THE EFFECT OF WORKLOAD REDUCTIONS ON ANAEROBIC WORK DURING HGH INTENSITY RUNNING

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ABSTRACT

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Anaerobic capacity has implications in health and sport. Sprint interval training improves anaerobic capacity, aerobic factors, as well as performance performance. Optimal durations for taxing anaerobic capacity have been shown to be 60 seconds, and have been elicited using the Anaerobic Speed Test. In order to maintain this optimal duration for multiple sets, a decreasing workloads method must be used as fatigue increases following each set. These work-loading methods must be compared to determine which protocol allows for the maximum exercise volume to be achieved. The purpose of this study was to compare the effects of three different workload protocols on exercise volume completed during multiple sets of exhaustive anaerobic running on a treadmill. Twelve recreationally active male subjects completed a preliminary session (VO_{2max} test) followed by three sessions of high intensity running on a graded treadmill with three different protocols using parameters adopted from the AST (20% grade, 8 mph to exhaustion). Four sets were completed during each protocol. Protocols included: 1) constant sets (CS): no descending work load in all four sets, 2) descending speed (DS): the speed is decreased by 10% for each subsequent set, 3) descending grade (DG): the grade is decreased by 10% for each subsequent set. Time to exhaustion, work, Stride

frequency, heart rate, and RPE were measure for every set. Total work achieved during the four sets of the DS protocol was significantly higher than both the CS ($p<0.01$) and DG ($p<0.01$) protocols. Time to exhaustion achieved during the 2^{nd}, 3^{rd} and 4^{th} sets of the DS protocol were significantly higher than the 2^{nd}, 3^{rd} and 4^{th} sets of the CS protocol, all under $p<0.01$. Stride frequency during the 3^{rd} set of the DS protocol was significantly lower than the 3^{rd} set of the CS protocol ($p<0.01$). Additionally, stride frequency during the 4^{th} set of the DS protocol was significantly higher than the 4^{th} sets of the CS and DG protocols ($p<0.01$). The longer times per set and greater work achieved during the DS protocol, in comparison to the DG and CS protocols, suggests the potential for a greater training effect. Differences in stride frequency values among the protocols could help explain differences in performance implicating muscle fiber type recruitment and fatigue.

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INTRODUCTION

High levels of aerobic and anaerobic fitness are required in many important occupations and sports in our society. Police officers, firefighters and professional athletes all rely heavily on both aerobic and anaerobic energy systems in their occupations. Additionally, aerobic fitness is a strong predictor of mortality and disease (Willoughby, Thomas, Schmale, Copeland, & Hazell, 2016). Traditional aerobic training methods improve aerobic capacity, however, they usually require a long exercise time (Willoughby et al., 2016). Some individuals find it difficult to complete these exercise programs due to the large time commitment (Willoughby et al., 2016). Anaerobic training methods like sprint interval training (SIT) provide a training option that improves both aerobic an anaerobic fitness while requiring less exercise time (MacDougall et al., 1998, Burgomaster et al., 2008).

Sprint interval training is characterized by repeated bouts of high intensity exercise (Burgomaster, Heigenhauser, & Gibala, 2006). SIT usually consists of all out intensities using continuous motion (running or cycling) with exercise bouts lasting 30 seconds, and high rest intervals of 2.5-4 minutes (MacDougall et al., 1998; Harmer et al., 2000). Predictably, SIT increases anaerobic performance as judged by an increased anaerobic capacity (AC) (McKenna et al., 1993), which is the total amount of work that can be done by anaerobic sources of energy during an exhaustive exercise bout (Green, 1995). Harmer et al. (2000) included seven recreationally active subjects in a seven-week SIT program on the cycle ergometer. Subjects were required to perform 30 seconds of

100% effort sprints, three times a week. Rest intervals remained constant throughout the study while the number of sets per session increased from four to ten. The authors of this study reported a significant increase in anaerobic work capacity completed (10.6%) after training. These results are consistent with the findings from similar research using sprint interval training to increase AC on the cycle ergometer (McKenna et al., 1993; Gibala et al., 2006) (See appendix: A).

Research on SIT utilizing the mode of running is limited, however, Willoughby et al. (2016), examined 12 untrained individuals of various ages in a SIT program on a curved, self -propelled treadmill. Participants completed four to six sets of 30-second all out sprints, three times per week for four weeks. Consistent with previous research in which a different mode was utilized, authors concluded that anaerobic capacity had significantly improved following four weeks of SIT training on the treadmill regardless of age.

Aerobic benefits from SIT utilizing both running and cycling protocols demonstrated in Literature. Significant improvements in VO_{2max} and VO_{2peak} (MacDougall et al.,1998; Willoughby et al., 2016; Burgomaster et al., 2008), increases in aerobic enzyme activity (Burgomaster et al., 2005) and performance in an aerobic time trial (Burgomaster et al., 2006) have been demonstrated following SIT programs.

