Comparison of the Effects of Seated, Supine, and Walking Interset Rest Strategies on Work Rate

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Abstract

Ouellette, KA, Brusseau, TA, Davidson, LE, Ford, CN, Hatfield, DL, Shaw, JM, and Eisenman, PA. Comparison of the effects of seated, supine, and walking interset rest strategies on work rate. *J Strength Cond Res* 30(12): 3396–3404, 2016—The idea that an upright posture should be maintained during the interset rest periods of training sessions is pervasive. The primary aim of this study was to determine differences in work rate associated with 3 interset 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 3 separate occasions to evaluate 3 interset rest strategies, which included lying supine on the floor, sitting on a flat bench, and walking on a treadmill ($0.67\ m\cdot s^{-1}$). 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 per second). Data were also collected during the interset rest periods (heart rate [HR], respiratory rate [RR], and volume of oxygen consumed) and were used to explain why one rest strategy may positively impact work rate compared with 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 ± 7.32, seated = 63.66 ± 8.37, and walking = 60.61 ± 6.42 average joules of work per second). Results also suggest that the passive strategies resulted in superior HR, RR, and oxygen consumption recovery. In conclusion, work rate and physiological recovery were enhanced when supine and seated interset rest strategies were used compared with walking interset rest.

Key Words rest strategy, active rest, passive rest, work-capacity, CrossFit

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Introduction

Many coaches believe 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 interset 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.

Although much research has focused on the assignment of interset rest periods to enhance physical performance and physiological recovery, the emphasis has been on determination of the optimal duration of the interset rest period and whether or not the interset rest should be active or passive. Little research has been performed to examine the influence of body posture assumed during the interset rest, and no research exists regarding the manipulation of interset rest to specifically enhance an athlete's work rate, defined as the amount of physical work that can be performed 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 with remaining upright and walking slowly (the rest method that is most commonly used).

The impact that the length of the interset 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 interset rest periods equate to increased training volume, although longer rest allows for more complete local substrate repletion (11,20,26,33,36–39).

When the goal of training is strength or power development, longer interset rest periods (at least 2 minutes) are typically recommended, so that lifting load and quality can remain high (30). A longitudinal study by de Salles et al. (11) supports the implementation of lengthier interset rest periods, 5 vs. 3 or 1 minute(s), over a 16-week mesocycle to result in a larger strength gains. When the goal of training is muscular hypertrophy, shorter rest periods coupled with moderate loads and high training volumes are recommended to create the necessary muscular stress and hormonal environment conducive to muscle protein synthesis (19). Although the literature provides guidance for structuring the duration of interset 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 interset rest periods. Furthermore, no studies have reported interset rest strategies during training sessions designed specifically to enhance an athlete's work capacity or the amount of work they are capable of performing in a given period.

In addition to the consistent research about the optimization of interset rest period duration, it has been equally well established that active rest strategies are superior to passive rest when the goal is lactate removal (2,3,7,10,15,34,35). However, studies comparing the effects of active and passive interset rest on performance are inconsistent, perhaps although 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 (1,4–6,9,16,21,22,31,32). Some studies support the idea that active interset rest allows for improved performance (performance defined as enhanced anaerobic power or higher lifting volume) when compared with passive interset rest (1,6,9,16), whereas others show the opposite relationship (8,12–14,28,29,31,32) or no difference (21,22). Therefore, further objective studies are necessary to determine the impact of body posture, active, and passive interset rest on training session work rate.

