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Changes in Power Assessed by the Wingate Anaerobic Test Following Downhill Running

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Abstract. Nottle, C., and K. Nosaka. Changes in power assessed by the Wingate Anaerobic Test following downhill running. *J. Strength Cond. Res. 21(1):145–150. 2007.*—Few studies have examined the effects of eccentric exercise-induced muscle damage on power despite power being a key performance variable in a number of sporting events. The aim of this study was to examine changes in anaerobic power (30-second Wingate Test), isometric strength of the knee extensors and flexors, muscle soreness, and plasma creatine kinase (CK) activity following downhill running. Eight men performed a 40-minute downhill (−7%) run on a treadmill, and measurements were taken on 6 occasions (2 baseline and 0.5, 24, 72, and 120 hours postrun). A second group of men ($n = 5$) had the measurements taken on 6 occasions without downhill running and served as a control group. A repeated measures analysis of variance revealed no significant changes in any measures across time for the control group. Following downhill running, significant ($p < 0.05$) decreases in strength (0.5–24 hours), and significant increases in muscle soreness (0.5–72 hours) and plasma CK activity (0.5–120 hours) were observed. A significant decrease in peak and average power (~5%) was evident only 0.5 hours postrun, and the decrease was smaller in magnitude than that of strength (~15%). These results suggest that power is less affected than strength after eccentric exercise, and the effect of reduced power on sport performance seems negligible.

Key Words. eccentric exercise, muscle damage, isometric strength, delayed onset muscle soreness, creatine kinase

Introduction

Delayed-onset muscle soreness is commonly experienced following a bout of unaccustomed exercise (26). It is generally absent immediately following exercise but develops 24–48 hours, and subsides by 5–7 days after exercise (19). Delayed-onset muscle soreness is often accompanied with varying degrees of muscle function impairment such as decreases in maximal voluntary strength and range of motion (21, 29). These phenomena in combination are often referred to as exercise-induced muscle damage (EIMD) (6).

To date, a large percentage of investigations relating to EIMD have been conducted using maximal exercise protocols that target a specific limb action such as elbow flexion or knee extension (12, 21, 25). However, it is unclear the degree to which these pure maximal eccentric exercise protocols represent the training and competition settings that result in EIMD which often involve more complex, multi-limb movements performed under both maximal and submaximal loading. Given that the magnitude of EIMD appears less following downhill running and walking than following maximal eccentric actions (10, 22, 24), this form of protocol may better represent the muscle damage that athletes experience in their training and competition.

Although a number of studies have quantified the declines in maximal voluntary strength associated with EIMD (21, 25), few have examined the effect of EIMD on power. From a sporting perspective, success in both team (2) and individual sporting events (3, 9) is often more dependent on power than strength. Since muscular power is the product of force and velocity (31), a similar reduction in power and strength following eccentric exercise would be expected. However, to date the relationship between power and strength losses associated with EIMD is not clear.

Muscular power can be assessed through a variety of standardized testing protocols that range in duration of less than 1 second to 60 seconds. In general shorter duration tests (<10 seconds) are considered to assess the maximal capacity of the adenosine triphosphate phosphocreatine (ATP-PC) energy system, while longer duration tests (20–60 seconds) assess the maximal capacity of both the ATP-PC and glycolytic energy systems (28). Although both forms of testing are applicable to various sporting situations, the 30-second Wingate Test has been shown to be a highly reliable and applicable test for predicting performance in both individual and team sporting events (1, 27).

Several studies have reported the effects of eccentric exercise on power (5, 10); however, few have used a protocol that assesses both the ATP-PC and glycolytic energy systems. Sargeant and Dolan (24) reported approximately 20% reductions of cycling power using an isokinetic cycling dynamometer (20-second test at 110 rev·min^{-1}) following loaded downhill walking to exhaustion. Kraemer et al. (18) reported declines in power output in a 30-second Wingate Test following repeated eccentric knee extension; however, the absolute percentage changes were not reported. Further investigation is therefore needed to confirm the effect of EIMD on power associated with both the ATP-PC and glycolytic energy systems and to confirm if the magnitude of the decrease in power is proportional to the decreases in strength, or the changes in other indices of muscle damage.

Therefore, the aim of the current study was to investigate the effect of downhill running on power assessed by a 30-second Wingate Test, and the relationship between power loss and changes in indices of muscle damage following downhill running.