Although SIT protocols have been shown to increase AC and aerobic performance, 30-second exercise bouts used in SIT are not optimal for fully exhausting AC (Green, 1995). Vandewalle, Kapitaniak, Grün, Raveneau and Monod (1989) demonstrated that 30 seconds of all-out, continuous exercise is an underestimation of AC. This is due to anaerobic metabolism continuing to dominate energy contributions beyond 30 seconds of continuous maximal exercise (Duffield, Dawson, & Goodman, 2005). Further, after 60 seconds of continuous maximal exercise, aerobic energy sources begin to dominate energy contribution and anaerobic capacity is no longer being assessed (Hermansen & Medbø, 1984). Therefore, an optimal exercise bout duration for testing and training AC is the range of 30-60 seconds. Training at this optimal exercise bout duration (30-60 seconds) may also be more effective at improving aerobic factors and performance when compared to 30-second durations. Green (1995) found a positive correlation between maximal work output over a 90-second exercise bout and VO_{2max} ($r=0.81$; $p<0.05$). This supports the notion that the longer the exercise bout, the greater the contribution of aerobic energy and the potentially greater aerobic training effect.

The Anaerobic Speed Test (AST) has been used to elicit exercise durations of 30 to 60 seconds (Cunningham & Faulkner, 1969). Further, the AST has been shown to be a valid (r=.82) and reliable (.97) test for measuring AC (Thomas, Plowman, & Looney, 2002). Developed by Cunningham and Faulkner (1969), the AST involves running on a treadmill at a speed of eight miles per hour and 20% grade to failure (momentary muscle fatigue). Zemková and Hamar (2004) documented that that there were no differences in mean power output production using the mode of treadmill running when compared to cycle ergometry. This suggests that treadmill running is an acceptable substitute for the cycle ergometer even using high intensity exercise. Further, Zemková and Hamar (2004) stated that slightly higher values of lactate were elicited from running when compared to cycling, suggesting a higher metabolic response from this mode of exercise.

Although the AST is an effective way to tax AC, repeated sets should be employed in order to utilize this method in a training program to cause adaptation. Multiple sets are commonly used in research related to resistance training (Willardson & Burkett, 2006) and are recommended by the National Strength and Conditioning Association. Additionally, specific rest intervals are for necessary for stressing the body to produce adaptations (Rahimi, 2005; Faraji, Vatani, & Arazi, 2011). However, a problem is that fatigue causes performance to decrease in subsequent sets given an insufficient rest interval (Willardson & Burkett, 2006; Willardson & Burkett, 2005). Further, maintaining exercise performance over subsequent sets in order to achieve the desired performance goal is paramount (Willardson et al. 2010; Anderson & Kearney, 1982). Therefore, in order to increase work output over multiple sets and maintain rest intervals, a descending work load method may be required (Kraemer, Noble, Clark, & Culver, 1987). Descending resistance protocols have been used to increase volume over multiple sets during resistance training (Willardson et al., 2016). However, there is no research using descending workloads during multiple sets of anaerobic running. Using parameters adopted from the AST, two variables could be manipulated in order to descend the workload. However, it is unclear if there would be differences in work performed using constant sets, descending sets of speed or descending sets of grade during anaerobic running on the treadmill.

Therefore, the purpose of this study was to compare the effects of three different work load methods on work achieved during anaerobic running on an inclined treadmill. It was hypothesized that the Descending protocols (descending sets of speed and descending sets of grade) would elicit greater amounts of work achieved when compared to the constant set protocol during multiple sets of exhaustive running.

METHODS

Experimental Approach to the Problem

In order to study the differences between constant sets, descending sets of speed and descending sets of grade, a total of four visits of incline treadmill exercise were required for all subjects. All sessions were completed on a Quinton Q-stress motorized treadmill (Quinton TM55, Mortara Instrument, Milwaukee, WI). For the first visit, all subjects completed the necessary paperwork (Informed consent form seen in appendix:B), PAR-Q, Medical history form), participated in a familiarization protocol, and completed a Bruce Protocol to determine VO_{2max}. The remaining three sessions were the experimental sessions which consisted of multiple bouts of high intensity running using parameters adopted the AST including: constant sets (CS), descending sets of speed (DS) and descending sets of grade (DG). Subjects completed these sessions in a counterbalanced order. At least 48 hours of rest between sessions was required to ensure adequate recovery. Subjects were encouraged to hydrate and to refrain from eating at least three hours prior to all sessions. A certified strength and conditioning specialist was present for all sessions to ensure all exercise and safety procedures were followed. Subjects were fitted with a RS800CX Polar watch heart rate monitor and a S1 Polar stride frequency measuring device prior to all sessions. After completion of each experimental session, the highest RPE for that session was recorded.

Subjects

The descriptive statistics of 12 recreationally active and healthy male subjects, who participated in the study are seen in Table 1. The main inclusion criterion was that subjects needed to have a $VO_{2\,max}$ classification of “good” or better based on normative data relative to their age (Pescatello & American College of Sports Medicine, 2014). Additionally, subjects were healthy adults ranging from 18-34 years of age with no neurological, orthopedic or cardiovascular disorders. All subjects were recruited from Humboldt State University and from the local community. Subjects were informed on all requirements and pertinent information regarding the study before participating. The protocols of this study were approved by the Humboldt State University Institutional Review Board and subjects were required to sign a consent form in accordance with human subject regulations.