For research on the impact of interset rest strategies on training session work rate to be of maximum value to the coach, information regarding body posture during the interset rest period is needed. Given the information provided by previous research, our research builds on the use of interset rest periods that are of sufficient duration (2–5 minutes instead of 45–60 seconds) to elicit high training volumes and enhanced recovery (26,36–39). Finally, testing was performed 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 3 interset rest strategies on training session work rate. Of secondary interest was the determination of which interset 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 interset rest would allow subjects to produce more work per unit of time and to have more complete recovery of their heart rate (HR), respiratory rate (RR), and oxygen consumption within the training sessions (12–14,28,29). Providing insight into the connection between specific interset 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 4 weeks. During week 1, pretesting occurred. The order of testing was body composition, maximal strength, and peak oxygen consumption assessment. Maximal strength was assessed 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 (24) to improve work capacity. During the training sessions, the loads used and the length of the interset rest periods were held constant across weeks 2–4; however, the interset rest strategy was modified to include supine, seated, or walking strategies. Therefore, the interset 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 HR, RR, and oxygen consumption, were measured during all interset 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 reported being free of injury, illness, and performance-enhancing drugs. Subjects 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. Before testing, the University of Utah IRB approved all methodology and subjects provided written informed 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

TABLE 1. Subjects' anthropometric and physical fitness characteristics.*

Sex	N	Age (y)	Height (cm)	Weight (kg)	Percent fat (%)	$\dot{V}O_2$peak ($ml \cdot kg^{-1} \cdot min^{-1}$)	Lactate threshold (% of $\dot{V}O_2$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

*3RM = 3 repetition maximum.

before 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. Although 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 because of the collection of oxygen consumption during rest periods.

Procedures

Pretesting. ***Anthropometric Measurements.*** On the first testing day, the subject's height was measured using a stadiometer, their body composition (weight and volume) was assessed by Bod Pod (COSMED, Concord, CA, USA) air displacement plethysmography (18), and the Siri equation was used to calculate body fat percentage (27).

Strength Testing. After the anthropometric testing, a 5-minute self-selected warm-up period was allowed before 3 repetition maximum (3RM) testing began. Three RM testing was performed in accordance with the guidelines from the National Strength and Conditioning Association. The NSCA 3RM testing guidelines outline proper interset rest length and load increases (30). 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 1 fluid motion. During the conventional deadlift, subjects started with their feet approximately hip width apart and their hands just outside 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 the study by Murphy (23).

Lactate Threshold and Peak Oxygen Consumption Testing. Ten minutes after 3RM testing, subjects were fitted with a Polar heart rate monitor (Lake Success, NY, USA) and underwent combined lactate threshold and peak oxygen consumption ($\dot{V}O_2$peak) testing on a RacerMate Velotron Dynafit Pro cycle ergometer (Seattle, WA, USA). Testing was conducted using the same incremental protocol for all those involved. Subjects began cycling at 100 W, and the resistance was increased every 3 minutes to elicit an increase of 25 W. 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 (Arkray, Quesnel, BC, Canada). 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 $mmol \cdot dl^{-1}$ was detected, subjects began the $\dot{V}O_2$peak portion of testing. Workload was increased by 25 W, every 60 seconds until $\dot{V}O_2$peak was reached. A Hans Rudolph (Shawnee, KS, USA) headpiece, nose clips, and mouthpiece were worn throughout the entire lactate and $\dot{V}O_2$peak testing protocol in the event that lactate threshold and $\dot{V}O_2$peak occurred at similar workloads. $\dot{V}O_2$peak was assessed by open-circuit indirect calorimetry (Parvo Medics TrueMax 2400 System, Sandy, UT, USA). 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 (24). 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 RR

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 1. Schematic representation of the training session protocol. A clock was left running from the start to finish of the training session. Recovery data (HR, RR, and $\dot{V}O_2$) were collected during the rest portions of the training session. Finally, data indicative of work performed were collected and summed across all sets.

and oxygen consumption ($\dot{V}O_2$) were collected during this initial rest period to familiarize subjects with the proper body posture. Subjects were then allowed a 10 minute, self-selected, warm-up period. After the warm-up, subjects began the training session using 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, USA). Subjects were blinded to rowing output during all tests. Subjects then rested for 2 minutes, during which HR, RR, and $\dot{V}O_2$ data were continuously collected by Parvo Medics TrueMax 2400 System Metabolic Cart (Sandy, UT, USA). After the third set of the above-mentioned exercise combination, 5 minutes of rest was taken. The 2 and 5 minutes of rest periods align with the protocol of O'Shea, with the 5-minute period allowed for extra rest before part 2 of the training session. Heart rate, RR, and $\dot{V}O_2$ 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 2 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.

