Original Research

Repeated Sprint Performance in Male and Female College Athletes Matched for VO_2max Relative to Fat Free Mass

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ABSTRACT

Int J Exerc Sci 4(4) : 229-237, 2011. The purpose of this study was to examine gender differences in repeated sprint exercise (RSE) performance among male and female athletes matched for VO_2max relative to FFM (VO_2max FFM). Thirty nine male and female college athletes performed a graded exercise test for VO_2max and hydrostatic weighing to determine FFM. From the results, 11 pairs of males and females matched for VO_2max FFM (mean ± *SD*; 58.3 ± 4.3 and 58.9 ± 4.6 ml·kg FFM^{-1}·min^{-1}; men and women, respectively) were identified. On a separate day, matched participants performed a RSE protocol that consisted of five 6-sec cycle sprints with 30-sec recovery periods, followed by 5-min active recovery and a 30-sec all-out sprint. Repeated 6-sec sprint performance did not differ between men and women; both maintained power output (PO) until sprint 4. PO_{FFM} (W·kg^{-1} FFM) did not differ between men and women during the five sprints. During the 30-sec sprint, men achieved a lower peak PO_{FFM} than women (11.7 ± 1.5 vs 13.2 ± 1.2); however, the decline in PO_{FFM} over 30 sec was greater in women. VO_2 (ml·kg FFM^{-1}·min^{-1}) was lower in men during recovery (24.4 ± 3.8 vs 28.7 ± 5.7) and at the beginning (29.2 ± 4.0 vs 34.7 ± 4.9) and end (49.4 ± 5.0 vs 52.3 ± 4.0). of the 30-sec sprint. These data indicate that men and women with similar aerobic capacities do not respond differently to short repeated sprints but may differ in their ability to recover and perform sprints of longer duration.

KEY WORDS: Anaerobic power, Wingate test, gender differences, aerobic power

INTRODUCTION

Physiological responses to repeated sprint exercise (RSE) and recovery periods are important topics of study for the purpose of developing effective strategies to improve sport performance. With increased participation of women in team sports, understanding gender differences in RSE is a necessary consideration. Relating to RSE performance, anaerobic power is required of the team sport athlete. The Wingate test has been used to test gender differences in anaerobic performance characterized by peak and mean power outputs (12, 13, 16, 18, 22, 26, 30). Women achieve approximately 60% of peak power output of men; however, body mass accounts for much of this difference (26, 30). Differences in metabolism between men and women performing a single Wingate test have been demonstrated with lower lactate accumulation and use of type I fiber glycogen in women (12, 16). Additionally, the relative contribution of the aerobic energy system may be higher in women,

possibly due to less reliance on glycolytic processes (12, 14, 19, 27).

Specific to RSE performance, a decrease in power output from one sprint to the next has been demonstrated in men but not in women during repeated Wingate tests (11). Likewise, when repeated explosive strength or resistance exercises are performed, women demonstrate a slower rate of fatigue and faster acute recovery (14, 17, 20, 27). These types of exercises have been useful in describing anaerobic performance differences between men and women; however, long duration (30 sec) sprints and resistance exercise do not accurately simulate the repeated short duration (< 10 sec) sprints performed during many types of sports. Thus, observing gender differences during repeated short duration sprints may be more applicable to the athlete. Few studies have addressed gender differences in this area and results are somewhat conflicting (2, 9, 20, 32). Billaut et al. (2) observed greater decline in power output during an 8-sec cycling sprint in women compared to men; however women were capable of recovering more power output for a second sprint following a 4-min recovery period. During ten 6-sec running sprints, Brooks et al. (9) observed similar decreases in power output in men and women. Yet, in another study a greater drop in running sprint performance was noted in boys compared to girls performing ten 5-sec sprints (32). Similar results have been demonstrated in adult men and women performing repeated 30-m sprints (20). Overall, physiological differences between men and women in response to RSE are not clearly defined.