Table 1: Subject characteristics

Subjects	Age	VO_{2max}	Height	Weight	BMI
Mean ± SD	22.7 ± 4.0	57.3 ± 6.0	172.9 ± 6.9	75.9 ± 10.3	25.3 ± 2.3

Procedures

Following completion of paperwork, the first session proceeded with a familiarization protocol that consisted of three short runs (5-10 seconds) on a treadmill at a speed of eight miles per hour and a grade of 20%. Subjects began by placing one foot on each side of the treadmill belt and placed their hands on the hand rail in front of them. After the treadmill was brought up to the appropriate speed, subjects were instructed to stride with one foot for a few seconds before running with both feet. Once the subject was running with both feet and was stable in their stride, they let go of the hand rails. Subjects were told to begin and end each set in this manner in the future sessions. Additional safety precautions were employed by placing a large pad on the ground behind the treadmill. After the familiarization protocol, a Bruce Protocol VO_{2max} (Pescatello & American College of Sports Medicine, 2014**)** test was completed and was the conclusion of the first session.

The second, third and fourth sessions were the experimental sessions and required subjects to complete four exhaustive exercise bouts (sets) on the treadmill, utilizing the CS, DS, and the DG protocols in a counter balanced order. During the CS session, the speed and grade remained constant (eight miles per hour and 20% grade) for all four sets. During the DS session, the speed was reduced by 10% for every set after the first, while the grade remained constant for all four sets. During the DG session, the grade was reduced by 10% for every set after the first, while the speed remained constant for all four sets.

A standard warmup consisting of five minutes of treadmill running at 6.5 mph was completed preceding all three experimental sessions. All subjects began and ended each set as they did during the familiarization session with hands on the safety rail and feet straddling the belt. Stop watches for each bout started timing when the subjects' hands let go of the handrails as they began to run. Timers for each exercise bout stopped when a subject's hands grab the handrail in front of them. As an additional safety precaution, a large pad was placed behind the treadmill in the unlikely instance of a subject falling form the treadmill.

Rest times between sets were calculated after the set was complete with a work to rest ratio of 1:5, as recommended by the National Strength and Conditioning Association. Active rest was employed between all exercise bouts by subjects walking at a speed that corresponding to 27% of VO_{2max} on a separate treadmill to maximize performance in subsequent sets (Spierer, Goldsmith, Baran, Hryniewicz & Katz, 2004). Once the subject completed a set, they stepped off of the exercise treadmill and stepped onto an adjacent recovery treadmill until their next set.

Upon completion of each of the experimental sessions, subjects walked on a treadmill in order to recover and allow the heart rate to slowly decrease. Subjects initial recovery speed was the same speed that was used during their inter-set rest and was decreased every 2 minutes until the heart rate was below 120 BPM (Pescatello & American College of Sports Medicine, 2014). Next, subjects were given the option to lay down with their feet elevated to increase circulation.

Post exercise nutrition was provided to subjects following all three experimental sessions in the form of 14 fluid ounces of Nesquik brand chocolate milk. Macro-nutrients of this post workout nutrition were approximated to be: 50 grams of carbohydrates, 16 grams of protein, and 2.5 grams of fat. This Post exercise nutrition was chosen because it offers an approximate 3:1 ratio of carbohydrates to protein, which is necessary for repletion of glycogen and muscle repair (Burke, 1997). Subjects consumed this chocolate milk within 20 minutes after the experimental session ended.

Measurements

The main measurement being recorded in this study is the amount of time (seconds) that subjects are able to remain on the treadmill for each exercise bout. Using the time, the speed, grade, and the body mass of the subject, work can be calculated for each exercise bout using the equation:

$$\mathrm{Work(kJ)} = \mathrm{Body\ mass(N)} \times \mathrm{speed}(\mathrm{m} \cdot \mathrm{s}^{-1}) \times \mathrm{Time(s)} \times \%\ \mathrm{Grade}$$

(Beam, 2011)

The measure of work is appropriate for this study because it allows for a comparison between the three protocols and individuals sets within each protocol. In addition, heart rate, stride frequency and maximal RPE per session were recorded.

Statistical Analysis

All statistical computations were performed using STATISTICA version 7.1 software (StatSoft, Inc., Tulsa, OK). A repeated measures, two factor analysis of variance (ANOVA) was used to compare the differences in protocols (CS, DS and DG) and the 4 sets for each variable; including time to exhaustion , RER, Stride frequency, heart rate and RPE. Total work values were compared using a one factor ANOVA. When a significant F-ratio was found, a Tukey's Honestly Significant Difference test was performed. Statistical significance set at $p \leq 0.05$. All data are shown as the mean ± SD.

RESULTS

Environmental Variables

There was no difference ($p<0.05$) in the ambient temperature, relative humidity or Barometric pressure during the three conditions. All Testing was done in the same controlled environment for every session (Humboldt State University Human Performance Lab).

