Repeated Sprint Performances among Girls and Women
少女與婦女的無氧能力

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Abstract

The aim of the study was to compare between girls and women, the recovery of Wingate Anaerobic Test (WAnT) power after two prior sprints of 15-seconds' duration with a short active recovery interval in-between the sprints. Participants with written informed consent were 19 girls (age: 13.6±1.0yrs; body mass: 51.2±7.6kg & stature: 1.59±0.06m) and 21 women (age: 25.1±2.7yrs; body mass: 57.9±7.7kg & stature: 1.61±0.05m). Lower limb muscle mass was determined using a Dual-energy X-ray Absorptiometric (DXA) procedure. Following a standardized warm-up, each participant completed a series of three 15-second WAnTs, with each test separated by a 45-second active recovery interval. WAnT power variables were computed over 1-second time periods and were corrected for the inertia of the cycle ergometer (Monark 834E). Whole blood lactate concentrations (BL) were obtained immediately post warm-up and at three minutes after the completion of the third WAnT. Peak power (PP), expressed in watts per lower limb muscle mass (W. kg^{-1}LLMM) were significantly greater in women than in girls in the first 15s WAnT (46.1±10.9 vs 37.4±2.3W.kg^{-1}LLMM, $p<0.05$). However mean power (MP) over the first test was not significantly different between the girls and women (33.8±2.1 vs 34.7±5.9W.kg^{-1}LLMM, $p>0.05$). Girls were better able to replicate their power achieved in the first WAnT, in the third WAnT than women (mean of the differences ± standard deviation of the differences for PP: 84±47W vs 174±84W; MP: 81±45W vs 161±65W, $p<0.05$). Despite the better recovery in WAnT power in girls during the third 15s cycle sprint, BL taken at post- warm–up (2.5±0.5 vs. 1.9±0.5 mM.L^{-1}, p >0.05), and at three minutes post exercise (9.2±1.2 vs. 8.4±1.3 mM.L^{-1}, p >0.05) were not significantly different in girls and women.

摘 要

本文以溫蓋特無氧功率試驗（Wingate Anaerobic Test, WAnT） 為研究方法，重複測定了少女和婦女15秒的無氧功率，旨在比較少女與婦女之間的無氧能力極其恢復。受試對象為19名少女(年齡：13.6±1.0歲；體重：51.2±7.6公斤；身高：1.59±0.06米）和21名婦女（年齡：25.1±2.7歲；體重：57.9±7.7公斤；身高：1.61±0.05米）。以雙光能X光吸收儀（DXA）測定受試者下肢的瘦體重。在標準化的準備活動之後，受試者在自行車測功儀（Monark 834E)上完成3次15秒最快速度的踏車運動，各次運動之間以45秒的活動性休息為間隔。在準備活動後即刻和第三次運動試驗后3分鐘采血測定血乳酸濃度。在首次15秒WAnT測試中，婦女組的最高功率（46.1±10.9瓦·公斤下肢瘦體重$^{-1}$）明顯高于少女組（37.4±2.3瓦·公升$^{-1}$肢瘦體重$^{-1}$，p<0.05），而婦女組與少女組的平均功率無顯著性差異，分別為34.7±5.9瓦·公升$^{-1}$肢瘦體重$^{-1}$與33.8± 2.1瓦·公升$^{-1}$肢瘦體重$^{-1}$（p>0.05）。第三次15秒運動試驗中，少女組的無氧功率明顯地較婦女組接近第一次WAnT測試中所達到的功率（p<0.05），最高功率均值差分別為84±47瓦與174±84瓦；平均功率均值差分別為81±45瓦與161±65瓦。雖然少女組在WAnT測試中顯示出較好的恢復能力，但無論是準備活動后還是第三次WAnT運動試驗后，少女組與婦女組血乳酸濃度的相差無顯著性意義（p>0.05），分別為2.5±0.5毫克分子·升$^{-1}$與1.9±0.5毫克分子·升$^{-1}$及9.2±1.2毫克分子·升$^{-1}$與8.4±1.3毫克分子·升$^{-1}$。

