study does not have conflict of interest and was not supported by internal or external funding.

FIGURE LEDGENDS

Figure 1: A clock was left running from the start to finish of the training session. Recovery data (HR, RR and VO2) were collected during the rest portions of the training session. Finally, data indicative of work performed were collected and summed across all sets.

Figure 2: Mean $\pm$ standard deviation for supine (62.77 + 7.32 J/s), seated (63.66 + 8.37 J/s) and walking (60.61 + 6.42 J/s). Significantly different ($p \leq 0.05$) from the walking trial is denoted (✦).

Figures 3 and 4: Comparison of HR decrements over 2 and 5 minutes of rest across all rest strategies (supine, seated and walking). Visual data indicates faster and more complete restoration of HR when rest was taken supine or seated compared to walking.

Figures 5 and 6: Comparison of VO2 decrements over 2 and 5 minutes of rest across all rest strategies (supine, seated and walking). Visual data indicates faster and more complete restoration of VO2 when rest was taken supine or seated compared to walking.

Sex	N	Age (y)	Height (cm)	Weight (kg)	Percent Fat (%)	VO2 Peak (ml•kg•min^{-1})	Lactate Threshold (% of VO2 Peak)	Deadlift 3RM (kg)	Thruster 3RM (kg)
Female	10	32±5	167.8±4.5	65.4±12	21.2±5.8	44.8±7.07	88.1±5%	88.6±9.8	42.7±5.4
Male	5	30±8	179.8±8.6	79.9±10.3	17.7±6.7	49.5±5.12	79±3%	123.2±10	68.6±9.4

Table 1: Subjects' anthropometric and physical fitness characteristics.

Group	F Value	Degrees of Freedom	Significance	Power
Omnibus	3.96	2	$p \leq 0.05$	.66
Supine vs. Walking	5.39	1	$p \leq 0.05$	.58
Seated vs. Walking	8.15	1	$p \leq 0.05$	.76

Table 2: Repeated measure ANOVA results and post-hoc comparisons for performance data show that resting supine or seated allowed for significantly higher work rate (more work done per unit of time) than resting via slow walking ($p \leq 0.05$).

Figure 1. Schematic representation of the training session protocol.

Before Training Session

Rest Familiarization	Warm-Up
5 Minutes in the prescribed rest position	10 Minutes of self-selected warm-up time

Training Session Part 1

Set 1	Rest	Set 2	Rest	Set 3	Rest
10x Thruster	2 Min	10x Thruster	2 Min	10x Thruster	5 Min
2 Min Row		2 Min Row		2 Min Row	

Training Session Part 2

Set 4	Rest	Set 5	Rest	Set 6	Rest
8x Deadlift	2 Min	8x Deadlift	2 Min	8x Deadlift	5 Min
2 Min Cycle		2 Min Cycle		2 Min Cycle	

Figure 2. Comparison of work rate means and standard deviations across rest strategies.