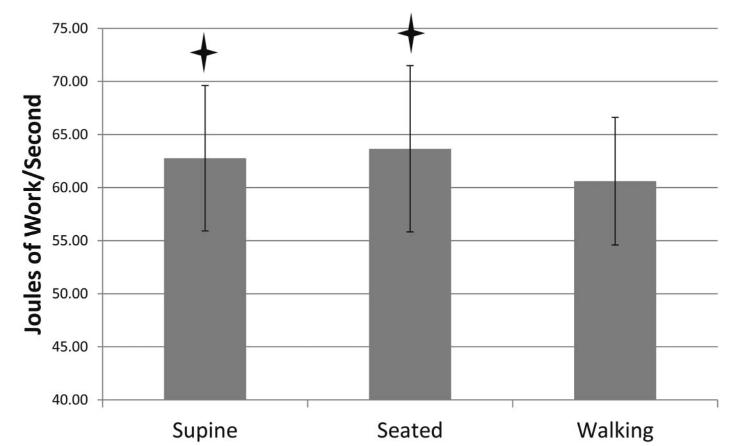

Figure 2. Comparison of work rate mean values and *SD*s across rest strategies. Mean ± *SD* for supine (62.77 + 7.32 $J\cdot s^{-1}$), seated (63.66 + 8.37 $J\cdot s^{-1}$), and walking (60.61 + 6.42 $J\cdot s^{-1}$). Significantly different ($p \leq 0.05$) from the walking trial is denoted (✦).

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.

TABLE 2. Repeated-measures ANOVA results and post hoc comparisons for performance data show that resting supine or seated allowed for significantly higher work rate (more work performed per unit of time) than resting by slow walking ($p \leq 0.05$).*

Group	*F*	*df*	Significant *p*	Power
Omnibus	3.96	2	≤0.05	0.66
Supine vs. walking	5.39	1	≤0.05	0.58
Seated vs. walking	8.15	1	≤0.05	0.76

*ANOVA = analysis of variance.

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 by slow walking took place on a research grade Quinton Q-Stress TM55 treadmill (Waukesha, WI, USA) set to $0.67\ \mathrm{m \cdot s^{-1}}$. 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 per second. 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, although this was a timed session.

Recovery Measures Calculation. Heart rate, RR, and $\dot{V}O_2$ were averaged every 15 seconds during data collection. Area under the curve was calculated for each marker of physiological recovery (HR, RR, and $\dot{V}O_2$) 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-minute 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 at each rest period.

Statistical Analyses

The SPSS statistical software program version 20 was used for statistical comparisons. A repeated-measures analysis of variance (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 $\dot{V}O_2$) associated with each rest strategy to safeguard against multicollinearity. A multivariate ANOVA followed by discriminant function analysis was used to determine if differences were apparent between the markers of physiological recovery by rest strategy, and if so,

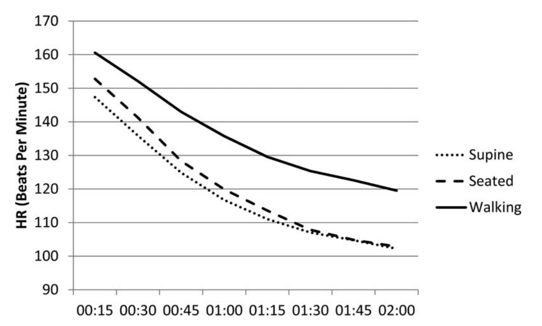

Figure 3. Average heart rate decrements during 2-minute interset rest periods across rest strategies. Comparison of HR decrements over 2 minutes of rest across all rest strategies (supine, seated, and walking). Visual data indicate faster and more complete restoration of HR when rest was taken supine or seated compared with walking.