Time to Exhaustion

The average time to exhaustion (seconds) decreased per set ($p<0.01$) and varied among the protocols ($p<0.01$), Figure 1. The protocol x set interaction effect was significant ($p<0.01$). In the DS protocol, the average time to fatigue in the 2nd set (42.8±9.2) was significantly higher than the 2nd set of the CS protocol (33.2±9.4) ($p<0.01$); the 3rd set (42.1±11.4) was significantly higher than the 3rd set of the CS Protocol (24.0±8.1) ($p<0.01$); the 4th set (50.6±16.1) was significantly higher than the 4th set of both the CS (20.6±7.6) and DG (41.3±12.3) protocols ($p<0.01$). In the DG protocol, the average time to fatigue in the 2nd set (39.8±8.1) was significantly higher than the 2nd set of the CS protocol (33.2±9.4) ($p<0.01$); the 3rd set (37.3±8.9) was significantly higher than the 3rd set of the CS protocol (24.0±8.1) ($p<0.01$); the 4th set

(41.3±12.3) was significantly higher than the 4th set of the CS (20.6±7.6) protocol but significantly lower ($p<0.01$) than the 4th set of the DS protocol (50.6±16.1)(Figure 1).

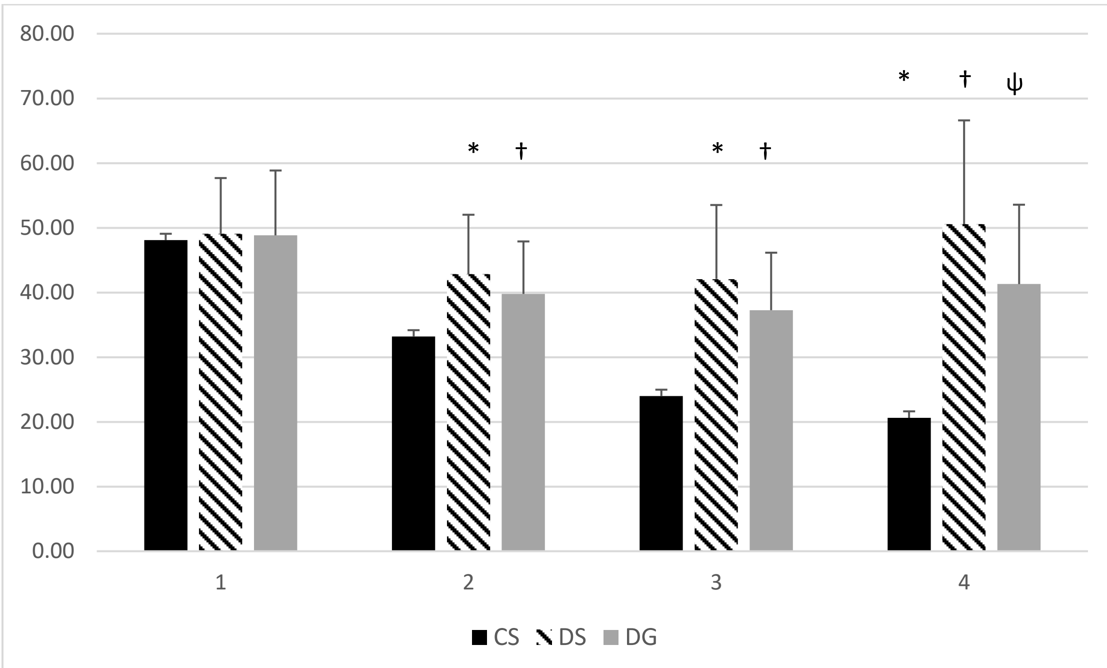

Figure 1: Time to Exhaustion

Work

There were significant differences in mean work between CS, DS and DG protocols (Figure 2). Mean work (kJ) of the DS protocol (83,657±22,875) was significantly higher ($p<0.01$) than both the CS protocol and the DG protocol

(67,150±20,922 and 76,207±17,960, respectively). Additionally, the mean work of the DG protocol was significantly higher that the CS protocol.

