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The Effects of High-Intensity Exercise on a 10-Second Sprint Cycle Test

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ABSTRACT

Nine men (25.11 ± 1.16 years) performed 3 different test sessions. In the control session, subjects performed a 10-second sprint cycle test and 1 repetition maximum (1RM) in the back squat. The 5-minute test session consisted of 10 × 1 repetition in the parallel back squat exercise at 90% of their 1RM, 5 minutes of rest, and then a 10-second sprint cycle test. The 20-minute test session consisted of the same test protocol as the 5-minute test session except that the subjects rested for 20-minutes prior to the sprint cycle test. Significant differences were found in average power and average power relative to body weight ($F = 5.684$, $p = 0.014$, and $F = 1.258$, $p = 0.006$, respectively) for the 5-minute test session. The authors conclude that this particular squat protocol could have a potential carry-over effect into improvements in 100-m sprint times when performing the squats 5-minutes prior to performance.

Key Words: anaerobic power, performance, resistance exercise, cycle ergometry

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Introduction

All athletes want to improve their performances. This can be done by improving the quality of their training and/or using ergogenic aids. Another possible way of improving performance is through the athlete's warm-up. Warming up can be active, passive, submaximal, maximal, general, or specific. Examples of an active warm-up include running, jogging, and swimming. Passive warm-up could be a hot bath or shower. General warm-up could also include stretching. Specific warm-up would be performing an activity that is similar to the performance. A warm-up could include any combination of these types. Research appears to be inconclusive as to whether or not warming up improves performance (6–9, 11, 12, 15, 16, 18, 22, 23). The reason for this inconclusiveness could be due to the fact that there are so many different ways to warm up. Some methods use stretching, whereas others do not. Various methods of warm-up differ in the intensity and duration.

Intensity can be defined as power output (24). A few studies have shown that a high-intensity warm-up prior to an explosive event, primarily a jumping event, can improve performance (2, 9, 21, 27). Empirical data suggests that a heavy resistance warm-up protocol enhances performance in strength and power events, such as sprinting. Some elite sprinters have performed 90% of their 1 repetition maximum (1RM) for 5 sets of 1 repetition in the back squat exercise with 2 minutes rest between sets and 20 minutes prior to competition, and coaches have reported an improved performance due to this warm-up protocol (20). Pfaff (20) has reported elite sprinters using this protocol with the result being an improved sprinting performance. Gullich and Schmidtbleicher (9) reported that vertical jump height was increased with the use of maximum voluntary contractions (MVCs) 5 minutes before jumping. They associated this improved vertical jump performance with an increased neural activation and noted that some individuals showed an increased neural activation up to 20 minutes after the completion of the MVCs (9). The authors of this investigation wished to determine if the protocol used by these elite sprinters was valid and to see how long the effect would last if it was present. Therefore, the purpose of this study was to investigate 2 research questions: (a) Is there an effect of a heavy resistance squat warm-up protocol on a maximal power test consisting of a 10-second sprint cycle test? And (b) does the effect last 20 minutes after completing the warm-up protocol? The authors' hypotheses are that a heavy-resistance squat warm-up protocol will improve maximal power, and the effect will last 20 minutes. A 10-second sprint cycle test is similar to a 100-m sprint because the energy demands are the same. Both events rely heavily

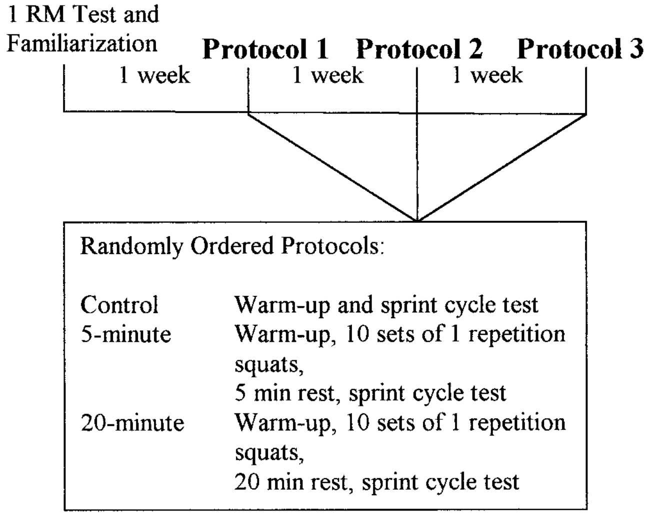

Figure 1. Time line of project design.

on the phosphagen energy system as their predominate source of adenosine triphosphate (ATP).