Based on the limited data concerning gender differences, evidence suggests that women rely less on glycolytic processes and more on aerobic metabolism during repeated high intensity exercise (11, 14, 19, 27). Aerobic fitness of men and women appears to be related to RSE performance in that those with higher maximal oxygen uptake (VO_2max) or lactate threshold demonstrate less decline in power output (4, 6, 7, 23, 29). Thus, an important consideration when investigating gender differences during RSE is aerobic fitness and training background. Because men typically have higher VO_2max and greater fat free mass (FFM), matching men and women for VO_2max expressed relative to FFM helps to identify males and females with similar aerobic capacities and thus, may provide some clarity to gender differences during RSE. Therefore, the purpose of this study was to examine gender differences in RSE performance among male and female athletes matched for VO_2max relative to FFM (VO_2max FFM). We hypothesized that women would demonstrate less of a decline in power output during short repeated sprints and a greater recovery of power output following 5 min of active recovery.

METHODS

Participants

Thirty-nine college athletes (17 males and 22 females) were recruited from Division II university sport teams. Participants represented men's soccer, women's soccer, baseball, softball, women's basketball and volleyball. Each participant read and signed an informed consent form approved by the university's Institutional Review Board. All participants were free of injury or illness and at low risk for a cardiovascular event during exercise.

Protocol

Hydrostatic weight of each participant was obtained via hydrostatic weighing to determine percent body fat and FFM. Measurements were taken with a calibrated Chatillon 806H mechanical scale (Precision Weighing Balances, Hartford, MA) read to the nearest 0.1 kg while the participant was completely submerged underwater and had blown out as much air as possible. Repeated measures were taken until there was no further increase in hydrostatic weight and at least 5 measurements had been obtained. The highest three measures were averaged and recorded as the participant's hydrostatic weight. Body density was estimated by correcting for residual volume and gas trapped in the GI tract, which was assumed to be 100 ml (31). Residual volume was obtained using the Crapo prediction equation (10). The Siri Equation (28) was used to convert body density to percent body fat of each participant. FFM was calculated as body mass x (1- the fraction of body fat).

Following the hydrostatic weighing, the participant completed a GXT on a motorized treadmill (Quinton, Medtrack SR60, Bothell, WA) for measurement of VO_2max. Prior to each test, flow volume and gas (CO_2 and O_2) calibrations were performed on an automated gas analyses system (ParvoMedics TrueOne 2400, Sandy, UT). A 16% O_2 and 4% CO_2 gas mixture was used to calibrate the gas analyzers. The flow meter was calibrated at various flow rates using a 3-L syringe.

The GXT protocol was continuous and included 2-min stages performed at a running speed determined during a 5-min warm-up period and associated with a rate of perceived exertion of 12-13 on the Borg scale (8). During the test, running speed was maintained while incline was increased 2.5% at each stage until volitional exhaustion. Vigorous prompts and encouragement were provided, especially during the final minutes. Throughout the GXT oxygen uptake was measured continuously from the collection and analyses of expired air. VO_2max was determined from the average of single-breath data collected during the final 30 sec. VO_2 ($ml \cdot min^{-1}$) was divided by FFM (kg) to determine VO_2max FFM.

All 39 participants performed the GXT and hydrostatic weighing. Tests were completed in the same order and on the same day. Eleven pairs of males and females matched for VO_2max FFM were scheduled to complete a RSE protocol.

Repeated Sprint Exercise

Prior to performing the RSE protocol, the men and women paired for VO_2max FFM completed a questionnaire that included daily dietary, sleep and training habits. From this, we concluded that the participants did not vary remarkably in schedules and habits (all athletes lived on the university campus and consumed daily meals from the student cafeteria). Further, it did not appear that any athlete was attempting to lose weight through dieting or excessive exercise. In preparation for the RSE, each participant was provided an energy bar and nutrition supplement drink (480 calories total) to consume during the 24-hr period prior to the RSE. Instructions covering the two days prior to the RSE included the following; consume meals regularly, consume the additional 480 calories the day before the test, drink extra fluids, avoid alcohol at least 24-hr prior, consume a meal and extra fluids 2-3 hrs

prior, and get adequate sleep the night before the test. Participants were also instructed to consume additional carbohydrates (a list of carbohydrate-rich foods typically available to the participants was provided) the evening before and the morning of the RSE.