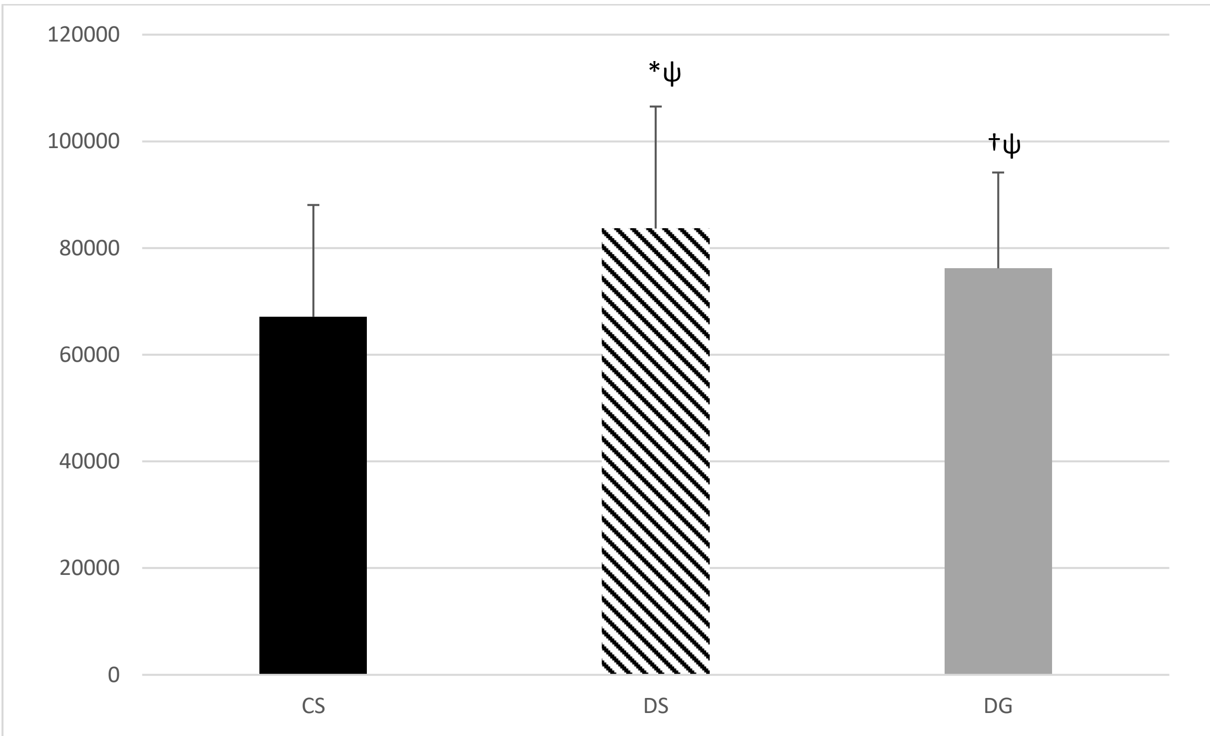

Figure 2: Total Work

Stride Frequency

The average stride frequency (steps by one foot/min) varied among the protocols ($p<0.01$), and decreased per set ($p<0.01$). Average stride frequency during the CS protocol (96.6±0.4) was significantly higher than in both the DS (91.9±4.4) and the DG

(92.7±2.6) protocols, both under $p<0.01$ conditions. In the CS protocol, the average stride frequency in the 3rd set (96.2±3.6) was significantly higher than the 3rd set of the DS protocol (89.6±4.2) ($p<0.01$); the 4th set (96.8±3.7) was also significantly higher than the 4th set of the DS protocol (87.6±4.3) and the 4th set of the DG protocol (89.5±6.5), both under $p<0.01$ conditions (Figure 3).

