Performances Of Men and Women in Repeated Cycle Sprints Separated by Limited Recovery Intervals

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Abstract

The purpose of the study was to examine the restoration of power in the Wingate Anaerobic Test (WAnT) in men and women during interval sprints that consisted of five 20-second cycle tests, which were separated active recovery periods of 45 seconds. 30 men (25.3±2.7yrs; 1.75±0.06m; 69.3±8.9kg) and 28 women (23.2±2.2yrs; 1.63±0.06m; 53.5±7.6kg) participated in the study. On separate occasions, participants completed an incremental treadmill test to determine peak oxygen uptake (VO_2) and a repeated cycle sprints protocol, where peak power (PP) and mean power (MP) in five consecutive sprints were measured, as were pre and post-exercise blood lactate (BL) concentrations. Results showed that men had higher peak VO_2 than women (53.2±8.7 vs. 42.8±6.8 ml/kg BM/min, $p<0.05$), greater differences in PP and MP between repeated sprints than women, yet demonstrated similar magnitude of power restoration for PP and MP between sprints. Men and women had similar blood BL profiles. Power restoration in the WAnT cannot be explained by differences in peak oxygen uptake in men and women.

Key words : power restoration, repeated sprints, adults

Introduction

The capability to recovery from previous bouts of high intensity exercise of a brief duration with limited recovery periods is an important component for consistent performance in sporting pursuits like netball, field hockey, basketball, soccer, and rugby. It is also important for effective training and during performance in multi-event competitions (Chia, 2001).

Team sports require many repeated sprints of a short duration, such as during offensive and defensive play in basketball or soccer, followed by low intensity activity periods, such as jogging back to position during recovery (Reilly, 1996). The routine of maximal intensity exercise bouts interspersed with limited active recovery repeats itself many times in many team games.

Quick restoration of power or the capability to perform work or replicate performance following prior exercise, many times over, is therefore a pre-requisite for sustaining high performance in any team sport, training and in multi-event competitions. Research has established that prior exercise of a high intensity is fatiguing and may affect subsequent exercise performance, especially when the recovery interval is short (Sargeant & Dolan, 1987; Hitchcock, 1989; Bogdanis, Nevill & Lakomy, 1994). Situations are exacerbated when the prior exercise involves multiple bouts of high intense exercise, which can impair or affect subsequent attainment of maximum power output (Chia, 2001).

In a study that examined the performances of 21 women and 19 girls in three 15-second Wingate Anaerobic Tests (WAnTs), separated by a 45-second active recovery period, PP and MP declined 18~20% in girls and 30~37% in women, in the third WAnT compared to PP and MP attained in the first WAnT (Chia, 2001).

Recovery of peak performance after exercise therefore depends on the mode, intensity and duration of the prior exercise, and on the characteristics of the recovery interval between successive exercise bouts (Gaitanos, Williams, Boobis & Brooks, 1993; Holmyard, Nevill, Lakomy & Sant' Ana, 1994). For example, Dotan, Falk and

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Raz (2000) reported that active recovery after 40 seconds of cycling at 150% at the exercise intensity, which elicited peak oxygen consumption, resulted in lower blood lactate concentration compared to when the sprints was separated by a passive recovery period.

Some studies alluded that enhanced oxygen availability during high intensity intermittent exercise decreases anaerobic metabolite concentration in the blood (Balsom, Ekblom & Sjodin, 1994a) and conversely, reduced oxygen availability during such exercise impairs performance (Balsom, Gaitanos, Ekblom & Sjodin, 1994b). However, a study that examined the recovery processes of seven male participants after repeated all-out intensity exercise at an altitude of 4,350 metres showed that prolonged exposure to high altitude did not impair the restoration of muscle power during two 20-second WAnTs, compared to the performance at sea level (Robach, Biou, Henry, Deberne, Letournel et al., 1997). Related data on women are apparently non-existent.

Juxtaposing the results of the cited studies, a hypothesis could be advanced that participants with higher peak oxygen uptake or aerobic fitness demonstrate better performance during intermittent maximal exercise by being better able to replicate the best performance in the initial bouts of maximal exercise. However, such a hypothesis needs to be tested.

Previous research on the restoration or recovery of muscle power after prior exercise has focused on comparisons between boys and men (Hebestreit, Minura & Bar-Or, 1994) and girls and women (Chia, 2001). For instance, Hebestreit et al(1994) examined the effect of recovery intervals of one minute, two minutes and 10 minutes on the performance of two 30-second cycle sprints. Chia (2001) on the other had fixed the recovery interval at 45 seconds and examined the power generated in three successive 15-second cycle tests.