Methods

Subjects

Nine men ($n = 9$) between the ages of 23 and 30 years participated in this study. Subjects were recruited from the Department of Human Movement Sciences and Education at The University of Memphis. The requirements for being a subject in this study were as follows: (a) ability to squat at least 1.5 times his body weight, and (b) systematic weight training involvement for no less than the previous year. The study was approved by the Institutional Review Board at The University of Memphis. Each subject completed a medical history and received both a verbal and written description of the study. Written informed consent also was obtained from each subject. Each subject completed a weight training history questionnaire. Body weight, percent fat, and lean body weight was assessed for each subject by using a 7-site skinfold test (14) and equation for body density (3). Four different training sessions were held. Figure 1 shows a time line and the description of the design of the study.

Procedures

On completion of the informed consent, medical history, and weight training history questionnaires, each subject participated in an orientation session. In this session, each subject performed a 1RM. This is defined as the maximum amount of weight a person can lift for only 1 repetition. The exercise the subject performed is a high bar parallel back squat using a regular Olympic barbell. This exercise is described in detail elsewhere (4). Parallel is defined as the top of the thighs being parallel to the floor (24). For safety reasons, a spotter was used. After determining the 1RM, each subject performed a 10-second sprint cycle test

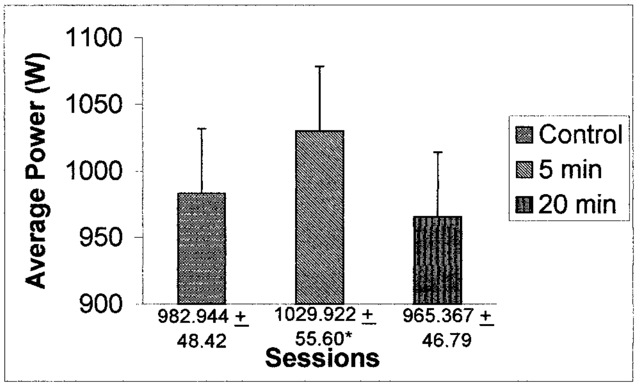

Figure 2. Average power for C, 5- and 20-minute sessions. The asterisk indicates $p < 0.05$ vs. controls. Means and standard errors are listed. Observed power was 0.788.

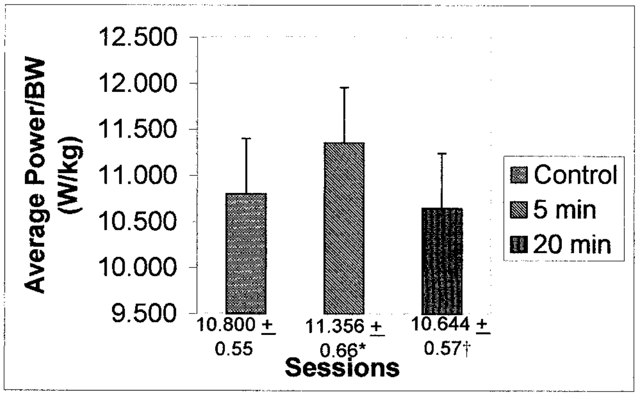

Figure 3. Average power/body weight (BW) for control, 5- and 20-minute sessions. The asterisk indicates $p < 0.05$ vs. controls. The dagger indicates $p < 0.01$ vs. 5 minutes. Values are listed in means and standard errors. Observed power was 0.882.

for the purposes of familiarization. Also, each subject performed the 10-second sprint cycle test in the same manner as they did in the latter sessions. All subjects were verbally encouraged to perform to the best of their ability. All sprint cycle tests were started with a flying start. This means that each subject began cycling at a self-selected pace prior to the resistance load being electronically added to the cycle ergometer. Three seconds prior to the initiation of the load, each subject began to pedal as fast as he could. The 10-second sprint cycle test was chosen as the testing modality because of the amount of data that can be collected as well as its similarities to the 100-m sprint.

The next 3 test sessions were in a randomized order for each subject. The randomization of sessions was balanced so that an equal number of subjects participated in each order of the sessions. Prior to the beginning of each session, each subject performed a warm-up that was specific to the test session. On the test session where only the sprint cycle test was performed, subjects cycled on a stationary cycle ergometer

Table 1. Age, mean body weight, lean body weight, and height for subjects. Values are listed in means and standard errors.*

Age (yrs)	BW (kg)	LBW (kg)	Height (m)	1RM (kg)	1RM : BW
25.11 ± 1.16	92.18 ± 5.14	77.09 ± 3.00	1.73 ± 0.02	175.75 ± 7.76	1.9

* BW = mean body weight; LBW = lean body weight; 1RM = 1 repetition maximum.