Methods

Experimental Approach to the Problem

To examine the influence of downhill running on power, 2 subject groups were tested using the same testing schedule with the exception that 1 group performed a bout of downhill running (DR group) on the third testing occasions in addition to the criterion testing protocol. The remaining group acted as a control (CON) group and was used to assess the effects of multiple testing occasions on the criterion measures. Familiarization with the measurements and baseline testing was conducted 120 and 72 hours prior to the downhill running. The measurements were repeated 30 minutes, and 24, 72, and 120 hours following the downhill run for the DR group, and at equivalent time intervals for the CON group. Therefore, measurements were taken on 6 occasions over a 12-day period for both groups. These measurement time intervals were chosen based on the known time course of recovery from muscle damage induced by both downhill running and walking for strength, soreness, and plasma creatine kinase (CK) activity reported previously (7, 8, 10).

Subjects

A total of 13 men between 18 and 25 years of age were recruited for the study, with 8 assigned to a DR group, and 5 to a CON group. The mean (± *SEM*) age, height, and weight characteristics of the subjects were 19.3 ± 0.3 years; 183.6 ± 2.0 cm; and 77.1 ± 2.7 kg, respectively. No significant differences were seen between the groups with the exception of weight which was significantly ($p < 0.05$) larger for the CON group (83.8 ± 4.8 kg) than the DR group (72.8 ± 1.6 kg). All subjects were currently active in sport; however, none of them regularly participated in distance running or eccentrically biased exercise of the lower limbs. While the level of competition the subjects participated in varied, typically each completed 1 or 2 training sessions and 1 competitive game per week (5.5 ± 1.1 hours per week), with most being involved in team sports such as Australian rules football and field hockey. Subjects completed an informed consent prior to participation in the study that had received ethical approval from the Edith Cowan University Committee for the Conduct of Ethical Research.

Procedures

Downhill Run Protocol. Based on the protocol described by Eston et al. (7), subjects in the DR group completed a 40-minute downhill (−7%) treadmill run on a modified Trackmaster (TM500) motor driven treadmill (JAS Manufacturing, Richardson, TX). Subjects ran for 5 sets of 8 minutes with 2 minutes of rest between sets. Treadmill speed was adjusted at 2-minute intervals during each set to maintain a heart rate (Polar A_3; Polar Electro Oy, Kempele, Finland) equal to 80% of the subjects' aged-predicted maximum. Water was provided ad libitum during the rest periods.

Maximal Voluntary Contraction Force. Maximal voluntary contraction force (MVC) of the left and right knee extensors and flexors was determined at an angle of 60° (from extension) of knee flexion using a Cybex 6000 isokinetic dynamometer (Cybex, Medway, MA). Verbal encouragement was given during all MVC measurements. Subjects completed 3 sets of 5-second MVC tests alternating between the extension and flexion movement with a 10-second rest between the movements, and a 20-second rest between sets. During each rest period feedback on performance in the previous efforts was given. All testing for one limb was completed before commencing the contralateral limb, with the start leg randomized across the 6 trials for each subject. Baseline values of strength used in comparisons across time represent the peak value of the 2 baseline testing occasions.

Muscle Soreness. Muscle soreness was determined using a verbal soreness scale with a range of 1–10 where 1 was equal to no soreness, and 10 indicated a very sore muscle (29). Subjects reported soreness for the gluteal, hamstring, quadriceps, gastrocnemius, and anterior tibialis muscle groups while walking at a comfortable pace on a stable and level surface. Soreness ratings were taken prior to the strength protocol on each testing occasion, with an average soreness score of the 5 muscles used for further analysis.

Anaerobic Power. Anaerobic power output was assessed by a 30-second Wingate Anaerobic Test (WAnT) using a Monark Ergomedic 843E cycle ergometer (Monark, Vansbro, Sweden), with the resistance set at 75 $g \cdot kg^{-1}$ body mass (16). Prior to each WAnT, subjects completed a 5-minute intermittent (30 seconds of exercise with 30 seconds of rest) warm-up protocol to elicit a heart rate of approximately 150 beats per minute (bpm). A 3-minute rest was then allowed before the commencement of the WAnT. The subjects began pedaling and the resistance was added once the cadence reached 180 rpm, marking the beginning the 30-second test period. Subjects were verbally encouraged throughout the test, and after completion of the 30-second maximal pedaling period, a 2- to 3-minute cool-down with no resistance was performed. Seat height was adjusted and kept constant for all subjects, and all tests were completed with the use of toe clips. Power readings were determined at 5-second intervals throughout the 30-second test period. Peak power was defined as the highest work output in a 5-second period, and average power as the average work output for the 30-second test period. The lowest work output in a 5-second period was considered to be minimum power, with the rate of fatigue assessed via the fatigue index. Values for power output and the FI were obtained directly from those values reported using the standard Monark Bodyguard AB (version 1.00) computer software program (Monark). Baseline values used for all power recordings represent the best value obtained from the 2 baseline testing occasions.