Introduction

Many team sports such as field hockey and netball require sporadic bursts of intense exercise (such as sprinting to cover ground during a counter attack) followed by periods of active recovery (such as jogging back to position) between such intense bouts of exercise. This routine of intense exercise interspersed by brief active recovery periods may be repeated many times over in the course of the game. The ability to recover quickly following intense prior exercise is therefore an important pre-requisite for sustaining high performance in any team sport. Intense prior exercise may impair muscle performance during a subsequent exercise bout. The recovery in muscle performance is dependent on the intensity, mode and duration of the prior exercise and also the nature and time of the recovery interval between the exercise bouts (Hitchcock, 1989; Hebestreit, Minura & Bar-Or, 1994; Sargeant & Dolan, 1987). A number of studies have shown that young people, albeit, all male participants, recovered faster than male adults after intense exercise. For instance, the recovery heart-rate following high intensity exercise is lower in children than in adults (Baraldi, Cooper, Zanconato & Armon, 1991). Additionally, Hebestreit et al (1994) reported that pre-pubertal boys recovered faster than adult men, following two 30s Wingate Anaerobic Test (WAnT) that were separated by recovery intervals of 1-, 2- and 10 minutes. However, the recovery in muscle function following intense prior exercise of a brief nature in female participants remains apparently unexamined and is in need of redress. Therefore, the purpose of the study was to compare the power recovery in the WAnT, in a group of girls and in a group of women.

Methods

Participants

Participants with informed written consent were 19 girls and 21 women. Date of birth and date of testing were used to compute the age of the participants. Body mass and stature of the participants were determined using a calibrated Avery 3306 ABV beam balance scales and a Holtain stadiometer, respectively. Lower limb muscle mass (LLMM) was determined using a Dual-energy X-ray Absorptiometric (DXA) procedure. The girls were from a secondary school whilst the women were university students. All participants were physically active but were not receiving any form of specialized sports training.

Wingate Anaerobic Test (WAnT)

The WAnT was conducted on a cycle ergometer (Monark Model 834E) and was calibrated in accordance to the manufacturer's instructions prior to the test sessions. Participants were habituated to the test protocol prior to the testing session. Saddle height was individually determined such that that was a slight bend at the knee when the pedal was at the lowest point of the cycle. Toe-clips were used to secure the feet to the pedals. . The test applied force was individually set at 0.74 $N \cdot kg^{-1}$ body mass (BM). The test protocol involved a standardized warm-up that consisted of four minutes of cycling at a steady rate of 60-70 revolutions per minute (rpm), against a minimal applied force (with the load basket supported). Incorporated into the four minutes of cycling were three all-out intensity sprints of 2-3 seconds' duration set against the test applied force. After four minutes of cycling, participants were taken through a series of specific and static stretches for the hamstrings, quadriceps and the groin muscles. The stretching took about two minutes. Participants were then sat on the saddle after which a capillary blood sample was taken from the thumb using a Softclix, II (Mannheim, boehringer) device. This was subsequently analyzed for whole blood lactate concentration (BL) using an automated and self-calibrating lactate analyzer (YSI 2500).

Multiple Sprint and Recovery Protocol

Participants each completed a series of three 15-second WAnT that were each separated by a 45-second active rest period where participants pedalled against a minimal applied force. Each sprint was initiated by asking the participant to pedal at between 60 and 70 rpm, after which a count-down of "3-2-1-Go" was given. On the word "Go", the participant pedalled as fast as they could against the test applied force, whilst remaining seated throughout the test. A clock was set for the active recovery and when 35 seconds of active rest time had elapsed, the participant was asked to take the pedal rpm up to between 60 and 70. A second count-down of "3-2-1-Go" was given to time it such that the participant was again pedalling as fast as she could, into the second 15-second sprint, at the 46^{th} second after the first 15-second sprint. The procedure was repeated for the third 15-second sprint. Verbal encouragement was given to all participants throughout the test. After the third sprint, another capillary blood sample was taken at three minutes post-exercise. This was subsequently analyzed for BL. Participants were encouraged to pedal for another five minutes at a self-selected pedal cadence, to recover from the three sprints. After cycling, they were also encouraged to lay supine with their feet elevated above their heart level, on a recovery coach for another five minutes.

Variables of Interest

Peak power (PP) and mean power (MP) in all three WAnT sprints were integrated over 1-second time periods and were also adjusted to take into account the inertia of the flywheel in accordance to the recommendations of Chia, Armstrong and Childs (1997). The differences between the power outputs in first and third sprints were computed to reflect the extent of recovery in power in the third WAnT in the girls and the women.