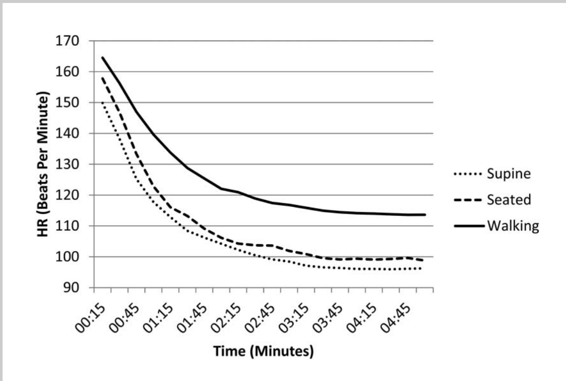

Figure 4. Average heart rate decrements during 5-minute interset rest periods across rest strategies. Comparison of HR decrements over 5 minutes of rest across all rest strategies (supine, seated, and walking). Visual data indicate faster and more complete restoration of HR when rest was taken supine or seated compared with walking.

which recovery variables (HR, RR, or $\dot{V}O_2$) best differentiated the 3 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 3 rest strategies when work rate, measured as joules of work per second, 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 with the walking trial; supine and walking significantly differ ($p \leq 0.05$), seated and walking significantly differ ($p \leq 0.05$).

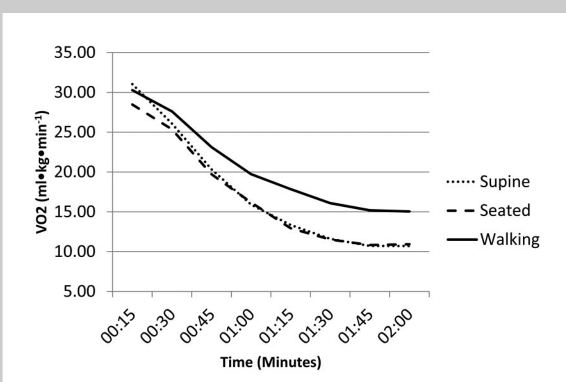

Figure 5. Average oxygen consumption decrements during 2-minute interset rest periods across rest strategies. Comparison of $\dot{V}O_2$ decrements over 2 minutes of rest across all rest strategies (supine, seated, and walking). Visual data indicate faster and more complete restoration of $\dot{V}O_2$ when rest was taken supine or seated compared with walking.

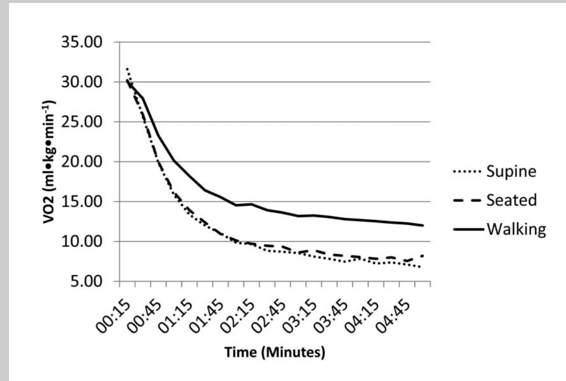

Figure 6. Average oxygen consumption decrements during 5-minute interset rest periods across rest strategies. Comparison of $\dot{V}O_2$ decrements over 5 minutes of rest across all rest strategies (supine, seated, and walking). Visual data indicate faster and more complete restoration of $\dot{V}O_2$ when rest was taken supine or seated compared with walking.

Bivariate Pearson's correlations within each rest strategy between the markers of physiological recovery ranged from 0.26 to 0.66, 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 $\dot{V}O_2$ during the 2- and 5-minute rest periods can be seen in Figures 3–6. Multivariate ANOVA showed significant group differences between recovery variables by rest strategy ($F = 1{,}148.37$, $df = 3$, $p \leq 0.05$). Discriminant function analysis revealed 2 functions, the first explaining 98.5% of variance, canonical $R^2 = 0.57$, and the second explaining 1.5% of variance, canonical $R^2 = 0.09$. Together, these functions significantly differentiated the rest strategies, $\Lambda = 0.60$, χ^2 (6) = 16.42, $p = 0.01$, but removal of the first function indicated that the second function did not differentiate the groups, $\Lambda = 0.99$, χ^2 (2) = 0.30, $p > 0.05$. The correlation between the outcomes and discriminant functions showed that HR and $\dot{V}O_2$ loaded highly on function 1 (0.90 and 0.82, respectively) and lower on function 2 (−0.39 and 0.37, respectively), whereas RR loaded evenly across the 2 functions (0.58 and 0.70). 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.