Table 2. Results of dependent measures and observed power. Means and standard errors are listed.*

	Control	5 minutes	20 minutes	Power
Peak power (W)	1,152.78 ± 59.05	1,197.444 ± 62.43	1,173.11 ± 59.17	0.559
Peak power/BW (W/kg)	12.68 ± 0.68	13.144 ± 0.66	12.91 ± 0.66	0.509
Peak power/LBW average	14.99 ± 0.58	14.44 ± 1.14	15.23 ± 0.55	0.114
Power/LBW (W/kg)	12.60 ± 0.53	13.08 ± 0.59	12.781 ± 0.47	0.340
Fatigue index (%)	40.000 ± 5.65	28.667 ± 2.75	33.111 ± 5.47	0.241

* BW = mean body weight; LBW = lean body weight.

for 4 minutes at 10% of the workload that was used for the actual resistance for the sprint cycle test. During the last minute of the warm-up, each subject performed a 1- to 2-second maximal sprint every 15 seconds. This warm-up protocol was similar to the warm-up of sprinters immediately prior to competition. For the test sessions where the subjects performed the squat exercise first, subjects performed 1 × 10 repetitions at 40% 1 RM, 1 × 10 at 50% 1RM, 1 × 5 at 60% 1RM, 1 × 3 at 75%, and 1 × 1 at 90% 1RM, with 3–5 minutes of rest between each set. At the completion of this warm-up, subjects rested 3–5 minutes before beginning the squat protocol. Stretching was not permitted because of the possibility of its interference with force (16, 17) and, consequently, power output.

In the control session, each subject performed a sprint cycle test. This is an ''all-out'' sprint for 10 seconds against a set resistance on a stationary cycle that is interfaced with a computer. The resistance used was 5.8 $J \cdot revolutions^{-1} \cdot kg^{-1}$ (1). Subjects began cycling as fast as they could 3 seconds prior to the beginning of the test and the addition of resistance to the cycle ergometer.

In the 5-minute test session, each subject performed 10 × 1 at 90% 1RM with 2 minutes rest between sets. Pfaff (20) has shown that multiple sets of 1 repetition at 90% 1RM produce an improved sprint time. The protocol we used is a modification of Pfaff's (20). At the conclusion of the 10 sets of squats, the subject rested for 5 minutes before performing a 10-second sprint cycle test that was described in the control test session. The 20-minute test session was the same as the 5-minute test session with the exception that the subjects rested 20 minutes at the conclusion of the back squats.

Statistical Analyses

SPSS was used to run a repeated measures multivariate analysis of variance (MANOVA) and pair wise comparisons to assess statistical differences between the control, 5-minute, and 20-minute sessions on peak power, peak power relative to body weight, peak power relative to lean body weight, mean power, mean power relative to body weight, and mean power relative to lean body weight. A univariate analysis of variance was used to assess statistical differences for fatigue index among the test sessions. The alpha level was set to 0.05. The results of this investigation were reported using means and standard errors ($\bar{X} \pm SE$).

Results

Descriptive statistics of the subjects are listed in Table 1. The means and standard errors for all dependent measures are listed in Table 2. Figures 2 and 3 show that average power and average power relative to body weight were significantly different for the 5-minute test session when compared with the control and 20-minute test session ($p = 0.012$ and 0.008, respectively). Univariate tests indicate similar possible trends in peak power ($p = 0.058$) and peak power relative to body weight ($p = 0.075$).

Discussion

The present study was aimed at investigating the effects of a heavy resistance exercise on a sprint cycling test because of it is similarities to a 100-m sprint. Because of the design of the study, fatigue was a possible contributing factor. The rest intervals may not have been long enough to allow for sufficient ATP resynthesis or recovery of the nervous system. Although pilot work in this area showed that fatigue would not play a role, research has shown that fatigue can vary greatly from 1 individual to the next (5). There were no significant differences between any of the conditions in terms of peak power. Other studies have shown that fatigue results in a decrease in force or power output (5, 10, 19). Because peak power and fatigue index did not significantly decrease when comparing the control session with either the 5-minute or 20-minute conditions, it is reasonable to assume that the back squat exercise did not elicit short-term anaerobic fatigue such as that used by 100-m sprinters. The 2 minutes of rest in between sets during the back squat exercise as well as the 5 and 20 minutes of recovery appears to have been enough time to allow for ATP resynthesis.

