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(MP, the mean for 30s) and peak power (PP, the highest 5s interval). Thigh volume (TV) by water displacement, lean body mass (LBM) from skinfolds and body weight (BW) were used as anthropometric variables. Absolute AnP of males was significantly higher than females (MP: $\bar{x}$ = 555 vs 334 W, p .001 and PP: $\bar{x}$ = 770 vs 503 W, p .001), as were pedal revolutions (male: 1.66 rev.s^{-1} vs. female: 1.29 rev. s^{-1}). The difference between genders decreased when power was expressed in terms of TV, BW and LBM, in that order. Correlation coefficients between power output values and the anthropometric variables for all subjects revealed that TV, BW and LBM explained 48%, 74% and 79% of the variation in MP and 53%, 71% and 76% in PP, respectively. For males alone, anthropometric variables explained no more than 50% of the variation in MP or PP. In females, however, TV explained 71% and 66% of the variation in MP and PP, respectively, and BW explained 66% of the variation in MP. These data reveal that a larger portion of the between gender variation compared to the within gender variation in AnP can be accounted for by the anthropometric variables. However, a significant portion remains that must be explained by the individual muscles' potential for glycolytic energy production.

Comparative anaerobic power of males and females

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Summary:

The purpose of this study was to determine the differences in anaerobic power between males and females and the contribution of anthropometric variables in accounting for these differences. Eighteen female and nineteen male subjects performed the Wingate test as a measure of anaerobic power (AnP). Each subject pedalled maximally for 30s against a resistance of 4.41 joules/pedal revolution/kg body weight on a modified Monark ergometer which allowed instantaneous application of resistance. Revolutions were determined by a computer interfaced frequency counter. AnP, measured in watts (W), was expressed as mean power (MP, the mean for 30s) and peak power (PP, the highest 5s interval). Thigh volume (TV) by water displacement, lean body mass (LBM) from skinfolds and body weight (BW) were used as anthropometric variables. Absolute AnP of males was significantly higher than females, (MP: $\bar{x}$ = 555 vs 334 W, $p<.001$ and PP: $\bar{x}$ = 770 vs 503 W, $p<.001$), as were pedal revolutions. (male: 1.66 rev.s^{-1} vs. female: 1.29 rev. s^{-1}). The difference between genders decreased when power was expressed in terms of TV, BW and LBM, in that order. Correlation coefficients between power output values and the anthropometric variables for all subjects revealed that TV, BW and LBM explained 48%, 74% and 79% of the variation in MP and 53%, 71% and 76% in PP, respectively. For males alone, anthropometric variables explained no more than 50% of the variation in MP or PP. In females, however, TV explained 71% and 66% of the variation in MP and PP, respectively, and BW explained 66% of the variation in MP. These data reveal that a larger portion of the between gender variation compared to the within gender variation in AnP can be accounted for by the anthropometric variables. However, a significant portion remains that must be explained by the individual muscles' potential for glycolytic energy production.

Key words: Anaerobic power, Wingate test, anthropometry, gender differences.

Introduction

The Wingate test of anaerobic power has become an increasingly popular performance test in recent years. Following its introduction as a reliable and valid test (Bar-Or 1978), numerous laboratories have adopted the procedure to measure anaerobic power (Jacobs 1980; Evans and Quinney 1981; Kaczkowski et al 1982). The Wingate test is a 30 second all-out cycling exercise performed at a resistance of 4.41 joules/pedal revolution/kg body weight. Although resistance is determined according to body weight, power output (PO) is usually expressed in watts and only occasionally relative to body weight. The question is presently raised as to whether power output should be described in absolute terms or be expressed relative to some anthropometric measure such as body weight, lean body mass, or thigh volume.

It has been shown that aerobic power measured on a cycle ergometer is not significantly correlated with body weight (Buskirk and Taylor 1957). For this reason, values for oxygen uptake are expressed in absolute terms as liters/min. It is possible, however, that body composition could be an important factor in eliciting power output from a supramaximal test such as the Wingate test. A heavier person may be able to generate a higher anaerobic power by virtue of his/her muscle mass when exercising at a high intensity for a short duration. In addition, relative measures may allow a more valid comparison between the genders.

The purpose of the present study was to compare anaerobic power output of males and females in absolute terms and relative to such anthropometric variables as body weight, lean body mass, and thigh volume in order to assess their ability to account for differences between and within the genders.

Materials and Methods

Nineteen male and eighteen female untrained but physically active laboratory personnel volunteered to participate in this study after signing an informed consent statement. Their physical characteristics are listed in Table 1. Testing included anthropometric measures, $\dot{V}O_2$ max determination, and the Wingate test (WT). These were performed on different days separated by at least 24 hrs.

