Original Article

LOAD ASSIGNMENT OF WINGATE TEST IN MINOR OVERFAT YOUNG ADULTS—IS COUNTING THE FAT MASS A PITFALL?

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It was wondered if the counting of fat mass (FM) in the workload of Wingate test (WAnT) of 75 g.kg^{-1} total body mass (TBM) would invalidate the test on evaluating leg anaerobic power in minor overfat young adults. This study examined the hypothesis that the neglect of FM in the WAnT workload assignment would improve the peak power (PP), mean power (MP) and fatigue index (FI) in minor overfat subjects. In this study, we found in 16 male and female young adults with normal percent body fat (%BF) that the WAnT workloads of 86 g.kg^{-1} and 95 g.kg^{-1} fat free mass, respectively, could develop the PP, MP and FI equivalent to those obtained from the original workload of 75 g.kg^{-1} TBM. When these new workloads were applied to 18 male and 15 female subjects with a little above-normal %BF, the PP and MP, but not the FI, were declined from the original values ($p < 0.05$). The declines were positively correlated to their %BF ($p < 0.05$). Such findings do not support our hypothesis. The findings show that the neglect of FM in the WAnT workload assignment lessens the maximum anaerobic power output of the minor overfat subjects. It further suggests that the counting of FM in the traditional WAnT workload of 75 g.kg^{-1} TBM may not impair their maximum performance. However, the interpretation of lack of negative influence of FM on the WAnT performance in minor overfat young adults should be made with caution.

Keywords: anaerobic power, fat mass, Wingate test, workload, young adults

Introduction

The Wingate test was developed in the 1970s at the Department of Research and Sport Medicine of the Wingate Institute for Physical Education and Sport in Israel. The classic test, which has long been considered to be a useful tool in the exercise physiology laboratory, has high validity ($r > 0.75$) and reliability ($r > 0.89$) for assessing anaerobic power as well as fatigability in the arms and legs (Inbar et al. 1996). For performing the Wingate anaerobic test (WAnT) for leg, subjects are required to cycle continuously and maximally for 30 seconds. The peak power that usually appears within the first 3–5 seconds represents the capacity of the immediate energy source of stored phosphagen; the mean power generated over the 30 seconds describes the maximal glycolytic power—anaerobic capacity (Dotan 2006).

Inbar et al. (1974) developed the WAnT and defined the workload at 75 g.kg^{-1} total body mass (TBM) of the subject. Van Praagh and Franca (1998) noted that there was a methodological shortcoming in the WAnT as

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the workload recommended was based on the TBM and did not take into account the active muscle mass. In humans, TBM is composed of several components including the mass of fat, bone, viscera and muscle, and it can be generally divided into fat mass (FM) and fat free mass (FFM). It is believed that the fat tissues, mainly the storage fat, in the body do not contribute to one's anaerobic power. Üçok et al. (2005) showed that the assignment of WAnT workload according to lean body mass would be more appropriate in young males. However, the influence of counting the FM in the WAnT workload on the maximal leg power output was not reported. It was not known if neglecting the FM in the WAnT load assignment could optimize the test in assessing the leg anaerobic power in young adults with excessive body fat. The purpose of this study was to investigate the influence of FM on evaluating leg anaerobic power with the WAnT workload of 75 g.kg^{-1} TBM in minor overfat young adults. We hypothesized that the WAnT workload assigned according to the FFM, which was equivalent to the original WAnT workload of 75 g.kg^{-1} TBM in normal young adults, would enhance the WAnT performance in minor overfat young adults.

In this study, experiments were divided into Phase I and Phase II. Phase I was to identify the WAnT workload, which was expressed as g.kg^{-1} FFM, in the subjects with normal percent body fat (%BF) that could develop maximal leg power equivalent to that obtained from the original test with workload of 75 g.kg^{-1} TBM (WAnT$_{\text{TBM}}$). In Phase II, the new workload of the WAnT (WAnT$_{\text{FFM}}$) was then applied to another group of subjects with %BF a little above the normal level. The variables of maximal leg power recorded in the WAnT$_{\text{FFM}}$ were compared with those obtained from the WAnT$_{\text{TBM}}$. The correlation between the possible discrepancy in the variables of leg power and the %BF in subjects was also examined. Since there are gender differences in anaerobic power (Mayhew & Salm 1990), the investigation was gender specific.