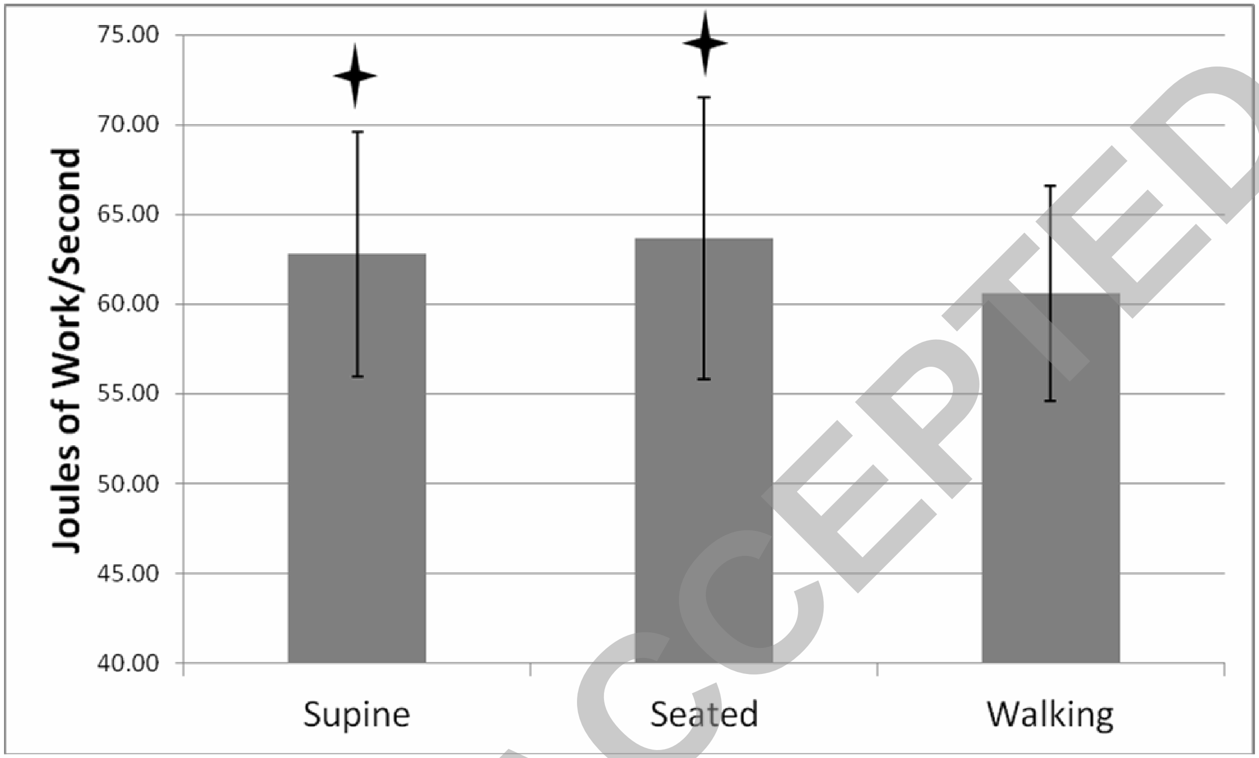

Figure 3. Average heart rate decrements during 2 minute inter-set rest periods across rest strategies.