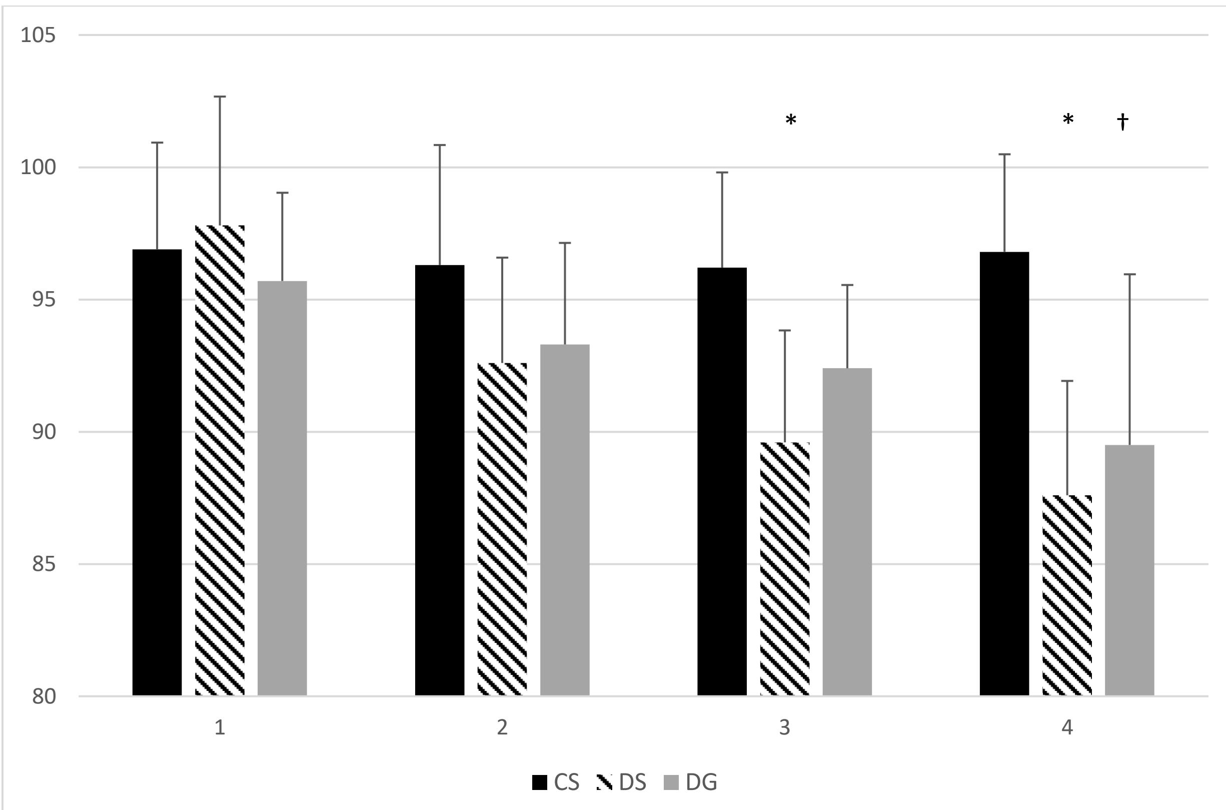

Figure 3: Stride Frequency

Heart rate

There were no significant differences in average heart rate ($p=0.23$).

RPE

There were no significant differences in average RPE ($p=0.07$).

DISCUSSION

The current study investigated the effects of load reductions during exhaustive treadmill running on work completed. The results confirm that reducing the workload (speed or grade) in subsequent sets increases time to fatigue and total work, while having an effect on stride frequency. Subjects time to fatigue and work completed during the first set of each protocol (AST, 8mph and 20% grade) can be assessed using unpublished AST normative data by Calmelat (2000). On average, subjects in the current study completed an average of 48.3±9.6 seconds and 25,789±6,460 kJ of work when completing the AST. According to the normative data, this would be classified as "Above average" (approximately 88th percentile) and "well above average" (approximately 93rd percentile), respectively.

The size principle states that motor units are recruited in order of their recruitment thresholds (Baechle & Earle, 2000). This means that slow twitch (ST) muscle fibers are recruited first, followed by fast twitch (FT) muscle fibers. However, given a sufficiently heavy workload in resistance training, both ST and FT muscle fibers are recruited to assist with muscle contraction (Rahimi, 2005). Shortly after FT muscle fibers become fatigued, the exercise bout ends because the slow twitch muscle fibers are not able to maintains muscle contraction at high intensities (Sale, 1987). Fast Twitch muscle fiber fatigue is due their reliance on the phosphagen and glycolytic energy systems for ATP re-synthesis, causing protons to accumulate at a higher rate during intense exercise (Rahimi, 2005). The accumulation of protons would lead to faster rates of fatigue due to a decrease in intracellular pH levels (metabolic acidosis), causing fatigue (Robergs et al., 2004).

Metabolic acidosis is caused when proton accumulation exceeds the rate at which protons can be buffered or removed. There are multiple molecules and ions in the muscle and blood that contribute to buffering capacity and thus delay fatigue. Bicarbonate ions, amino acids, inorganic phosphate molecules, creatine phosphate molecules and lactate molecules all have the potential to absorb protons during intense exercise. The greater buffering capacity, the greater the body's ability to tolerate proton release from intense exercise (Robergs et al., 2004), which comes into play repeatedly if multiple sets with limited rest intervals are used.

When multiple sets of exhaustive exercise are used, repeated exhaustion and recovery would occur. Inter-set recovery is a complicated topic especially when both aerobic and anaerobic energy systems are heavily involved in the exercise (Jones et al. 2010). However, it should be stated that rest interval length dictates the amount of recovery achieved (Weiss, 1991) and therefore influences performance in subsequent sets. This is especially true within FT muscle fibers as they are less oxidative (Rahimi, 2005; Sale, 1987). Conversely, ST muscle fibers are more oxidative and would require less recovery time to perform (Weiss, 1991).

In the current study, both descending workload protocols (DS and DG) elicited significantly greater amounts of anaerobic work when compared to the Constant protocol (CS). Further, the DS protocol elicited a significantly greater amount of anaerobic work when compared to the DG protocol. Potential reasons for this can be explained through the phenomenon of FT muscle fiber recruitment in relation to rest intervals. Specifically, the descending workload protocols elicited greater amounts of work because reliance on FT muscle fibers was less or delayed due to the slightly lower work load required. Conversely, during the CS protocol, the work load remained the same for all four sets. Thus, a greater amount of FT muscle fibers would have caused a faster fatigue rate due to a greater accumulation of protons causing metabolic acidosis and ending the set. Further, rest intervals in subsequent sets using the CS protocol were shorter because of 1 to 5 work to rest ratio based on time. This would allow for less recovery time and therefore less buffering time between sets. In this situation, FT muscle fibers may remain in a fatigued state, causing performance to decrease in subsequent sets. Therefore, within the context of the protocols used in this study, a greater amount of work completed during the descending sets, corresponded to less or delayed reliance of FT muscle fiber recruitment, resulting in a slower fatigue rate. Further, the longer rest intervals during the descending sets contributed to the greater performance in subsequent sets.