Statistical Analyses

Using the values obtained in the familiarization sessions, the reliability of the criterion measures was determined by calculation of the coefficient variation (CV) and the intraclass correlation coefficient (ICC; 95% confidence interval) between the 2 baseline testing occasions. The CV (%) for knee flexor strength, knee extensor strength, and peak power output was 2.9, 3.7, and 1.9%, respectively, and the ICC for these same measures was 0.86, 0.94, and 0.87, respectively. Each dependent variable (strength, power, muscle soreness, and plasma CK) was analyzed using a 1-way analysis of variance with repeated measures test. Where a significant time effect ($p \leq 0.05$) was found, a paired sample *t*-test was used to indicate differences from baseline. To assess the relationships between the test variables of power, muscular strength, and muscle soreness, Pearson product moment correlation coefficients were calculated. All analyses were conducted separately for the DR and CON groups (comparisons to baseline only). Statistical significance was set at $p \leq 0.05$ for all analysis, with data presented as mean ± *SEM* unless otherwise stated. While a power calculation revealed a required sample size of 38 subjects, previous investigators using similar methodologies have demonstrated signifi-

TABLE 1. Effects of repeated measurements on strength (knee extensors and knee flexors), plasma creatine kinase (CK) activity, power (peak, average, and minimum) and the fatigue index for the control group (mean ± *SEM*).

	Baseline	Testing interval (hours)			
		0.5	48	72	120
Extensor strength (Nm)	279.8 ± 17.3	277.8 ± 17.0	286.3 ± 17.7	274.7 ± 24.2	292.3 ± 18.0
Flexor strength (Nm)	146.2 ± 7.8	141.4 ± 7.6	138.3 ± 7.0	140.3 ± 8.2	137.6 ± 6.9
Plasma CK activity ($IU \cdot L^{-1}$)	115.4 ± 20.5	115.1 ± 25.8	109.8 ± 9.3	99.6 ± 22.6	110.7 ± 28.7
Peak power (W)	760.8 ± 26.8	772.8 ± 46.7	790.3 ± 38.1	776.5 ± 54.5	797.7 ± 35.9
Average power (W)	589.2 ± 37.7	591.8 ± 37.0	580.7 ± 30.9	584.7 ± 33.0	597.6 ± 36.1
Minimum power (W)	435.7 ± 33.2	421.6 ± 20.3	422.7 ± 22.7	425.3 ± 23.1	450.2 ± 29.4
Fatigue index	43.8 ± 4.0	45.2 ± 2.1	46.2 ± 3.3	45.3 ± 3.7	43.6 ± 2.6

cant differences with sample sizes ranging between 4 and 10 subjects (5, 8, 24). The number of subjects tested in the current investigation was therefore based on previous work rather than the power calculation. The sample size selected demonstrated a statistical power of 0.25–0.90 depending on the criteria measure in question.

RESULTS

Control Group

No significant differences from baseline were recorded for any of the criterion variables for the CON group (Table 1). Any variations from baseline remained within the predetermined CV.

Downhill Running Group

Strength. Significant ($p < 0.01$) decreases in extensor strength from baseline (258.1 ± 12.1 Nm) were seen 30 minutes (16.7%) and 24 hours (10.9%) after downhill running, but strength returned to baseline by 72 hours postrun (Figure 1). No significant decreases in flexor strength from baseline (143.6 ± 7.3 Nm) were evident ($p = 0.57$).

Plasma CK Activity. Significant ($p < 0.05$) increases in plasma CK activity from baseline (108.2 ± 41.1 $IU \cdot L^{-1}$) and above the normal reference range (200 $IU \cdot L^{-1}$) were observed at all time points following downhill running (Figure 2). Variations in the magnitude of increase in plasma CK activity were seen with the 24 hours postrun values ranging from 116 to 1400 $IU \cdot L^{-1}$ among subjects.