Body weight was measured daily for five days prior to the RSE at the same time each day. Day-to-day fluctuations did not exceed ±2% of original body weight and all but two participants began the RSE at a higher body weight. RSE was scheduled so that the participant did not engage in strenuous physical activity during the 24-hr period prior to the test. All participants reported that instructions were followed and were able to consume additional calories during the two days prior to the RSE.

A Monark Ergomedic 894E Peak Cycle (HealthCare International, Seattle WA) was used for the RSE protocol. The protocol consisted of a 5-minute warm-up that included three short maximal accelerations. Resistance on the cycle flywheel was set at 7.5% of body mass. The protocol began with five 6-sec sprints separated by 30-sec active recovery periods. The fifth sprint was followed by a 5-min active recovery. Following the recovery, an all-out 30-sec sprint was performed. During the recovery periods, participants maintained 40-50 RPMs while pedaling against 1.0 kg load. The average absolute power output (PO, Watts) achieved during each of the 6-sec sprints was determined. Peak power output (PPO) was calculated from the initial 5 sec and the final power output (FPO) was calculated from the final 5 sec during the 30-sec sprint. Power output was expressed in absolute terms and relative to FFM (PO_{FFM}, $Watt \cdot kg^{-1}$ FFM).

For VO_2 measures, single breath expired gases were collected continuously throughout the RSE protocol. VO_2 measures were expressed relative to FFM (VO_{2FFM}) and determined from the average of the single breath data during each 6-sec sprint, the 5-min recovery period, and the initial and final 5 seconds of the 30-sec sprint. Metabolic calibrations as described earlier were performed prior to each RSE.

Statistical Analysis

Data are presented as mean and standard deviation (*SD*). Significance was set at $p \leq .05$. The five 6-sec cycle sprints were analyzed using a two-way repeated-measures ANOVA (sprint x gender). In the case of a significant sprint effect, a Bonferroni test for multiple comparisons was performed and significance readjusted to $p \leq .01$ (.05/5). Two-way repeated measures were also performed to test differences between the initial 5 sec and final 5 sec of the 30-sec sprint and the interactive effect between gender and time. For descriptive characteristics, a paired *t*-test was used to compare genders. Analyses of data were completed using the Statistical Package for the Social Sciences, version 17 (SPSS Inc, Chicago, IL).

RESULTS

Of the 39 participants tested, 11 male (6 baseball and 5 soccer athletes) and female (5 soccer, 4 softball, 1 volleyball and 1 basketball athlete) pairs were identified based on VO_2max relative to FFM. Group characteristics are presented in Table 1. Percent difference in VO_2max FFM between matched pairs ranged from 0.1 to 2.6% (mean ± SD, 1.0 ± 0.8%).

Table 1. Descriptive characteristics of male and female participants matched for VO_2max relative to FFM.

	Men	Women
Age, yr	20.8 ± 1.1	19.7 ± 1.8
Height, cm	182.0 ± 4.9	166.4 ± 5.6*
Body mass, kg	81.7 ± 11.0	62.5 ± 4.9*
Body fat, %	8.5 ± 4.6	21.6 ± 4.0*
Fat free mass, kg	74.4 ± 8.0	49.0 ± 4.3*
VO_2max, l·min^{-1}	4.32 ± 0.45	2.87 ± 0.29*
VO_2max, ml·kg BM^{-1}·min^{-1}	53.1 ± 5.1	46.1 ± 3.3*
VO_2max, ml·kg FFM^{-1}·min^{-1}	58.3 ± 4.3	58.9 ± 4.6

* denotes gender difference, $p \leq 0.05$. BM = body mass, FFM = fat free mass.

Men achieved higher absolute PO than women during each of the five sprints and at the beginning and end of the 30-sec sprint (Table 2). The main effect of 6-sec sprints was a decline in PO but multiple comparison statistics revealed this to occur only between sprint 2 and each of the final two sprints. FPO at the end of the 30-sec sprint was lower than PPO for both men and women. There was no interactive effect between sprints and gender.

Table 2. Absolute power output during each of the five 6-sec sprints and during the 30-sec sprint.