Methods

Subjects

A total of 34 male and 31 female undergraduate Physical Education students were recruited for this study. Thirty-two subjects with 16 in each gender (Gp1) were recruited in Phase I. The %BF of male and female subjects were below the cutoff of 15.0% and 23.5%, respectively, which was defined by Lohman (1992) and McArdle et al. (2001) as "average" in young adults either normal or athletic trained. In Phase II, 18 males and 15 females with a little above-normal %BF were recruited (Gp2). The anaerobic power and fatigability in knee extensors and flexors of the subjects in Gp2, which were measured with an isokinetic test, were comparable to that of the subjects in Gp1 (Table 1). After being fully informed of the experimental procedures and possible discomfort associated with the exercise test, subjects gave their written consent. Ethical approval for this study was obtained from the Committee on the Use of Human and Animal Subjects in Teaching and Research of Hong Kong Baptist University. The physical characteristics of the subjects in both phases are presented in Table 1.

Procedures

Preliminary testing

Prior to the experimental trials, isokinetic leg test and body composition assessment were measured. In the isokinetic test, maximal power in knee extensors and flexors of both legs were measured by following the protocol previously described (Tsaklis 2002). Briefly, the subject was stabilized on an isokinetic dynamometer machine (Humac Norm, CSMI, MA, USA). Range of

Table 1. Physical characteristics of the subjects*

	Age (yr)	Height (cm)	Weight (kg)	%BF (%)	FFM (kg)	Isokinetic test in legs	
						MPO (W)	FI
Gp1							
Male (*n* = 16)	20.6 ± 1.2	176.8 ± 6.4	65.8 ± 6.2	12.9 ± 1.1	57.4 ± 5.8	640.1 ± 109.4	39.3 ± 10.0
Female (*n* = 16)	20.2 ± 1.4	162.8 ± 5.7	49.4 ± 5.3	20.5 ± 2.9	39.2 ± 3.9	368.3 ± 68.2	43.5 ± 7.9
Gp2							
Male (*n* = 18)	21.3 ± 2.7	174.9 ± 7.0	70.9 ± 9.3	19.6 ± 3.6†	56.9 ± 6.8	617.1 ± 146.2	46.6 ± 9.3
Female (*n* = 15)	20.5 ± 1.1	161.1 ± 4.1	56.9 ± 5.3	28.7 ± 4.1†	40.4 ± 2.3	384.6 ± 48.5	46.9 ± 9.0

*Data are presented as mean ± standard deviation; †different from corresponding normal group, $p < 0.05$. %BF = percent body fat; FFM = free fat mass; MPO = mean power output; FI = fatigue index.

motion in the knee was set at 120° (0° refers to full extension). The angular velocity was $240°.s^{-1}$ for both flexion and extension. The subject performed extension-flexion reciprocally at the maximal effort to reach 30 repetitions. The integrated anaerobic power in legs was the sum of the medium power of the extensors and flexors of both legs. The fatigue index was the % decline in the power between the initial and the final repetition.

For assessing body composition, bioimpedance measurement was performed using a leg-to-leg BIA body fat analyzer (Tanita, TBF-410; Tanita Corp., Tokyo, Japan). The measuring procedure has been described previously (Lu et al. 2003). Briefly, subjects were asked to stand barefoot on the metal sole plates of the machine. Gender and height details were entered manually into the system via a keyboard. %BF, FM and FFM were estimated using the standard built-in prediction equations for young adults. All the measurements were taken in the morning before breakfast, with subjects having fasted for at least 8 hours.

Familiarization

At least two familiarization trials with loading identical to the experimental trial were undertaken to familiarize the subjects with the WAnT protocol and the electromagnetically braked ergometer (17985, Excalibur; Lode, Groningen, Netherlands) that would be used in subsequent tests. Seat and handlebar positions were adjusted and kept constant for each individual subject during the course of the study.

Wingate anaerobic test (WAnT)

Before each trial, the subject refrained from eating for at least 2 hours and from participation in strenuous physical activity for at least 1 day. All trials were scheduled to occur at the same time of day and were separated by a minimum of 3 days.