Muscle Soreness. All subjects reported some degree of soreness with peak soreness recorded 24 hours postrun. Significant ($p < 0.05$) increases in soreness were recorded at all time intervals postrun with the exception of 120 hours (Figure 3).

Power Output. Peak and average power before the downhill run were 678.3 ± 33.2 W and 541.9 ± 18.0 W, respectively. Significant ($p < 0.05$) declines in both peak (4.5%) and average (5.4%) power from baseline were recorded only at 30 minutes postrun (Figure 4). No significant ($p > 0.05$) differences from baseline were evident 24–120 hours following downhill running for average power; however, peak power was significantly ($p < 0.05$) higher (4.9%) than baseline 120 hours postrun. No significant changes from baseline were found for either the FI ($p = 0.28$) or minimum power ($p = 0.21$).

Relationship Between Testing Variables

When all time intervals were combined, significant ($p < 0.05$) correlations between extensor strength, flexor strength, peak power, and average power were recorded (Table 2). However, no significant correlations between soreness and plasma CK activity ($r = 0.15$), any of the performance variables and plasma CK activity ($r = 0.17$–0.40), or soreness and any of the performance variables ($r = 0.07$–0.47) were evident.

DISCUSSION

The main focus of this study was to assess the influence of a bout of downhill running on power output in the 30-second Wingate Test. The significant decreases in strength (Figure 1), increases in plasma CK activity (Fig-

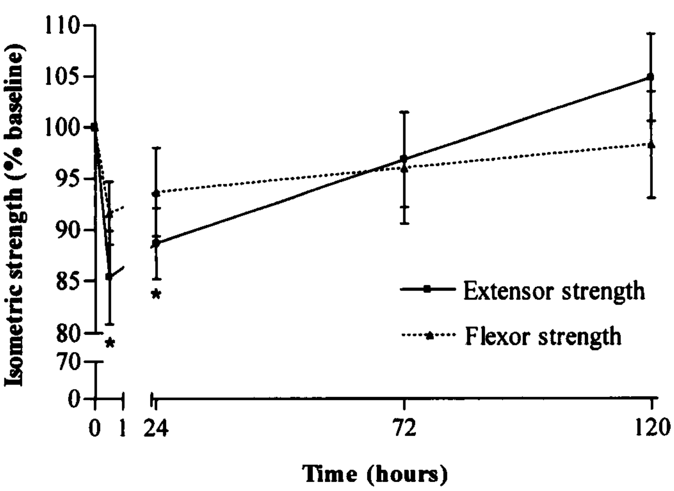

FIGURE 1. Changes (mean ± *SEM*) in knee flexor and extensor strength (as a percentage of baseline) 0.5, 24, 72, and 120 hours following downhill running. * $p < 0.01$ difference to baseline.

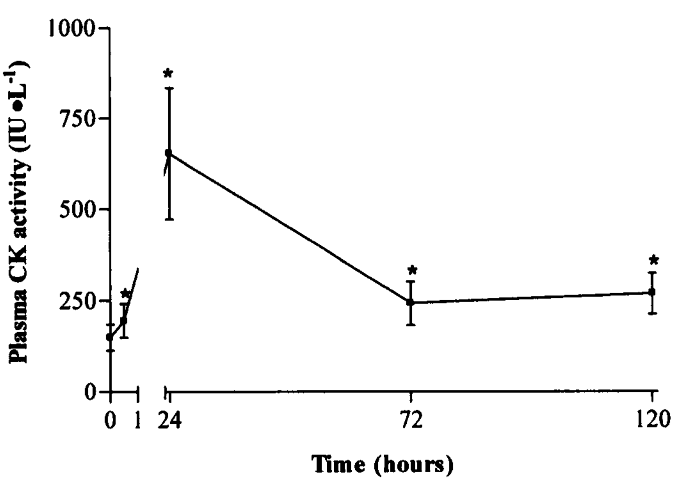

FIGURE 2. Changes (mean ± *SEM*) in plasma creatine kinase (CK) activity 0.5, 24, 72, and 120 hours following downhill running. * $p < 0.05$ difference to baseline.