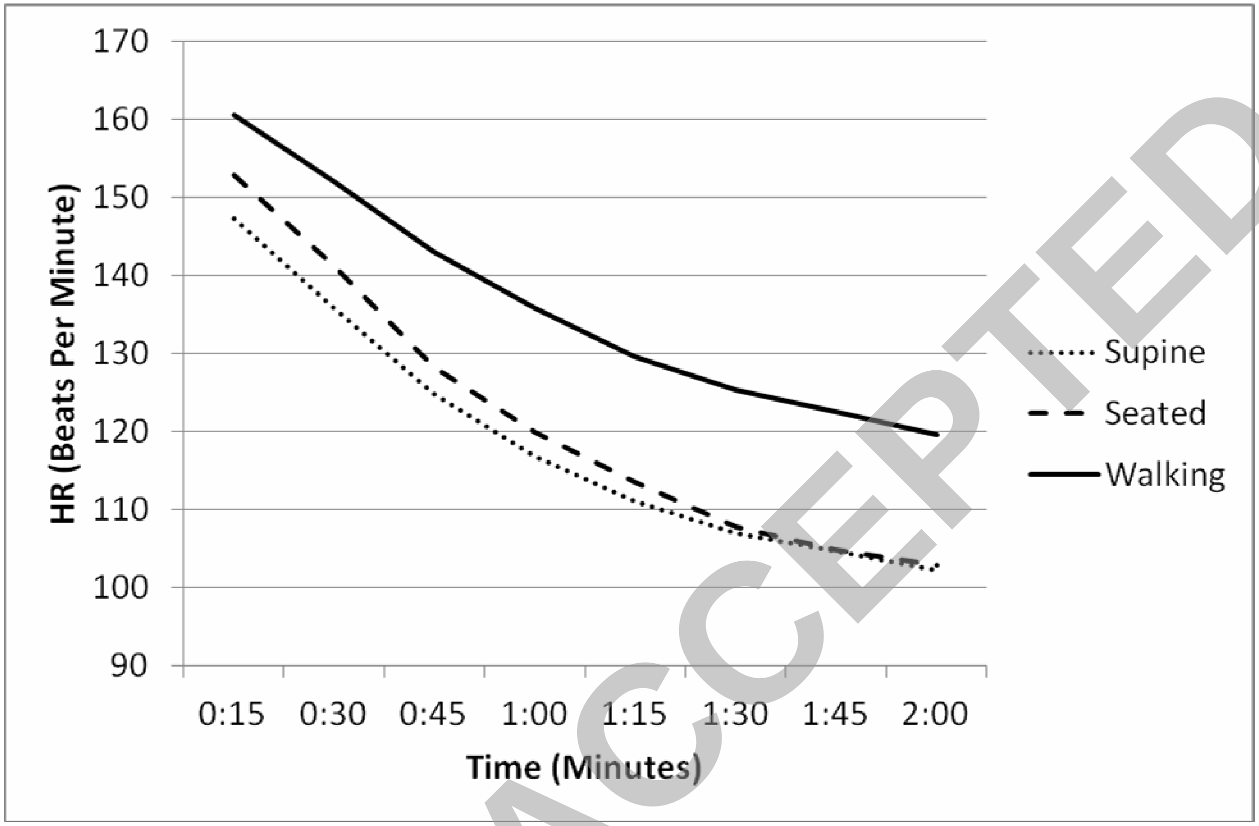

Figure 4. Average heart rate decrements during 5 minute inter-set rest periods across rest strategies.