Statistical Analysis

Data garnered were stored in database and were subsequently analyzed using SPSS for windows software (version 10.0). Data normality for PP and MP and for LLMM were checked using normality plots and by examining the Sharpiro-Wilks outcome statistics for those variables. Descriptive statistics (means ± SD) of the participants for age, stature, body mass LLMM, PP and MP in the WAnT and BL were generated. Bivariate Pearson Product Moment correlations were used to establish the relationships between PP and MP in the WAnT with body size descriptors, BM and LLMM. Power values were expressed in ratio to BM and LLMM. Differences between power outputs in the first and third WAnTs were also described as means ± SD. Homogeneity of variances between the data sets of the girls and the women were examined using the Levene test statistic. Differences in power in the WAnT between sprint 1 and sprint 3 in the girls and women were analyzed using repeated measures analysis of variance (RM-ANOVA). Differences in WAnT performances and the extent of the recovery of power in the WAnT, between girls and women, were analyzed using one-way analysis of variance (ANOVA). Statistical significance was set at $p < 0.05$.

Results

Data Normality and Homogeneity of Variance

Normality plots for PP and MP in both data sets and statistical tests for normality of distribution were confirmed (Sharpiro-Wilks test statistic, $p > 0.05$). In comparing the data sets between girls and women, there was also homogeneity of variances (Levene test statistic, $p > 0.05$).

Physical Characteristics

The physical characteristics of the girl and women participants are shown in Table 1.

Table 1. Physical Characteristics of the Participants.

Variable	Girls (N=19)	Women (N=21)
Age (yrs)	13.6±1.0	25.1±2.7*
Stature (m)	1.59±0.06	1.61±0.05
Body mass (kg)	51.2±7.6	57.9±7.7
Lower limb muscle mass (kg)	12.5±1.2	12.8±1.9

* difference between girls and women is significant at $p<0.05$.

The women were significantly older than the girls. However, the girls had similar body mass and stature as the women. Additionally, LLMM, as determined using DXA was not significantly different between the girls and women.

Associations between Power in the WAnT and Body Size Descriptors

Bivariate Pearson Product Moment correlation coefficients for power in the first 15-second WAnT and body size descriptors are summarized in Table 2. In girls, both PP and MP were better associated with LLMM than with BM but the situation in women was reversed.

Table 2. Associations between Power in the First WAnT and Body Size Descriptors in Girls and Women.

WAnT variable	Pearson Product Moment correlation coefficient (BM)	Pearson Product Moment correlation coefficient (LLMM)
PP (in girls)	0.79*	0.88*
MP (in girls)	0.83*	0.93*
PP (in women)	0.56*	0.31
MP (in women)	0.55*	0.36

* denotes statistical significance at $p<0.05$.

Power in the First 15-second WAnT

Peak power (PP), expressed in watts per lower limb muscle mass ($W.kg^{-1}$LLMM) were significantly greater in women than in girls in the first 15s WAnT (46.1±10.9 vs. 37.4±2.3$W.kg^{-1}$ LLMM, $p<0.05$). However mean power (MP) over the first test was not significantly different between the girls and women (33.8±2.1 vs. 34.7±5.9$W.kg^{-1}$LLMM, $p>0.05$). However, when expressed in ratio to BM, girls and women generated similar PP (9.0±0.7 vs. 10.1±2 $W.kg^{-1}$BM, $p>0.05$) and MP (8±0.6 vs. 7.7±1.2$W.kg^{-1}$BM, $p>0.05$)

Power in the Multiple Sprints and Blood Lactate Concentrations

Table 3 is a summary of the WAnT power achieved in the three 15-second sprints in the girl and women participants. Active recovery periods of 45 seconds separated sprint 1 from sprint 2 and sprint 2 and sprint 3. BL taken at post- warm–up (2.5±0.5 vs. 1.9±0.5 $mM.L^{-1}$, $p>0.05$), and at three minutes post exercise (9.2±1.2 vs. 8.4±1.3 $mM.L^{-1}$, $p>0.05$) were not significantly different in girls and women.

Table 3. Exercise Performances of Girls and Women in the Three WanTs.