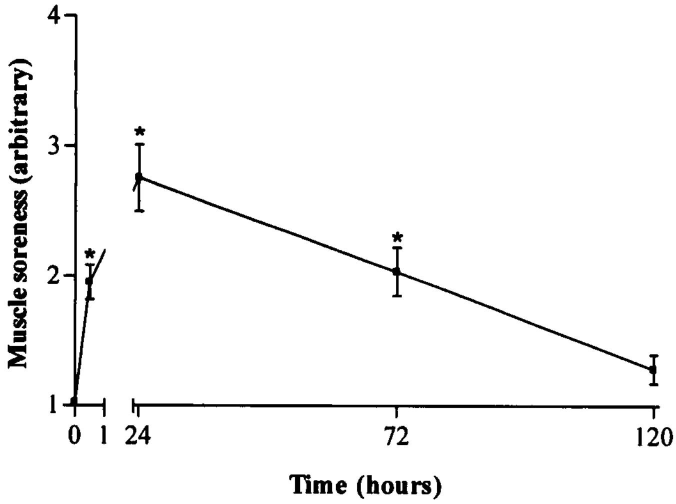

FIGURE 3. Changes (mean ± *SEM*) in muscle soreness results 0.5, 24, 72, and 120 hours following downhill running. * $p < 0.01$ difference to baseline.

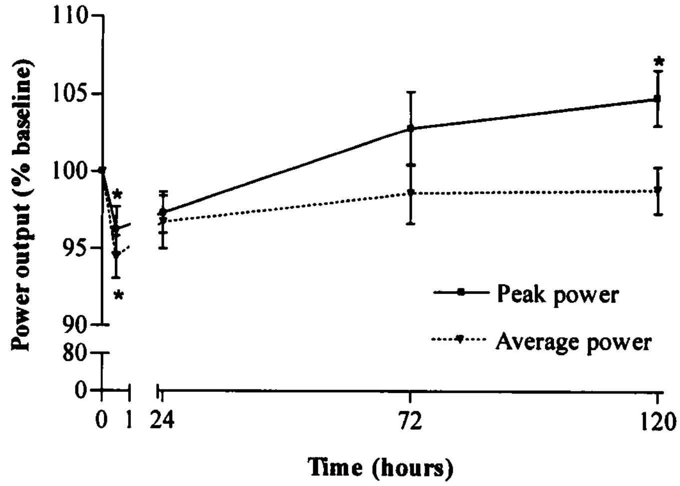

FIGURE 4. Changes (mean ± *SEM*) in peak power and average power (as a percentage of baseline) 0.5, 24, 72, and 120 hours following downhill running. * $p < 0.05$ difference to baseline.

TABLE 2. Correlation coefficients for strength (knee extensors and flexors) and power (peak and average).

	Flexor strength	Peak power	Average power
Extensor strength	0.84*	0.75*	0.67*
Flexor strength	—	0.82	0.80*
Peak power		—	0.81*

* $p < 0.05$ (2-tailed).

ure 2) and soreness (Figure 3) following downhill running indicate the presence of muscle damage (32). The 15% decline in strength was similar to that of previous investigations using loaded downhill walking (10) and downhill running (7). Furthermore, given the absence of any significant differences across time for the CON group (Table 1), it seems reasonable to state that the changes observed in the DR group were the direct results of muscle damage induced by the downhill running protocol, not of the repeated measurements.

It could be argued that the declines seen in the DR group were the result of either fatigue caused by the run protocol (17), or decreased effort due to soreness (30); however, the current results and previous investigations (5, 20) suggest otherwise. Had fatigue resulted in the power declines, it would have been expected that changes in either minimum power or the fatigue index would also have been evident (16). However, no significant changes in either of the variables were observed (Table 1). Had soreness been the contributing factor, it seems reasonable that a significant correlation between soreness and power would have been found. However, the greatest declines of both strength and power were seen 30 minutes postrun, while muscle soreness did not peak until 24 hours postexercise. Thus, it is unlikely that fatigue and muscle pain were responsible for the observed performance declines following eccentric exercise. It is important to note that the delayed recovery of strength, the presence of soreness, and the increase in plasma CK all indicate that damage was present following the downhill running protocol (7, 20, 21).