Prior to the WAnT, a standard 5-minute warm-up exercise at 25 W and 50 W for female and male, respectively, was performed on the Lode ergometer. After the subsequent 5-minute leg stretching exercise on the floor, the subject sprinted twice on the ergometer at 50–75% of the prescribed testing load for 15 seconds, with a recovery interval of 30 seconds. After completion of the warm-up, the subject continued to pedal at $60\ rev \cdot min^{-1}$ with minimal resistance for 1 minute and started to accelerate the pedal frequency. Following a 3-second countdown, the load was immediately applied and the subject was verbally encouraged to pedal as fast as possible in the subsequent 30 seconds. During the test, the subject was required to remain seated. After completion of the test, the subject continued to cycle at light load for recovery. In the WAnT, peak power (PP) was the instantaneous highest power output; mean power (MP) was the average power output; fatigue index (FI) was the percentage drop in power output from the PP to the lowest power recorded. The ergometer was interfaced with a computer loaded with software (Lode ergometry manager) for manipulating the testing load and measuring the three parameters of power output. The WAnT was repeated twice in both phases for examining the reliability of the variables.

Statistical analysis

The repeatability coefficient of Bland-Altman plot and intraclass reliability coefficient were calculated for determining the reliability of the PP, MP and FI. The interactive effect of WAnT ($WAnT_{TBM}$ and $WAnT_{FFM}$) and groups (Gp1 and Gp2) on the three variables, the testing load and the peak pedal frequency were examined using two-way ANOVA with repeated measures in one factor. *Post hoc* analyses with Newman-Keuls were performed when the main effects of ANOVA were significant. Relationships between variables were determined using simple regression. All tests for statistical significance were standardized at an alpha level of $p < 0.05$, and all results are expressed as mean ± standard deviation.

Results

In Phase I, we computed for each subject in Gp1 the WAnT workload expressed as $g.kg^{-1}$ FFM that was equivalent to the original WAnT workload of $75\ g.kg^{-1}$ TBM. The group mean of the workload for male and female subjects was $86.1 \pm 1.1\ g.kg^{-1}$ FFM (range, 83.9–87.9 $g.kg^{-1}$) and $94.5 \pm 3.3\ g.kg^{-1}$ FFM (range, 87.6–98.0 $g.kg^{-1}$), respectively. The WAnT workload of $86\ g.kg^{-1}$ and $95\ g.kg^{-1}$ FFM was therefore applied in the subsequent $WAnT_{FFM}$ for both Gp1 and Gp2 in Phase II.

With regard to the reliability of the PP, MP and FI in $WAnT_{TBM}$ and $WAnT_{FFM}$ in Phase II, the repeatability coefficient was 12.6%, 6.2% and 27.8% respectively, and the mean difference between the first and repeated trials was 19.9 ± 78.2 W, 3.0 ± 21.5 W and $0.9 \pm 5.4\%$, respectively. The intraclass reliability coefficient for the PP, MP and FI were 0.98, 0.99 and 0.80, respectively. For data analyses, the power output data in the second trial were selected.

In the $WAnT_{TBM}$, the PP, MP and FI in Gp1 and Gp2 were similar while the peak and mean pedal frequency in Gp1 were slightly higher than those in Gp2. In the

Table 2. Peak power output (PPO), mean power output (MPO), fatigue index (FI), peak pedal frequency (PPF) and mean pedal frequency (MPF) in the two Wingate anaerobic tests (WAnT) with which the testing load was either assigned according to total body mass (WAnT_{TBM}) or fat free mass (WAnT_{FFM})*