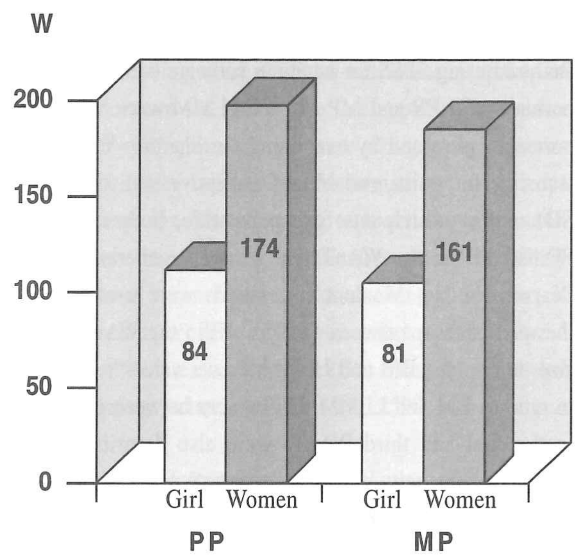
Group	WAnT variable	Sprint 1	Sprint 2	Sprint 3
Girls	PP [W]	471±61	421±67	387±71*
	MP [W]	422±58	371±58	341±53*
Women	PP [W]	584±145	526±133	410±122*
	MP [W]	439±65	367±48	277±38*

* denotes significant difference between sprint 1 and sprint 3.

Recovery in WAnT Power in Girls and Women

Figure 1 depicts the recovery in PP and MP in girls and women in terms of mean of the differences±SD of the differences. In terms of mean percentages, girls were able to achieve 82% of their PP and 81% of their MP in the third WAnT of that achieved in the first WAnT. In women, the corresponding percentages were 70% for PP and 63% for MP, using the same mode of comparison.

Figure 1. Mean Difference in Power (W) in the WAnT between Sprint 1 and Sprint 3 in Girls and Women. The Differences between the Extent of Recoveries in PP and MP were significant ($p<0.05$) between Girls and Women.



Discussion

In adults, the recoveries of force and power output after intense isometric (Sahlin & Ren, 1989), cycling (Hitchcock, 1989) and treadmill-sprint (Holmyard, Nevill, Lakomy & Pereira, 1994) exercise have been examined. Although the cited studies differed in test protocol, the consensus explanation for the recovery in muscle power after intense exercise is that it parallels the time course for the re-synthesis of intra-muscular creatine phosphate (CP) (Harris, Edwards, Hultman, Nordesjo & Nylind, 1976). In contrast, data that elucidate the recovery in power following intense exercise in young people are sparse. Apparently no previous study has examined the recovery of power in the Wingate Anaerobic Test following prior all-out intensity sprints of a short duration in girls and women. The main finding in this study was that girls were better able to replicate their power achieved in the first WAnT, in the third WAnT than women (mean of the differences±standard deviation of the differences for PP: 84±47W vs. 174±84W; MP: 81±45W vs. 161±65W, $p<0.05$; see Figure 1). Notwithstanding that there are absent data on female participants, a number of studies have shown that young people recovered faster than adults after high intensity exercise. For instance, Baraldi *et al*, demonstrated that heart-rate following high intensity exercise was lower in children than in adults. Lending support also are the findings of Hebestreit *et al*. In their study, the authors reported that pre-pubertal boys attained nearly 90% of MP achieved in the first 30s WAnT compared with 71% of MP in men, following an active recovery period of 60 seconds. In the present study, in terms of mean percentages, girls were able to achieve 82% of their PP and 81% of their MP in the third WAnT of that achieved in the first WAnT. In women, the corresponding percentages were 70% for PP and 63% for MP, using the same mode of comparison. It should be pointed out that there are notable differences in the test protocols over the two studies. Firstly, the study conducted by Hebestreit *et al* used male subjects (8 boys and 8 men), involved two 30s WAnT that were separated by recovery intervals of 1-, 2- and 10 minutes whereas the present study involved female subjects, and involved three 15s WAnT that were each separated by active recovery intervals of 45 seconds each. Secondly, in the present study, the comparisons in recovery of power achieved in the WAnT were between those achieved in the first sprint and those attained in the third sprint whereas, in the cited study of Hebestreit *et al*, the recovery in MP was compared between the second and the first 30s WAnT. Even so, by juxtaposing the findings of Hebestreit *et al* and the present study, it can be argued that the recovery in power in the WAnT, following prior sprint(s) of a brief nature is faster in young people of both sexes than in adults.