This is the first study to use the Wingate Test to assess power following downhill running. The results of the study showed that both peak and average power output in the 30-second Wingate Test decreased following downhill running, but the magnitude and time course of the decrease in power was different to that of strength (Figures 1 and 4). No previous study investigated the effect of downhill running on power assessed by a 30-second Wingate Test, although some studies reported the effect of muscle damage on power using a different exercise model or a different power test. Sargeant and Dolan (24) used prolonged downhill (−25%) walking and reported 33% (peak) reductions in power output during a fixed cadence (110 rev·min^{-1}) cycling test 24 hours postexercise, with the reductions persisting until 96 hours postexercise. The differences between the magnitude of power loss in the current study (5%) and that by Sargeant and Dolan (24) are likely to be due to the difference in the exercise protocol rather than differences in the power test. In the study by Sargeant and Dolan (24), subjects performed the exercise to the point of collapse while the current investigation employed a fixed time protocol (40 minutes). Kraemer et al. (18) showed significant decreases in power output (values not specified) during a 30-second Wingate Test immediately following repeated eccentric knee extensions.

As shown in Table 2, a high correlation between power (both peak and average power) and strength was evident. Despite this correlation, it should be noted that the declines in isometric strength were greater in magnitude (~10–15%) and more prolonged than those for peak and average power (~5%). This was similar to that of Sargeant and Dolan (24) who reported progressive declines in maximal isometric strength of 45%, while a lesser peak reduction of 23% was found for short-term cycling power output immediately after eccentric exercise.

The difference in magnitude of decrease between strength and power in the present study can be explained, at least partially, by the kinematic differences between the 2 testing protocols. A kinematic study (8) has shown that the extensors of the knee, gastrocnemius, tibialis anterior, extensor hallicus longus, and extensor digitorum longus are all activated during downhill running. The strength testing protocol adopted in the present study targeted the knee extensors and flexors. In contrast, during cycling in the Wingate Test, not only the knee extensors, but also the extensors and flexors of the hip and ankle joints and the gluteus maximus contribute to mechanical energy production (11, 15, 23). Therefore, only the quadriceps and gastrocnemius appear to be common contributors to mechanical work during the strength and power measurements in this study. This may explain why a significant decrease in strength was seen in the extensors only. The large contribution by the activity of other muscles in the power output of a cycling action, compared with the kinematics of downhill running, may explain the smaller reductions seen in peak and average power compared to those for isometric extensor strength.

In addition, it has been previously demonstrated that greater decrements in force generation during isometric contractions occur following eccentric exercise compared to those for isokinetic force generation possibly due to the storage and release of elastic energy (4, 12, 14). Therefore, it is possible that greater force generation from the storage of elastic energy may have occurred during the cycling protocol compared to the isometric strength protocol. Thus, from a practical point of view, it may be possible that the long-term improvements that can be obtained by eccentric training (13) may be greater than the short-term performance decrements observed immediately following the exercise. In team sporting situations where performance is dependent on both physical and skill based parameters, the relatively short duration decline in power of approximately 5% may have limited influence on overall performance.

It is also important to highlight the apparent supercompensation effect observed in the current study in relation to peak power output in the DR group, with the group demonstrating a significant increase of approximately 5% in power by 120 hours (Figure 4). Had this increase occurred due to practice alone, the same increase would have been expected for the CON group; however, this was not the case. While it is unclear how long this increase may have been sustained, the relatively short duration between the exercise and the increase in power has implications for events that have weekly or biweekly competition cycles. The results suggest that while eccentric exercise may result in short-term declines in power, it may also offer short-term increases in power.

In conclusion, the results of this study showed that both average and peak power output assessed using a 30-second Wingate Test were decreased (~5%) after downhill running that also resulted in reductions in isometric strength (~15%); however, the decreases were not prolonged. Given that the decrements in power are less in magnitude and faster to recover than those for isometric strength, the effect of eccentric exercise on power may not affect sport performance, at least where the magnitude of muscle damage induced by eccentric exercise is comparable to that of downhill running, and the muscle groups involved in the power performance are not the sole contributors to performance of the eccentric exercise.

Practical Applications

This study showed that both peak and average power were decreased following downhill running; however, the magnitude of decrease in power was not as large or as long-lasting as that of isometric strength. In sporting situations where power is more desirable than strength alone, the current study would suggest that the short-term losses in strength experienced in training or after competition, may affect power by a lesser degree. Therefore, the influence of eccentric exercise that would induce a similar magnitude of muscle damage to that of downhill running may not cause serious declines in power which affects performance. Further studies investigating the influence of repeated eccentric exercise bouts on power output are warranted given that a repeated bout effect is known to occur in relation to strength declines following eccentric exercise (5, 9).

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