In the two cited studies, the authors reported that young people recover faster from their maximal efforts than adults, even though the authors proposed different reasons in accounting for the results. Hebestreit et al.(1994) argued that in boys, the restoration of PP and MP in the second 30-second WAnT was faster than men because they generated lower PP and MP, and had lower blood lactate concentration after exercise than men. Contrarily, Chia (2001) presented data showing that in spite of similar power and lactate profiles following three 15-second WAnTs, which were separated by a 45-second active recovery, girls demonstrated a swifter recovery in WAnT power than women.

Ratel, Duche, Hennegrave, Van Praagh and Bedu (2002) proposed that in repeated cycle sprints that were separated by 30 seconds of passive rest between sprints, boys recovered faster than men because they regulated the blood H^+ ions concentration better than adults by ventilating more during the initial rest intervals between sprints.

Prior research has employed either 30-second (Hebestreit et al., 1994; Ratel et al., 2002) or 15-second (Chia 2001) sprints during intermittent exercise to study the effects of fatigue on subsequent performance. A 20-second sprint was used in the present study as it was felt by the investigator that while fatigue could be induced in multiple sprint efforts using either 15 or 30-second sprints, multiple sprints of 20-seconds represented the midpoint duration between 15 and 30-second time periods.

Moreover, few studies have examined the differences in the restoration of PP and MP during intermittent maximal exercise bouts that are separated by a limited recovery period in men and women. Moreover, data that are exclusively male have been extrapolated or generalised to the rest of the adult population, despite the absence of data on females. This could lead to erroneous conclusions, in situations where sex differences in performance exist. Comparative data of men and women that emanate from the present study would provide a more complete picture about the specific research question that is addressed.

The purpose of the study was twofold: (i) to examine the restoration of WAnT power in intermittent 20-second maximal cycle efforts that were separated by a 45-second recovery period in between sprints in men and women, and (ii) to elucidate if differences in peak oxygen uptake between male and female participants accounted for the recovery in WAnT power between men and women.

Method

Participants

Thirty men and 28 women, with the appropriate informed written consent participated in the study. Participants were healthy and physically active adults but were not involved in any form of weight training or sports training in the previous month before the study commencement. Body mass and stature of the participants were determined using calibrated beam balance scales (Avery 3306 ABV) and a stadiometer (Holtain), respectively.

Testing sequence

Participants completed a treadmill run test to volitional exhaustion on one test occasion to determine peak oxygen uptake. This was followed by four sessions to familiarise participants to repeated maximal effort sprinting using an abbreviated Wingate Anaerobic Test (WAnT) protocol. Another occasion was used to conduct the repeated sprints test. The entire test series was conducted over a period of two weeks.

Determination of peak oxygen uptake (peak $\dot{V}O_2$)

After a standardised familiarisation with treadmill running, participants were instructed to continue running on the treadmill (Milwaukee, WI) to the point of volitional fatigue. A modified Balke Test protocol was used. The test commenced at a constant treadmill speed of between 10 and 12 $km.hr^{-1}$, with a 0% grade for the first minute and 2% for the second minute. The grade was increased 1% per minute thereafter. At a treadmill limit of 25%, the speed was then increased 13.4 $m.min^{-1}$ each minute. Volitional fatigue was induced between 15 and 20 minutes. The expired air was collected by Sensormedics (2900Z) and the breath-to-breath oxygen consumption was averaged over the last 30 seconds of each stage. The automated gas analysers were calibrated before each test using standard calibration procedures.

Heart rate was monitored throughout the test and recorded at 15-second intervals using a short- range radio telemetric system (Polar Vantage NV). Volitional exhaustion and the attainment of peak $\dot{V}O_2$ was confirmed when the terminal exercise heart rate was 95% of age and sex specific predicted maximum heart rate of the participants and that the participants exhibited signs of unsteady running gait and signs of maximum effort (e.g. facial flushing and profuse perspiration).