Recent research has used load reductions in resistance training (Willardson et al., 2012; Willardson et al., 2010). Willardson et al. (2010) found that greater repetitions (amounting to a greater volume) were achieved in subsequent sets of back squat when the resistance was reduced by 10 and 15% when compared to constant resistance sets. This is due to a greater FT muscle fiber recruitment during higher resistance sets resulting in a faster fatigue rate (Sale, 1987). Further, load reductions of 15% yielded more repetitions than load reductions of 10%. The authors alluded to this to this being dependent training background of the individual. Specifically, if a subject had a background of lifting with moderate to high repetition sets and short rest intervals, they would be more adapted to exercise that causes fatigue (Kraemer et al., 1987). In the current study, significantly greater set times (corresponding to greater amounts of anaerobic work) were completed during the descending workload protocols (DS, DG) when compared to the constant workload protocol (CS). Similar to previously discussed research, this is likely due to a greater FT muscle fiber recruitment during constant sets. An additional key finding from the current study was that a significantly greater amount of anaerobic work was completed during the DS protocol when compared to the DG protocol. This sheds light on the relationship between reductions in speed vs. reductions in grade. Specifically, it appears that within the context of the parameters of this study, a greater amount of FT muscle fibers are recruited from the higher speed aspect than the higher grade aspect.

Stride frequency was not significantly different between the four sets within the CS protocol. However, in the DS and DG protocols stride frequency decreased in subsequent sets and was significantly different from the CS in the 3rd and 4th sets. Further, the DS was significantly lower that the 4th set of the DG. There appeared to be an inverse relationship between anaerobic work achieved and stride frequency per set. Specifically, for a given set, the greater the work, the lower the stride frequency (Figure 3). Nyberg (2016) showed that muscle glycogen is depleted preferentially from FT muscle fibers during intense exercise, supporting the previously discussed notion that high intensity exercise recruits a greater FT muscle fiber recruitment. In the current study, stride frequency decreased as work achieved per set increased. This suggests a relationship between stride frequency and FT muscle fiber recruitment, such that the lower the stride frequency for a given set, the less FT motor unit recruitment. Studies using the mode of cycling have found energetically optimal stride frequencies during submaximal exercise (Sacchetti, Lenti, Di Palumbo, & De Vito, 2010; Umberger, Gerritsen & Martin, 2006). However, the exercise intensities used in these studies would have relied on predominately on aerobic metabolism, which is associated with the use of fatigue resistant, ST muscle fibers (Sacchetti, 2010). Given the energetic and mechanical differences between slow twitch and fast twitch muscle fibers (Bottinelli & Reggiani, 2000), optimal stride frequencies at anaerobic exercise intensities, which are associated with FT muscle fibers, may be more difficult to discover.

CONCLUSIONS

Descending workload sets during anaerobic treadmill running resulted in greater total work achieved when compared to constant workload sets. This was likely due to less or delayed reliance of FT muscle recruitment, resulting in a slower fatigue rate and the relatively longer rest intervals allowing for greater recovery. Additionally, the DS protocol elicited a greater amount of total work than the DG protocol, suggesting that a greater amount of FT muscle fibers are recruited from the higher speed aspect of this exercise compared to the higher grade aspect. The stride frequency of a given set appeared to have a negative relationship with anaerobic work completed during a given set, suggesting that stride frequency influences performance. There is little research relating stride frequency and FT motor unit recruitment to performance during high intensity running suggesting a future research path.

Practical Applications

The findings of this study could improve the quality of exercise focusing on anaerobic capacity and the associated aerobic fitness improvements. This study manipulated parameters of the AST to elicit exercise times to effectively tax anaerobic capacity. Coaches and trainers could use this information to manipulate an exercise program to achieve the greatest amount of work to elicit a specific exercise goal or variable. Given the reliance of both anaerobic and aerobic metabolism (and their associated muscle fibers) during the protocols used in this study, these findings are applicable to many sports in which both energy systems are required. Training programs could be made using similar protocols to increase factors including anaerobic work capacity, fast or slow twitch muscle fiber recruitment and buffering capacity in the hopes of increasing performance in the applicable sports and occupations.

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APPENDIX A: LITERATURE REVIEW TABLE

Table 2: Literature review table

Study	Mode	Number of Sets	Duration of Sets (min)	Study length/ Frequency/week	Measure that Increased
1	Cycling	4-10	4-2.5	7 weeks/ 3x per week	Anaerobic capacity Aerobic capacity
2	Cycling	4-10	3-4	7 weeks/ 3x per week	Anaerobic capacity -
3	Cycling	4-10	4-1	7 weeks/ 3x per week	Anaerobic capacity -
4	Cycling	4-6	4	2 weeks/ 3x per week	Anaerobic capacity Aerobic capacity
5	Cycling	4-7	4	2 weeks/ 3x per week	Aerobic capacity -
6	Cycling	4-6	4	2 weeks/ 3x per week	Aerobic capacity -
7	Cycling	4-6	4.5	6 weeks/ 3x per week	Aerobic capacity -

Study	**Mode**	**Number of Sets**	**Duration of Sets (min)**	**Study length/ Frequency/week**	**Measure that Increased**
8	Running	2	10	8 weeks/ 3-4x per week	Anaerobic capacity -
9	Running	4-6	5	7 weeks/ 3x per week	Anaerobic capacity Aerobic capacity
10	Running	4-6	5	4 weeks/ 3x per week	Anaerobic capacity Aerobic capacity
11	Running	Until fatigue	unknown	6 weeks	Anaerobic capacity -
12	Running	1	Not needed	1 session	N/A