	Watts	
Sprint	Men	Women
1	929 ± 100	639 ± 77*
2	953 ± 126	640 ± 65*
3	921 ± 141	625 ± 48*
4†	890 ± 119	626 ± 66*
5†	888 ± 148	607 ± 68*
PPO	870 ± 135	648 ± 85*
FPO	418 ± 62‡	278 ± 54*‡

* denotes gender difference, $p \leq 0.05$. † $p \leq 0.01$ from sprint 2. ‡ $p \leq 0.05$ from PPO. PPO = initial 5 sec of 30-sec sprint, FPO = final 5-sec of 30-sec sprint.

No gender differences in PO_{FFM} during the five 6-sec sprints were observed (Figure 1). During the 30-sec sprint, PPO_{FFM} was higher in women while no difference in FPO_{FFM} between men and women was seen. PPO_{FFM} was greater ($p \leq .05$) than FPO_{FFM} in both men and women and an interactive effect between PO_{FFM} and gender revealed a greater ($p \leq .05$) decline in PO_{FFM} in women during the 30sec sprint.

During the five 6-sec sprints, VO_{2FFM} increased from sprint 1 to sprint 2, with no further increases observed thereafter (Figure 2). VO_{2FFM} did not differ between men and women during the 6-sec sprints. During the 5-min recovery period, VO_{2FFM} was lower in men. From initial to final, VO_{2FFM} increased during the 30-sec sprint in both men and women ($p \leq .05$). However, VO_{2FFM} was lower in men than women.

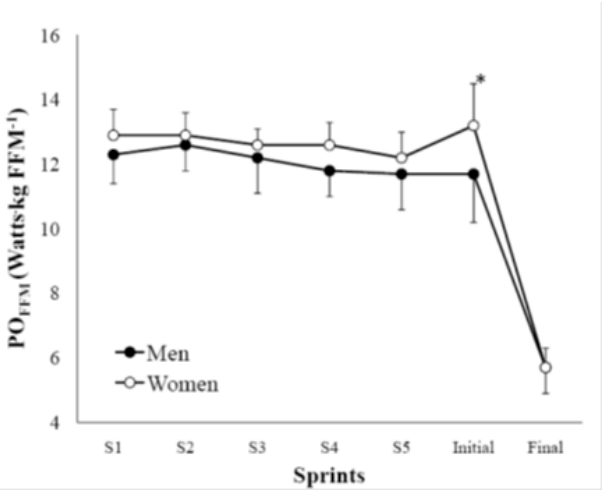

Figure 1. Power output relative to fat free mass in men and women during five 6-sec sprints and the initial and final 5 sec of a 30-sec sprint performed after a 5-min recovery period. * denotes gender difference, $p \leq 0.05$.

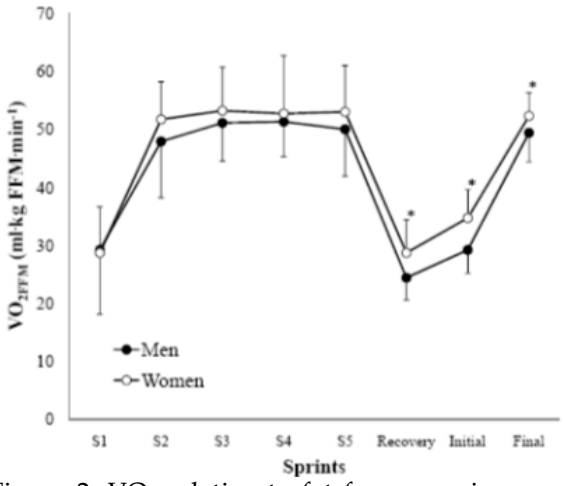

Figure 2. VO_2 relative to fat free mass in men and women during five 6-sec sprints, 5-min recovery and the initial and final 5 sec of a 30-sec sprint. * denotes gender difference, $p \leq 0.05$.