Familiarization with intermittent maximal effort cycle sprinting

Participants had at least four prior sessions with maximal cycle sprinting. In each session, partici-pants completed a series of three 20-second Wingate Anaerobic Tests (WAnTs), which were separated by a passive recovery interval of 45 seconds. Participants were instructed to avoid pacing and to give a maximal effort in every sprint effort. The familiarization sessions were also used to determine the optimal applied force for each participant that elicited the highest power over the 20-second WAnT. The applied resistance for the participants was set between 0.74N and $0.98N.kg^{-1}$ body mass.

Intermittent maximal exercise protocol

The cycle sprints were conducted on a calibrated friction-loaded cycle ergometer (Monark 834*E*) that was interfaced to a computer. The instrumentation of the cycle ergometer to take into account the inertial and frictional characteristics of the system have been described elsewhere (Chia, Armstrong & Childs, 1997; Chia, 2000).

Saddle height was individually adjusted for each participant such that there was a slight bend at the knee when the pedal was at the lowest point of the cycle. Toe-clips were used to secure feet to the pedals.

Following a standardized warm-up, which consisted of four minutes of constant rate pedalling at 70~80 revolutions per minute (rpm) against a minimal applied force (with the load basket supported), participants completed three maximal sprints of three to five seconds against the individually determined applied resistance to elicit the highest power over a 20-second WAnT. This protocol has been described in detail elsewhere (Chia, Armstrong & Childs, 1997).

The test commenced from a rolling start (70~80 rpm) and participants were verbally encouraged as they sprinted at maximum effort without pacing during each of the five 20-second WAnTs. An active (back pedaling against a minimal resistance at a self-selected rpm) rest interval of 45 seconds separated the sprints. This test protocol has been described in detail elsewhere (Chia, 2001).

At the end of the repeated sprints, participants recovered passively in an upright position on the saddle of the ergometer for five minutes after which they pedaled against a minimum resistance for another five minutes at a self-determined pedal rate.

Blood lactate measurements

A post-warm-up blood sample was obtained from the thumb using a Softclix II device (Boehringer Mannheim) and serial sampling for blood lactate was done at one-minute intervals for five minutes after the completion of the five WAnTs. The blood samples were subsequently analysed in duplicate as whole blood lactate (BL) using an automated and self-calibrating analyzer (YSI 2300 StatPlus). Calibration was checked regularly against commercially prepared standards of known concentration.

Statistical analyses

Data garnered were stored in database and were subsequently analysed using the Statistical Package for Social Sciences (SPSS) for windows software (Version 11.0). Variables of interest were inertia-corrected peak power (PP) integrated over 1 second and inertia-corrected mean power (MP) integrated over 20 seconds (Chia, Armstrong & Childs, 1997) for all of the five WAnTs.

Power differences between the sprints were computed and recovery and fatigue indicators were computed based upon the extent (mean difference and mean percentage) of power recovery in a subsequent sprint compared to the previous sprint (Chia, 2001).

Descriptive data (means and standard deviation) of the participants, PP and MP achieved in the WAnTs were computed. Differences in power between sprints within each sex group (male or female) were analysed using repeated measures analysis of variance (RM-ANOVA) and sex differences in peak $\dot{V}O_2$, PP and MP were analysed using one-way analysis of variance (OW-ANOVA). Normality of distribution and the homogeneity of variance in the data sets were checked using the appropriate statistical tests (i.e. Sharpiro-Wilks and Levene Tests, respectively). The level of statistical significance was set at $p<0.05$.

Results

Physical characteristics and peak $\dot{V}O_2$ of the participants

Participant characteristics are summarized in Table 1. Male participants were older, taller and heavier than the female participants. Males also had higher peak $\dot{V}O_2$ values than females.

Table 1. Participant and peak $\dot{V}O_2$ characteristics

Variable	Male (N=30)	Female (N=28)
Age(yrs)	25.3±2.7	23.2±2.2*
Height(m)	1.75±0.06	1.63±0.06*
Body mass(kg)	69.3±8.9	53.5±7.6*
Peak $\dot{V}O_2$ (ml/kg BM/min)	53.2±8.7	42.8±6.8*
Heart rate at peak $\dot{V}O_2$(bpm)	180.9±10.8	186.9±8.6

*Significantly different at $p<0.05$.

Normality of distribution and homogeneity of the data sets

Peak $\dot{V}O_2$ data, peak power and mean power in WAnTs were normally distributed (i.e. Sharpiro-Wilks statistic, $p>0.05$) and there was homogeneity of variance for PP and MP (i.e. Levene statistic, $p>0.05$).