	WAnT_{TBM}					WAnT_{FFM}				
	PPO (W)	MPO (W)	FI	PPF ($\text{rev} \cdot \text{min}^{-1}$)	MPF ($\text{rev} \cdot \text{min}^{-1}$)	PPO (W)	MPO (W)	FI	PPF ($\text{rev} \cdot \text{min}^{-1}$)	MPF ($\text{rev} \cdot \text{min}^{-1}$)
Gp1										
Male (n=16)	1561.8 ± 169.9	863.6 ± 102.5	46.2 ± 7.3	209.3 ± 10.8	176.1 ± 11.1	1578.0 ± 169.7	872.8 ± 81.4	47.3 ± 7.8	214.6 ± 8.2‡	179.6 ± 9.5‡
Female (n=16)	943.1 ± 174.2	483.6 ± 90.4	28.9 ± 6.7	168.8 ± 11.0	135.4 ± 10.0	951.4 ± 153.0	491.1 ± 82.3	29.1 ± 6.7	173.0 ± 14.0‡	138.6 ± 10.9‡
Gp2										
Male (n=18)	1522.9 ± 149.3	857.6 ± 127.4	47.1 ± 7.8	200.6 ± 13.4†	164.6 ± 12.1†	1508.9 ± 165.6	823.2 ± 125.9‡	45.3 ± 6.5	208.3 ± 10.2‡	172.6 ± 9.8‡
Female (n=15)	1061.6 ± 136.9	546.8 ± 58.0	33.8 ± 7.7	171.4 ± 11.1	134.7 ± 12.5	989.4 ± 123.3‡	509.3 ± 54.3‡	30.9 ± 6.2	178.1 ± 11.4‡	141.9 ± 12.1‡

*Data are presented as mean ± standard deviation; †different from corresponding normal group, $p < 0.05$; ‡different from WAnT_{TBM}, $p < 0.05$.

Table 3. Correlations between percent body fat (%BF) and percent change in mean power (MP) and peak power (PP) in the overfat group

%BF	MP	PP
Male (n=18)	0.66*	0.33
Female (n=15)	0.75*	0.67*

*$p < 0.01$.

WAnT_{FFM}, the workload was reduced significantly ($p < 0.05$) from that of the WAnT_{TBM} in both male and female subjects in Gp2 while the difference in Gp1 was not significant ($p > 0.05$). The peak and mean pedal frequency were increased slightly in Gp1 and Gp2 in both genders while the increase in mean pedal frequency in Gp2 was of a greater extent compared with that in Gp1 (Table 2). In Gp2, although the pedal frequency was increased in the WAnT_{FFM}, the PP and MP, but not the FI, in female subjects were decreased from those recorded in the WAnT_{TBM} ($p < 0.05$). Similar results were found in the male subjects but only the decrease in MP reached statistical significance (Table 2). In contrast, neither variable in Gp1 was changed with the new workload in the WAnT_{FFM} ($p > 0.05$). When the differences in the variables in Gp2 were expressed as a percentage of those recorded in WAnT_{TBM}, significant positive correlations with %BF were found in MP in both male and female subjects and in PP in female subjects (Table 3).

Discussion

It is generally agreed that the fat compartment of body composition does not contribute to anaerobic power output. Rather, body fatness was negatively correlated to the anaerobic capacity measured in the WAnT in various populations including athletes and adolescents (Lafortuna et al. 2004; Armstrong et al. 2000; Pilis et al. 1997). On the other hand, Blimkie et al. (1988) found that the PP and MP in arm were related to arm volume and lean body mass in adolescents. Similar correlations were also observed in leg (Van Praagh et al. 1990). In the WAnT, a loading of 75 g.kg^{-1} TBM is used in the general healthy population and is based on an assumption that these people have a similar relationship between muscle mass and TBM. However, populations with abnormal muscle mass to TBM ratio, such as individuals with muscle atrophy and muscle dystrophy, may invalidate the determination of the optimal loading in the WAnT based on the TBM (Van-Mil et al. 1996).