APPENDIX B: INFORMED CONSENT FORM

Humboldt State University Department of Kinesiology

Consent to Participate in Research

The Effect of Workloads on Work and Mean Power Output during Repetition Training

Purpose and General Information

You are being asked to participate in a research study conducted by Taylor Kennon (Principle Investigator)-and Young Sub Kwon, Ph.D. (supervising staff member). The purpose of this research is to compare the effects of two different work loading methods on work and mean power output during repetition training on a treadmill. This form will explain the study, including possible risks and benefits of participating, so you can make an informed choice about whether or not to participate. Please read this consent form carefully. Feel free to ask the investigators or study staff to explain any information that you do not clearly understand.

What will happen if I participate?

This proposed project will be developed based on science and theory in the fields of Exercise Science. All testing will take place in the Human Performance Lab (HPL) and the indoor training facility at Humboldt State University (HSU). For to all sessions, you will be asked to refrain from eating for at least three hours prior. If you agree to be included in this study, you will be asked to read and sign this consent form. Upon signing, the following will occur:

- The study will be described in detail and your questions will be answered, then you will fill out all pre-screening forms in a private room in the Human Performance Lab. You will be introduced to the study, the purposes and procedures, and the risks and benefits. Following this introductory information, a Health History and Activity Questionnaire will be completed. The investigators will provide a detailed description of the protocol both verbally and in writing. You will be encouraged to ask questions.
- The period of this study is from May 1, 2017 through September 1, 2017. Your cardiorespiratory fitness and anaerobic capacity will be assessed in this time period. Cardiorespiratory endurance assessments in a laboratory test and field test will be completed, and anthropometric assessments will be completed.
- The risk of breaching confidentiality will be minimized by using only professional personnel to perform all study activities, identification numbers instead of names, and rooms at times when others will not need access. A private room is available for discussion and testing, and all study data will be kept in a

file cabinet in the P.I.'s office. All data will continue to be coded so that your identity is not revealed throughout the duration of the research.

- All participants will be required to complete four sessions. Each session will last for approximately 60-75 minutes

What are the possible risks or discomforts of being in this study?

Every effort will be made to protect the information you give us. Every effort will also be made to minimize any risk by allowing proper warm-up. As with any research, there may be unforeseeable risks. These risks include muscle soreness, muscle fatigue, and common injuries and issues associated with exercise.

For more information about risks, contact the Principal Investigator,

Taylor Kennon (707) 834-1966

tkk99@humboldt.edu

How will my information be kept confidential?

Your name and other identifying information will be maintained in files, available only to authorized members of the research team for the duration of the study. For any information entered into a computer, the only identifier will be a unique study identification (ID) number. Any personal identifying information and record linking that information to study ID will be retained for 3 years after the study is completed. After this 3-year period, all digital and hard copies will be destroyed or deleted. Information resulting from this study will be used for research purposes and may be published; however, you will not be identified by name in any publications.

Will I be paid for taking part in this study?

There will be no compensation.

Can I stop being in the study once I began?

Yes, you can withdraw from this study at any time without consequence.

Right to Withdraw

Your authorization for the use of your health information shall not expire or change unless you withdraw or change that information. Your health information will be used as long as it is needed for this study. However, you may withdraw your authorization at any time provided you notify the Humboldt State University investigators in writing. To do this, please contact:

Taylor Kennon

(707) 834-1966

tkk99@humboldt.edu

Please be aware that the research team will not be required to destroy or retrieve any of your health information that has already been used or shared before your withdrawal is received.

What if I have questions or complaints about this study?

If you have any questions, concerns, or complaints about this study, please contact Young Sub Kwon, Ph.D. (faculty adviser) at 707.826.5944 from Monday thru Friday 8am - 5pm. (or at 505-350-4345 after hours).

If you would like to speak with someone other than the research team,

If you have any concerns with this study or questions about your rights as a participant, contact the Institutional Review Board for the Protection of Human Subjects at irb@humboldt.edu or (707) 826-5165.

You may email the Institutional Review Board (IRB) at irb@humboldt.edu. The IRB is a group of people from Humboldt State University and the community who provide independent oversight of safety and ethical issues related to research involving human subjects.

Refusal to Sign

If you choose not to sign this consent form, you will not be allowed to take part in the project.

Liability

No compensation for physical injury resulting from participating in this research is available.

Consent and Authorization

You are making a decision whether to participate in this study. Your signature below indicates that you read the information provided (or the information was read to you). By signing this Consent Form, you are not waiving any of your legal rights as a research subject.

Sincerely,

Taylor Kennon

I have read and had the opportunity to ask questions and all questions have been answered to my satisfaction. By signing this consent form, I agree to participate to this study and give permission for my health information to be used or disclosed as described in this consent form.

A copy of this consent form will be provided to me.

Signature of participant Date