Intermittent maximal cycle sprint performance

PP and MP achieved in the five 20-second WAnTs that were separated with a 45-second active recovery period between successive sprints are shown in Figure 1 and Figure 2, respectively.

The decline in PP in successive sprints was more marked in men than in women. The decline in MP in successive sprints was of a similar pattern in men and women.

Power differences between successive sprints

The mean differences and the standard deviations of the differences in PP and MP between successive sprints (e.g. PP and MP differences between Sprint 1 and Sprint 2, Sprint 2 and Sprint 3, etc) are summarized in Table 2.

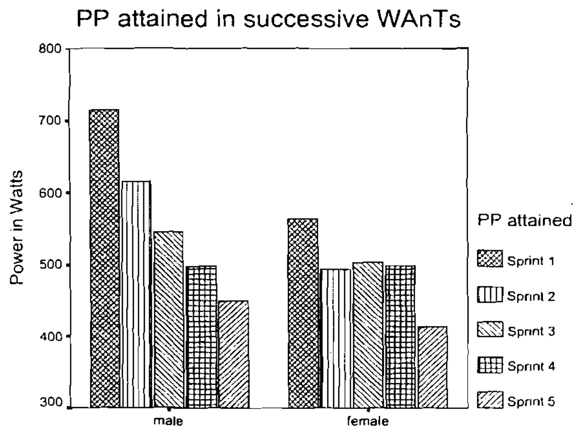

Figure 1. Peak power in watts attained in five 20s Wingate Anaerobic Tests separated by 45s recovery periods between successive sprints. OW-ANONA revealed that apart from Sprint 3 and Sprint 4, sex differences in PP were significant ($p<0.05$).

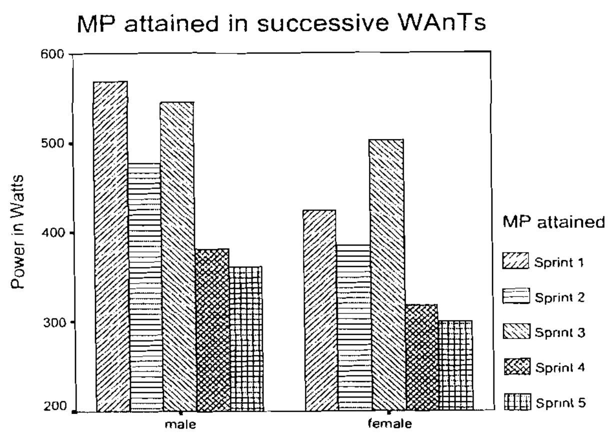

Figure 2. Mean power in watts attained in five 20s Wingate Anaerobic Tests separated by 45s recovery periods between successive sprints. OW-ANOVA revealed that sex differences in between Sprint 1 to Sprint 5 were significant ($p<0.05$).

Repeated measures ANOVA for PP and MP in males and females, with or without body mass entered as the covariate, revealed significant differences ($p<0.05$) in the mean differences in PP and MP that were attained between successive sprints in the WAnT.

With PP and MP attained in successive sprints expressed as a percentage of the highest PP and MP achieved in Sprint 1 (indicated within brackets), however, the men and women showed similar profiles for recovery of PP and MP.

Blood lactate concentration (BL_{conc})

The post-warm-up and post-exercise BL concentrations after the five 20s WAnTs, obtained serially at 1-minute intervals during an active recovery are summarized in Figure 3.

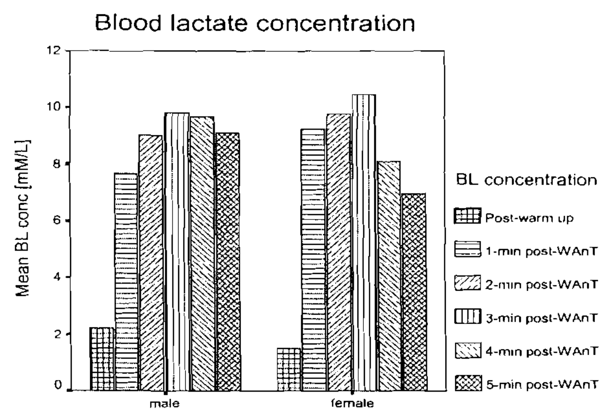

Figure 3. Blood lactate concentration post-warm-up and sampled at 1-minute intervals after the five 20s WAnTs. RM-ANOVA revealed no sex difference in post-WAnTs blood lactate concentration. Peak BL_{conc} was attained by 3 minutes post exercise in men and in women (since BL_{conc} in men at 3 min vs. 4 mins, $p>0.05$).