Üçok et al. (2005) suggested that the assignment of the WAnT load according to lean body mass would be more appropriate in young adults when they observed a significant higher PP in the WAnT using a workload of 100–110 g.kg^{-1} lean body mass. However, the findings did not determine the effect of FM that would impair the maximal leg power output in the WAnT in those who were minor overfat. In the present study, the new WAnT workloads of 86 g.kg^{-1} and 95 g.kg^{-1} FFM are equivalent to the 75 g.kg^{-1} TBM in young male and female subjects, respectively, with normal %BF in Gp1. The new WAnT workloads, which neglected the FM of subjects, could develop similar PP, MP and FI recorded in the WAnT$_{TBM}$. When comparing the maximal power outputs in WAnT that resulted from the original and the new loads in Gp2, we found that the MP in the WAnT$_{FFM}$ in male subjects was decreased by 3.9 ± 5.7% from the original value. The decrease in maximal power output was more pronounced in the female subjects: PP and MP decreased by 6.2 ± 10.7% and 6.6 ± 6.5%, respectively. The decreases in PP and MP were further found to be correlated to the %BF of the subjects (Table 3). The decreases in the PP and MP in the WAnT$_{FFM}$ found in Gp2 should not be attributed to inferior leg muscle condition as the group means of maximal power output in knee flexors and extensors during isokinetic testing were similar in both Gp1 and Gp2. Further, it should not be interpreted as due to impairment in power capacity and anaerobic endurance in legs consequent upon the application of new workload as the FI was not changed from the original level in both male and female subjects.

In the WAnT$_{FFM}$, the testing load in Gp2 was reduced by 7.8 ± 4.1% and 9.7 ± 5.1% from that in the WAnT$_{TBM}$ in male and female subjects, respectively, while the peak and mean pedal frequency were increased. However, the small increase in the pedal frequency was not sufficient to bring the PP and MP back to the original levels. Since the reduction in the original testing load in the WAnT$_{FFM}$ was according to the %BF, this may partly explain why the impairment in the PP and MP was positively correlated to the fatness of the subjects and was more severe in female subjects who possessed higher %BF than male subjects did. The factors limiting the marked increase in pedal frequency are not clear. Motivation status should not be a major factor as PP and MP were highly reproducible in subjects. The intraclass reliability coefficients found in male and female subjects are in agreement with those previously reported (Bar-Or et al. 1977). Dotan (2006) noted that the peak pedal frequency in the WAnT is not exclusively dependent on anaerobic capacity. Cycling skill and training as well as leg muscle fiber-type profile are decisive.

As the power output during the WAnT depends on the cycling load and velocity while the maximal pedaling velocity is limited by factors independent of leg anaerobic capacity, the assignment of the testing load becomes crucial in the test validity. Various studies reported that a load of 75 g.kg^{-1} TBM commonly used in the WAnT was inadequate to obtain the highest power outputs (Patton et al. 1985; Dotan & Bar-Or 1983). Bar-Or (1987) reported that for obtaining the highest values in PP and MP in the WAnT, the testing load should be at 90 g.kg^{-1} TBM for adults while athletes, especially the anaerobic type, should be at 100 g.kg^{-1} TBM. Such setting was further confirmed when the load factors ranging from 90 to 95 g.kg^{-1} TBM were shown as most appropriate in track-and-field athletes for obtaining maximal power output in the WAnT (Liu et al. 2001). In the present study, the declines in the PP and MP in the minor overfat subjects do not support our hypothesis. Rather, they indicated that the new workloads in the WAnT$_{FFM}$ moved further away from the optimal values. Although we did not show any improvement in the PP and MP with the new workload, the interpretation of lack of negative influence of FM on WAnT performance in this population should be made with caution. As the original load of 75 g.kg^{-1} TBM has not been shown to be the optimum to produce the highest PP and MP in the WAnT in both Gp1 and Gp2, the current findings may not fully reveal the influence of FM on WAnT performance. Further investigations at the optimal WAnT loads in these two groups are recommended.

In conclusion, for the young male and female subjects with normal %BF, the workloads of 80 g.kg^{-1} and 95 g.kg^{-1} FFM, respectively, in the WAnT were found to develop the PP, MP and FI to equivalent to those obtained from the original workload of 75 g.kg^{-1} TBM. When the new workloads were applied to subjects with %BF greater than the cutoff of “average”, the PP and MP, but not the FI, declined from the original values. The declines were positively correlated to their %BF. Such findings show that the neglect of FM in the original WAnT workload assignment lessens the maximum anaerobic power output of minor overfat subjects. The findings further suggest that the counting of FM in the traditional WAnT workload of 75 g.kg^{-1} TBM may not impair the maximal power output in this population. However, the current findings did not imply that there was lack of negative influence of FM on WAnT performance. Further investigations at the optimal loads in the WAnT in both normal and minor overfat adults may arrive at the truth.

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