DISCUSSION

We tested repeated sprint performance in male and female college athletes matched for VO_2max relative to FFM and observed no difference between genders in the ability to maintain power output during five 6-sec cycle sprints. A previous report also found a similar decline in power output over 10 sprints between men and women despite the greater work output in men (9). However, gender differences have been reported elsewhere (2, 11, 32). In one study, women demonstrated greater decline in power output during an 8-sec sprint, but recovered more power output for the second sprint compared to men (2). During three 30-sec sprints, Esbjörnsson-Liljedahl et al. (11) observed a significant decrease in power output from sprint 1 in men, but not in women. Further, a greater power output decline in males has been shown during repeated running sprints (20, 32). It is possible that inadequate matching of men and women for aerobic capacity could have contributed to the observed differences reported in these studies. Likewise, the lack of gender difference in this study regarding power output loss during short sprints may be attributed to the similar aerobic capacity between men and women.

In this study, men and women actively recovered for five minutes following the five 6-sec sprints before an all-out 30-sec sprint was performed. We observed a greater recovery of PO_{FFM} in women at the beginning of the 30-sec sprint compared to men. A higher rate of recovery following high intensity exercise in women has been previously demonstrated (2, 14, 17). As noted earlier, Billaut et al. (2) observed greater recovery of power output when a second 8-sec sprint was performed following a short recovery period. Likewise, faster acute recovery from intermittent isometric exercise performed at maximal voluntary contraction has been demonstrated in women (14, 17). Because recovery during repeated sprints relies heavily on aerobic processes (1, 5, 7, 15), the greater recovery of PO demonstrated in women in this study may be associated with a greater aerobic contribution to recovery, evidenced from the higher VO_{2FFM} observed in women.

In addition to having a higher PPO_{FFM}, women in this study demonstrated a greater absolute drop in power output during the 30-sec sprint. Contrary to this, the decrease in power output during the Wingate test has been reported to be lower in women (13). However, the greater drop observed in men may have been related to their higher initial PO because when change in power output is expressed as a relative change ((PPO-FPO)/PPO x 100), the differences disappear (13, 18, 30). Thirty-second sprint performance following four minutes of recovery is characterized by

an increased reliance on aerobic energy processes associated with phosphocreatine depletion and a reduction in glycolytic rate (7). As an indication of this, we observed an increase in VO_2 in both men and women during the sprint. However, VO_2 was higher in women than men, despite the greater drop in power output. Evidence that women rely more on oxidative phosphorylation compared to men during high intensity exercise has been shown (19, 27). Further evidence for this is the lower rate of glycogen use observed in women during repeated 30-sec sprints (11). Thus, it is possible that women do not draw from glycolytic processes enough to maintain power output and may rely more heavily on aerobic processes (11, 14, 19, 27).

A limitation to this study is that VO_2max was determined from a treadmill GXT, while repeated sprint performance was measured during cycling. Thus, it is possible that men and women were not matched for cycle VO_2max relative to FFM. If there were differences between men and women, this could confound the results. Another limitation is that diet intake was not controlled prior to RSE; thus it cannot be accurately determined if athletes maintained adequate intake. However, given that body weight change was minimal for five days prior to the RSE and that most athletes demonstrated an increase in body weight, we believe this provides some evidence that the athletes received adequate hydration and energy intake prior to the RSE protocol.

In summary, when matched for VO_2max relative to FFM, male and female college athletes achieve similar PO_{FFM} during five 6-sec sprints separated by 30 seconds of active recovery. During an active 5-min recovery, women demonstrated higher VO_{2FFM}. Following this recovery period, women were better able to recover power output at the beginning of a 30-sec sprint, but then demonstrated a greater drop in PO despite having higher VO_{2FFM} at the beginning and end of the sprint. These data indicate that men and women with similar aerobic capacities do not respond differently to short repeated sprints but may differ in their ability to recover and perform sprints of longer duration. Our results contribute to the limited data concerning gender differences in sprint performance; however, further research directed toward the physiological mechanisms associated with faster recovery in women is needed. Addressing this issue with a training study that includes men and women initially matched for aerobic and anaerobic powers might add significant insight into the gender differences observed during repeated sprints. Women's increased participation in team sports raises the importance of learning how men and women differ in response to exercise in order to develop effective training strategies for each gender. Regarding current training practices, our data suggest that male athletes may benefit by shifting the focus somewhat away from peak power improvements and toward enhancing aerobic endurance or ability to recovery from repeated sprints. Female athletes may benefit from an increased focus on anaerobic endurance or ability to sustain high power output for long durations.

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