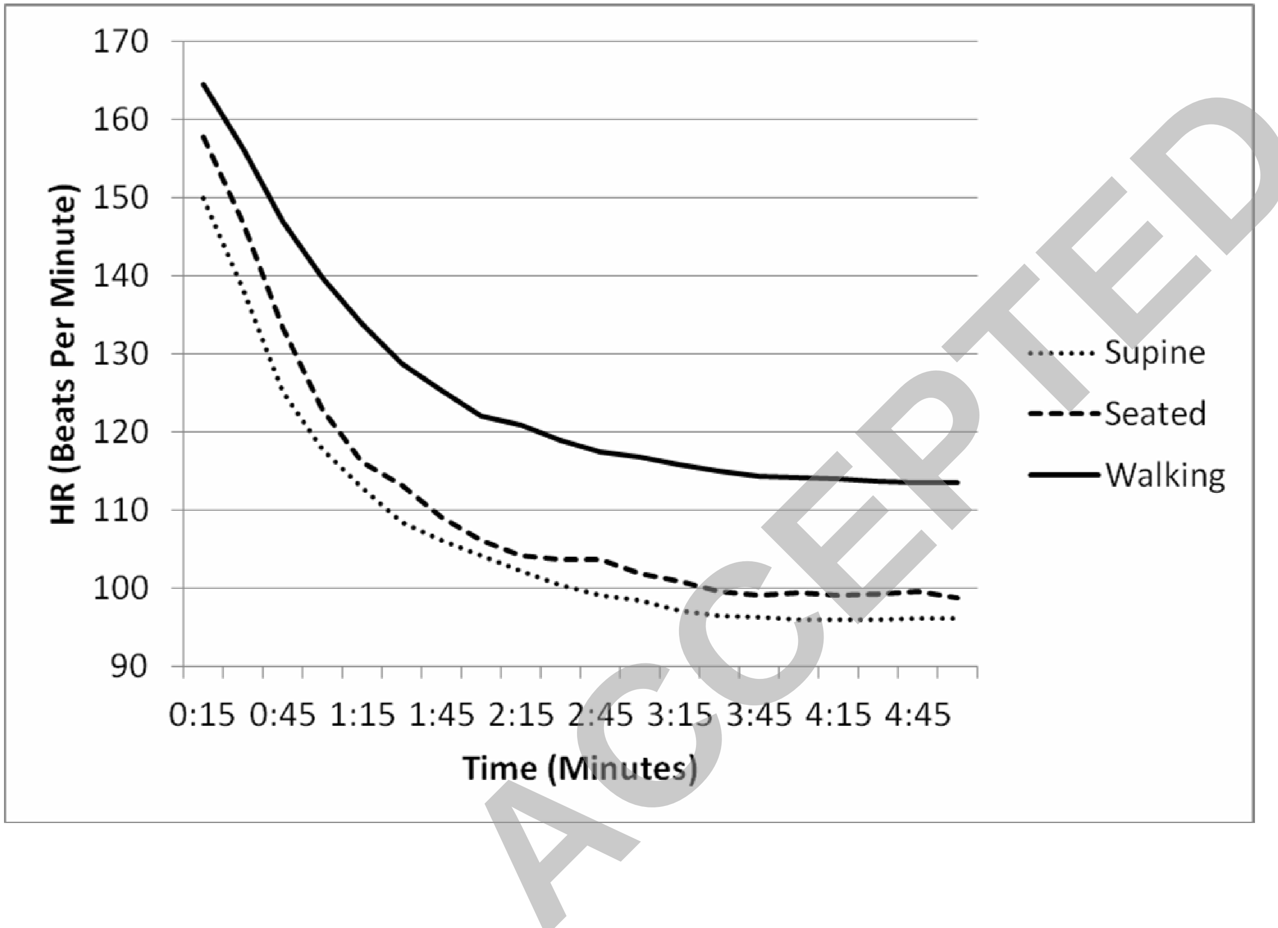

Figure 5. Average oxygen consumption decrements during 2 minute inter-set rest periods across rest strategies.

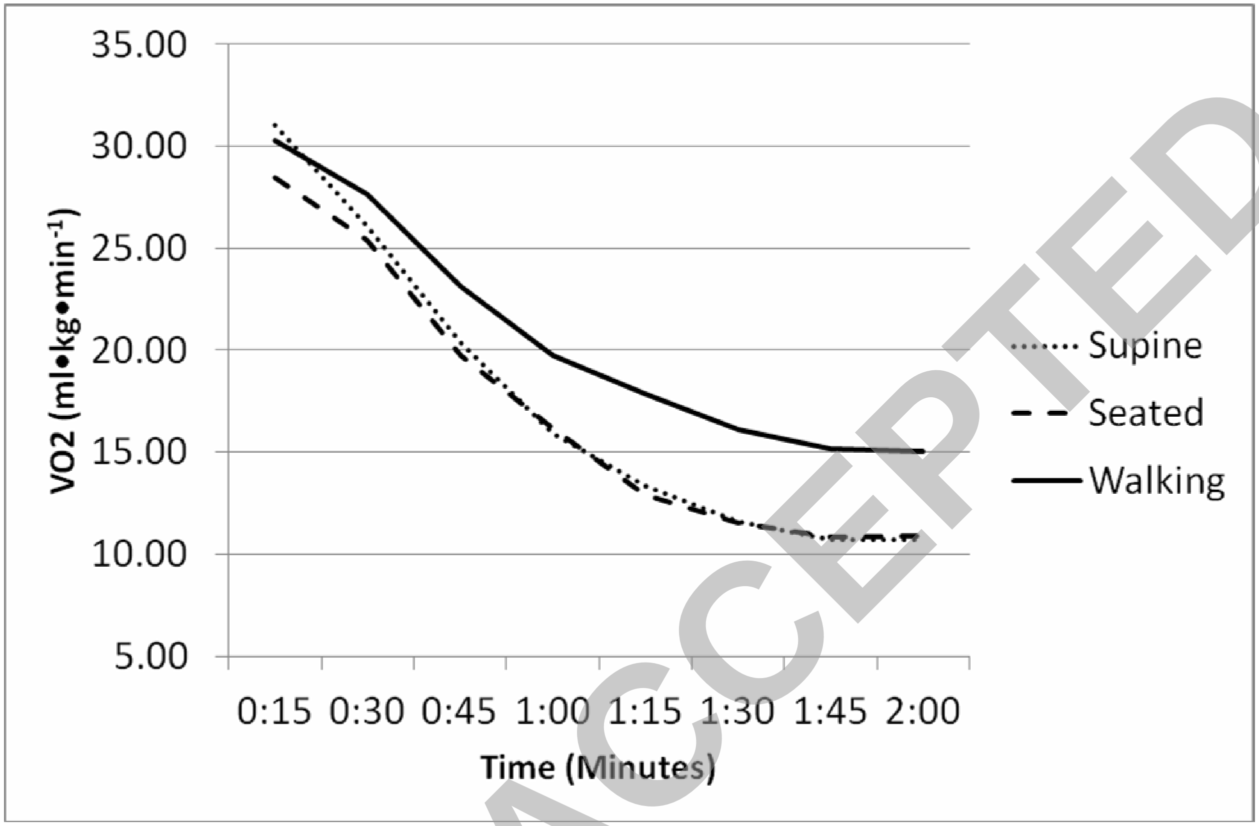

Figure 6. Average oxygen consumption decrements during 5 minute inter-set rest periods across rest strategies.