Table 2. Differences in PP and MP in successive sprints and PP and MP achieved in subsequent sprints expressed as a percentage of PP and MP achieved in Sprint 1 in brackets. The recovery interval between sprints was 45 seconds.

Variable	Sex	$Mean_{diff} \pm SD_{diff}$ SP1 & SP2	$Mean_{diff} \pm SD_{diff}$ SP2 & SP3	$Mean_{diff} \pm SD_{diff}$ SP3 & SP4	$Mean_{diff} \pm SD_{diff}$ SP4 & SP5
PP (W)	Male	107±64* [88±9%]	72±63* [78±13%]	55±37* [71±11%]	48±35* [65±13%]
	Female	70±18 [87±14%]	30±11 [89±16%]	14±4 [89±11%]	86±70 [72±16%]
MP (W)	Male	91±39* [84±6%]	58±38* [77±12%]	45±32* [67±9%]	21±16* [64±11%]
	Female	40±18 [90±5.3%]	52±16 [77±10%]	15±8 [74±13%]	18±11 [67±14%]

*Sex difference is significantly different at $p<0.05$.

Post-exercise blood lactate concentration peaked by three minutes in men and women. Thereafter, BL_{conc} declined. There was no sex difference in BL concentration ($p>0.05$).

Discussion

Measurements made on participant characteristics showed that the men were significantly older, taller and heavier than the women (see Table. 1). The men also had higher peak oxygen uptake (see Table 1) and generated greater peak power and mean power in the first 20-second Wingate Anaerobic Test (see Figures 1 and 2). These results are comparable to those reported elsewhere (Armstrong & Welsman, 1997; Inbar, Bar-Or & Skinner, 1996).

Intense repeated exercise, which are interspersed with limited recovery result in an accumulation of BL in male and female adults (Hebestreit et al., 1994; Chia, 2001). Some researchers (Ratel et al., 2002) suggest that elevated post exercise BL concentration and the associated decrease in blood pH, is directly associated with local muscle fatigue by possibly affecting the contractile mechanism (Falk et al., 1995). Others believe that the associations between BL, blood pH and muscle fatigue are indirect (Sahlin & Ren, 1989).

In adults, albeit exclusively male, the recovery of force and power output after intense isometric contraction (Hitchcock, 1989) and after treadmill sprinting (Holmyard, et al., 1994) has been explained. In essence, the restoration of force or power in subsequent performance is said to parallel the time course of the resynthesis of creatine phosphate (CP) in the muscle (Harris, Edwards, Hultman, Nordesjo & Nylind, 1976; Gaitanos, Williams, Boobis & Brooks, 1993), rather than the time course for the clearance of BL.

For example, Holmyard et al (1994) reported that after a 30-second maximal treadmill sprint followed by a passive rest interval of 30 seconds, a high proportion of PP could be restored in a subsequent six-second-treadmill sprint, even when BL concentration was nearly 10 times that of the pre-sprint values. The half time for CP resynthesis is estimated at 22 seconds while full replenishment is estimated at 170 seconds (Harris et al., 1976). On the other hand, the return of elevated levels of blood lactate to pre-exercise levels might take several hours (Dotan, Falk & Raz, 2000).

Comparisons in power recovery in a second or successive WAnT of different durations, and of different recovery intervals, have been made between boys and men (Hebestreit et al., 1994), and between girls and women (Chia, 2001). Despite differences in the methodology between the cited studies, the juxtaposed data suggest that prior exercise such as that performed during a WAnT has a fatiguing or detrimental effect on subsequent power generation in the WAnT for active recovery intervals of 45 seconds (Chia, 2001), one minute, two minutes and 10 minutes (Hebestreit et al., 1994).

The present data set confirmed the cited observations. For instance from Figures 1 and 2 and Table 2, PP and MP attained by men and women in subsequent WAnTs, declined from WAnT 1 to WAnT 5, with the exception for MP in WAnT 3. In men, the mean differences in PP and MP achieved in WAnT 1 and WAnT 5 were 48 ± 35 W and 18 ± 11 W, respectively.