Discussion

The primary finding in this study was that when subjects assumed a supine posture or sat quietly on a bench during their interset rest periods, they were able to produce significantly higher work rates (greater joules of work per second) than when they walked slowly during the interset 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 performances 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 interset rest periods during multimodal work-capacity style training sessions such as the interval weight-training protocol.

It has been proposed that the length of interset rest may be individualized by assigning a recovery HR, instead of the traditional method of assigning an interset rest period (25). Under the premise that an optimal recovery point exists, our analyses were performed to determine if superior recovery, defined as greater reductions in HR, RR, and $\dot{V}O_2$ during rest periods (Figures 4–6), was associated with any of the rest strategies (supine, seated, or walking rest). Discriminant function analysis results showed that HR and $\dot{V}O_2$ were the primary variables that differentiated our conditions, and therefore, HR and $\dot{V}O_2$ may indeed be acceptable indicators of recovery as they were lower as a result of supine and seated interset rest. Simply put, higher work rates and lower recovery HR and $\dot{V}O_2$ values were observed during the training sessions that used supine and seated rest compared with the training session that used 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 × 4 seconds sprints, set 25 seconds apart). Spencer et al. revealed that active rest leads to greater performance decrements over 6 maximal cycling sprints: 7.4 ± 2.2% decrement in peak power with active rest compared with 5.6 ± 1.5% decrement with passive rest (28). A follow-up study using 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 interset rest became more intense (29). Both investigations attributed the reduced fatigue indices associated with passive rest to greater phosphocreatine (PCr) replenishment, which they confirmed by muscle biopsy (28). 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 this study indicated that HR and $\dot{V}O_2$ differentiated between the passive (supine and seated) and active (walking) rest strategies. Because 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 with 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. (8) recruited young basketball athletes to complete 10 × 30 m shuttle runs interspersed with 30 seconds of passive rest or active rest, running at 50% of maximal aerobic speed. Results showed that fatigue indices were significantly different ($p \leq 0.05$) between the active and passive conditions (3.39 ± 2.3 and 5.05 ± 2.4, respectively), and on average, athletes were able to run faster when rest was passive rather than active (6.17 ± 0.10 and 6.32 ± 0.10 seconds per sprint shuttle, respectively). Dupont et al. (13) used a protocol where subjects ran as many 15 set-distance sprints as possible interspersed with 15 seconds of active or passive rest. Time to exhaustion between the conditions was significantly different ($p \leq 0.05$), 745 ± 171 seconds during the passive rest condition and 445 ± 79 seconds compared with the active rest condition. Dupont et al. (13) suggest that 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 (17). 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 (14). It is possible that the supine and seated interset rest strategies reduced energy demands more than the walking interset 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 $\dot{V}O_2$, differentiated between the passive (supine and seated) and active (walking) rest conditions. The idea that HR and $\dot{V}O_2$ 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 2, HR would certainly be the more practical method for monitoring recovery than $\dot{V}O_2$. 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 with 190% of resting HR after 2 minutes and 180% of resting HR after 5 minutes of active (walking) rest.

This study has demonstrated that seated or supine rest may allow for superior training session work rates (4.22% greater joules of work per second 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) to augment recovery during exceptionally taxing, mixed modal, work-capacity training sessions. Strength coaches may also opt for more objective measures of recovery (HR for example) to determine if an athlete is fully recovered between sets.

Practical Applications

The use of high-intensity, multimodal, 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 and various athletes. During sessions such as the interval weight-training and those designed to create similar metabolic and muscular demands and ultimately improve work capacity, allowing athletes to lie supine or sit during their interset rest periods may enhance work rate and recovery. Therefore, if strength and conditioning coaches are seeking to optimize work rate, allowing athletes to 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 on work capacity.

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

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