In the present study, PP expressed in ratio to LLMM was significantly higher in women than in girls, but MP in $W.kg^{-1}$LLMM, as was, PP and MP expressed in ratio to BM, were similar in girls and women. BL taken immediately post warm-up, and at three minutes after the third 15s WAnT were also similar in girls and women. A previous explanation for the swifter recovery in power following prior high intensity exercise, has been that since boys generated significantly lower power outputs in the WAnT than the men, their recovery in power in the subsequent sprint was therefore swifter than the men (Hebestreit *et al*, 1994). This same explanation appears untenable in the present study as only PP in $W.kg^{-1}$LLMM was higher in the women than the girls. Given that young girls are known to have typically higher body mass related peak $V0_2$ than women (Armstrong & Welsman, 1997), that young people have swifter and shorter oxygen uptake transients than adults in response to intense exercise (Barstow, 1994), and that oxygen is necessary for the resynthesis of intra-muscular CP (Gaitanos, Williams & Boobis, 1993), it may be argued that the time-course for the resynthesis of CP in young people could be faster than those that have been documented for adults. Of course further research is recommended to prove or debunk the conjecture.

With reference to PP and MP generated in the first 15s WAnT, the finding that in girls, both power outputs were significantly correlated with LLMM is expected, but the situation where LLMM in women was not significantly correlated with PP or MP, but instead was significantly correlated with BM was unexpected. The result suggested that in women, power output cannot be simply explained by the amount of LLMM as was primarily the case in the girls. It is difficult to speculate whether these difference between girls and women are due to physiological phenomena or due to subject sampling.

In conclusion, power recovery in the WAnT after prior sprints of a brief nature, was swifter in girls and than in women. Girls were able to achieve 81-82%, and women 63-70% of the power attained in the first WAnT, in the third WAnT. Differences in peak $V0_2$, oxygen uptake transients in response to intense exercise and the time course for the resynthesis of CP between girls and women could account for the faster recovery in power in the WAnT in girls.

References

Armstrong, N., & Welsman, J. (1997). *Young People and Physical Activity*. Oxford, UK: Oxford University Press.

Baraldi, E., Copper, D.M., Zanconato, S. & Armon, Y. (1991). Heart-rate recovery from 1 minute of exercise in children and adults. *Pediatric Respiration*, *29*, 575-579.

Barstow, T.J. (1994). Characterisation of oxygen uptake kinetics during heavy exercise. *Medicine & Science in Sports & Exercise*, *26*, 1327-1334.

Chia, M., Armstrong, N., & Childs, D. (1997). The assessment of children's anaerobic performance using modifications of the Wingate anaerobic test. *Pediatric Exercise Science*, 9, 80-89.

Gaitanos, C.G., Williams, C., & Boobis, L.H. (1993). Human muscle metabolism during intermittent maximal exercise. *Journal of Applied Physiology*, *75*, 712-719.

Harris, R.C., Edwards, R.H.T., Hultman, E., Nordesjo, L.O., & Nylind, B. (1976). The time course of phosphocreatine re-synthesis during recovery of the quadriceps muscle in man. *Plug. Arch-European Journal of Physiology*, *367*, 137-142.

Hebestreit, H., Minura, K-I., & Bar-Or, O. (1994). Recovery of muscle power after high intensity short-term exercise: comparing boys to men. *Journal of Applied Physiology*, *74*, 2875-2880.

Hitchcock, H.C. (1989). Recovery of short term power after dynamic exercise. *Journal of Applied Physiology*, *5*, 667-681.

Holmyard, D.J., Nevill, M.E., Lakomy, H.K.A., & Santana Pereira, J. (1994). Recovery of power output after maximal treadmill sprinting. *Journal of Sports Science*, *12*, 140.

Sahlin, K., & Ren, J.M. (1989). Relationship of contraction capacity to metabolic changes during recovery from fatiguing contraction. *Journal of Applied Physiology*, *67*, 648-654.

Sargeant, A.J., & Dolan, P. (1987). Effect of prior exercise on maximal short term power output in humans. *Journal of Applied Physiology*, *63*, 1475-1480.