Although many studies have investigated the effects of a high-intensity exercise on vertical jumps (2, 9, 20, 27) or horizontal jumps (25), to the authors' knowledge no study has looked at the effects of a heavy-resistance exercise as a way to improve performance in a sprint cycle test. One study did investigate the effects of 15 minutes of treadmill running (30 seconds on, 20 seconds off) on Wingate anaerobic test performance. The results of the study did show a mean power improvement of 7% in a group of 7- to 9-year-old boys (13). However, the majority of the studies in this particular area of research look at improvements on vertical jump. A 10-second sprint on a cycle might seem incomparable to a vertical jump; however, the metabolic demands are somewhat similar. An explosive event such as a vertical jump or a 10-second sprint utilize the phosphagen system as their predominate source of energy. The duration of the sprint cycle test, 10 seconds, was chosen because that is the approximate amount of time it takes to sprint 100 m as well as the typical duration for the phosphagen system to be used predominately. The power measures for a sprint cycle test and a vertical jump are different. Also, a vertical jump is not cyclic but is 1 explosive repetition, whereas the sprint cycle test is cyclic and lasts 10 seconds. Therefore, the 10-second sprint cycle test has a greater anaerobic endurance component than a vertical jump. This does help to explain why the peak power for the vertical jump is typically greater than the peak power for the 10-second sprint cycle test.

This particular warm-up protocol with 5 minutes rest prior to a high-intensity event such as sprinting improves the mean power output. Maintaining a higher average power in a sprinting event translates into running faster. More force is translated to the ground with each foot contact. The net result is a more forceful push down the track or on the down phase of a pedal cycle and a faster sprint time, as well as the ability to maintain power over the entire 10 seconds of the sprint. This type of warm-up protocol would be most beneficial to track and field sports, particularly the sprinting events and jumping events. Typically, the sprinter who maintains his or her velocity or slows down the least wins the race. This ability to maintain velocity particularly affects mean power relative to body weight. The sprinter with the higher mean power relative to body weight usually wins the race.

The alternative hypothesis that there would be an effect that would last 20 minutes was rejected. The 20-minute condition was not significantly different from the control session. However, it was significantly lower than the 5-minute condition. This means that the posttetanic potentiation had already occurred during the 5 minutes after the squats and returned to baseline 20 minutes after the squats.

In several research studies, electromyography (EMG) has been used to assess the muscle activity. Hoffman reflex (H-reflex) has been used to measure neuromuscular activation. When using the H-reflex, electrodes are placed on the nerve and the muscle it innervates. When the nerve is stimulated with a low frequency, the excitation potential travels via the efferent pathway to the motor end plate in the muscle and, at the same time, via the afferent pathway to the spinal cord. Once the excitation potential reaches the spinal cord, the stimulus is transferred monosynaptically to the motor end plate of the muscle. Therefore, the stimulus triggers 2 responses. The muscle generates the *M* wave after about 5 msec, and the H-reflex generates the *H* wave after about 30 msec. The peak-to-peak amplitude of the H-wave reflects the number of motor units activated (9). During constant stimulation, if the H-wave varies, this indicates a changed activation pattern (9).

If a nerve to the muscle is tetanized using a high-frequency current, both the tendon reflex and the H-reflex are potentiated. This potentiation results in 2 responses, the postactivation depression and the posttetanic potentiation. Postactivation depression develops immediately after muscle relaxation and usually lasts 10–60 seconds (26). Posttetanic potentiation develops after several seconds and can last 1–5 minutes (26).

In conclusion, the use of 10 sets of 1 repetition with 2 minutes in between sets and 5 minutes rest prior to a 10-second sprint cycle test increases the mean power and mean power relative to body weight. This effect seems to disappear when allowing 20-minutes rest in between the back squats and the sprint cycle test. Therefore, coaches appear to have a good idea with this acute power enhancement. However, the effects may not last 20 minutes, and thus coaches may need to adjust the timing of this protocol to be somewhat closer to the beginning of the sprinting event.

Practical Applications

Performing 10 sets of 1 repetition with 2 minutes rest increases average power and average power relative to body weight. This acute enhancement lasts at least 5 minutes and less than 20 minutes. Applying this high-intensity warm-up becomes a timing issue. This could be useful in events when the exact starting time is known, such as in track and field. Care must be taken to avoid fatiguing the athlete. Other protocols may also prove to be effective.

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