The corresponding mean differences for women were 86 ± 70 W for PP and 21 ± 16 W for MP. Even though the mean difference in PP and MP between WAnT 1 and WAnT 5 in men and women were significantly different, when PP and MP achieved in WAnT 5 were expressed as a percentage of that attained in WAnT 1, men and women demonstrated similar patterns power restoration or recovery (PP: 65 ± 13 vs. $72\pm16\%$; MP: 64 ± 11 vs. $67\pm14\%$; see Table 2).

The similar pattern of power restoration during successive sprints in men and women is interesting considering that PP and MP differences between successive sprints was markedly greater in men than in women. That means that men had a greater magnitude of power to recovery from whereas women had less. However, post-exercise peak blood lactate concentration between men and women was not significantly different. A number of explanations may be considered.

During intermittent maximal exercise, it has been reported that enhanced oxygen availability reduced anaerobic metabolite concentration in the blood, and conversely reduced oxygen availability, thus negatively affected subsequent sprint performance (Balsom et al., 1994a; 1994b).

There is however, evidence to the contrary (e.g. Robach et al., 1997). In the cited study (i.e. Balsom et al., 1994b), the authors reported that reduced atmospheric oxygen availability at high altitude did not impair the restoration of power generated in two 20-second WAnTs compared to the results of a similar experiment conducted at sea level.

In the present study, the men had significantly higher body mass-related peak $\dot{V}O_2$ than women (see Table 1), a finding that is expected as many other studies report similar results (e.g. Armstrong & Welsman, 1997). However, this did not translate to a better restoration of PP and MP in subsequent sprints for men compared to women (see Table 2).

The present result is in agreement with the findings of Aziz, Chia and Teh (2000), which examined the relationship between maximal $\dot{V}O_2$ and repeated sprint performance indices in 17 male field hockey and 23 male soccer players. The researchers reported that there is only a 12% shared variance, between maximal $\dot{V}O_2$ and total sprint time for eight 40-metre sprints that were separated by a 30-second recovery period between sprints.

Interestingly, Aziz, Chia and Teh (2000), reported that higher aerobic fitness did not contribute to the repeated sprint performance of the adult male participants. Contrarily, McMahon (1998) reported that in 20 male rugby players, maximal $\dot{V}O_2$ is an important determinant of the ability to perform intermittent maximal exercise and for the recovery between sprints. Differences in the intermittent sprint protocol, participant characteristics, and the nature of the recovery between the cited studies of Aziz *et al* and McMahon, and the present study might account for the dissimilar findings.

On the balance of evidence, findings appear to be equivocal, with regard to whether a high level of aerobic fitness *per se* facilitated the restoration of muscle power in subsequent exercise. In the present study, the data did not support this hypothesis. It is plausible that there might be a threshold value for aerobic fitness that is beneficial for repeated sprint performance. Thereafter, other physiological processes such as the oxygen uptake transients during high intensity exercise and during the recovery intervals might be more important than the level of aerobic fitness, but further research in this area is advised.

In Figure 3, it can be seen that BL concentration generated by the repeated maximal exercise peaked by three minutes post-exercise in both men and women (since BLconc in men at 3 min. vs. 2 min. and 4 min., $p<0.05$). However, it must be noted that peak BL concentration after exercise is dependent on the type, intensity and duration of the preceding exercise (Chia, Armstrong & Childs, 1997), the nature and type of the recovery (Dotan, Falk & Raz, 2000), and sampling and analytical procedures (Armstrong & Welsman, 1997).

Moreover, BL concentration is a function of its production and its clearance from the blood, and must be taken as a blunt indicator of the processes that occurred at the muscle level during the preceding exercise. It is therefore important to standardize the procedures involved in sampling and analyzing BL after exercise. The interpretation of BL concentration is therefore fraught with difficulties (Armstrong & Welsman, 1997) and prudence is advised when explanations based on BL concentration are made.

Conclusion

Performances of men and women in five 20-second WAnTs separated by active recovery intervals of 45 seconds were described. Results showed that prior sprints of a short duration has a fatiguing effect on subsequent sprint performance and that 45 seconds of active recovery was not sufficient to restore PP and MP achieved in the previous sprint.

Men and women demonstrated similar patterns of power restoration in a series of five WAnTs, which were separated by a 45-second period of active recovery, in spite of differences in PP and MP and peak $\dot{V}O_2$ in men and women. The hypothesis that participants with higher peak $\dot{V}O_2$ had higher power restoration in repeated WAnTs was not supported by the results.

Future research should examine the mechanisms that account for the restoration of power in men and women during intermittent maximal exercise.

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