The anthropometric measures of percent body fat, lean body mass (LBM), and thigh volume (TV) were determined on the same day. A four-point skinfold measurement was utilized to estimate percent body fat and lean body mass by the equations of Durnin and Womersley (1974). To determine thigh volume, two measurements were made; the first was the lower leg measured to a site at the minimal circumference above the knee and the second was the whole leg measured to the gluteal furrow (Jones and Pearson 1969). The difference between these two measurements yielded thigh volume. A plexiglass tank was used to immerse the limb and to collect the displaced water. The water volume was weighed to the nearest gram and converted to liters by correcting for its density according to water temperature. Three trials were performed in order to obtain a mean of two trials in which the volume was within .05ℓ.

$\dot{V}O_2$ max was determined for each subject by means of a discontinuous protocol on a Monark cycle ergometer using the Douglas bag technique (McArdle et al,1973). Heart rate was recorded during the last 15 seconds of each gas collection.

Each subject performed the WT after a familiarization period which occurred at least 24 hours before the actual WT. The test was performed using a Monark cycle ergometer that had been modified with a lever arm to which weights were attached for instantaneous application of resistance (Frederick et al, 1983). Revolutions were counted by means of four magnets attached to the flywheel whose signals were picked up by a coil and diode. This was connected to a Hewlett Packard (HP) universal counter (5328A) interfaced with a HP-85 computer. Upon lowering the lever arm, a switch was opened allowing the magnetic pulses from the flywheel to be collected by the counter and converted to pedal revolutions and watts by the computer. Real-time data aquisition and the timing of the test were controlled by the computer. The resolution of this system was 0.067 revolutions.

Prior to the test, the subjects warmed up for 2-4 min on a standard Monark ergometer at an intensity of 75-125 W with 2-3 intermittent sprints. They were then seated on the modified ergometer with feet fastened in toe clips and the seat height adjusted such that there was a slight bend in the knee upon extension. They were instructed to pedal at an initial rate of approximately 120 RPM for males and 100 RPM for females. On the command "ready, go" they started to pedal as fast as possible without resistance, enabling them to overcome the inertial resistance of the flywheel. Upon attaining maximal pedal revolutions, the lever arm was lowered, applying the load and simultaneously triggering the computer to start timing the test and counting flywheel revolutions. Strong verbal encouragement was given to the subjects throughout the duration of the test, but they were not allowed to sit up and out of the seat. At 30s the computer stopped collecting data and the lever arm was lifted removing the resistance. At this time, the subjects were told to pedal at a comfortable rate without any resistance applied until they had sufficiently recovered.

Three indices were calculated to describe anaerobic power in absolute terms: peak power (PP), the mean power output (PO) in watts during the first 5s interval; mean power (MP), the mean PO in watts for the entire 30s duration; and power decrease (PD) in watts•sec^{-1}, the difference between the lowest 5s interval and the peak power divided by the elapsed time. All three indices were expressed in relative terms by dividing watts or watts•sec^{-1} by ℓ TV, kg BW, and kg LBM in order to compare genders.

The power outputs of males and females were compared using an independent Student's t-test. The relationship of PO to anthropometric variables for males and females seperately and together as well as the intercorrelation of anthropometric variables were assessed using Pearson's correlational analysis. A stepwise multiple regression was performed on males and females seperately to determine the percent of PO which can be explained by TV, BW and LBM.

Results

Table 2 lists PO in absolute and relative terms and the mean force and pedal revolutions.sec^{-1} for both males and females. The power output variables were significantly higher for males than females expressed on either an absolute or relative basis except power decrease expressed relative to kg LBM. The percent difference between genders decreased, however, as PO was expressed in relative terms. PP decreased from a difference of 35% on an absolute basis to 23%, 17% and 10% when watts were expressed in terms of ℓ TV, kg BW, and kg LBM, respectively. MP decreased from an absolute difference of 40% to 28%, 23% and 17% for watts expressed in ℓ TV, kg BW and kg LBM, respectively. Similarly, PD showed a drop in percent difference in the same order from 34% absolute to 23%, 18% and 8% relative. In addition, both mean force and pedal revolutions were significantly lower for females than for males.

It was consistent for all variables that LBM was the best relative measure resulting in the least percent difference between genders followed by BW and TV. These trends are graphically represented in Figure 1 where PO is plotted each 5s for both males and females. The difference between male and female curves is reduced as the PO is expressed relative to ℓ TV, kg BW and kg LBM in that order; however, the gender difference is still significant for all relative measures.

Correlation coefficients of the anthropometric measures and PO variables for males and females calculated separately and combined are presented in Table 3. For all subjects, LBM explains most of the variation in mean and peak power followed by BW and thigh volume. The order in which these variables account for the difference between genders is consistent with the descriptive data in Table 2 and Figure 1. When correlations are performed for each gender seperately, the variables assume different importance. For males, no more than 50% of the variablility in PP, MP or PD can be explained by any of the anthropometric variables. In females, however, thigh volume explained 66%, 71% and 50% of the variability in PP, MP and PD, respectively. In addition, body weight explained 52% and 66% of the variability in PP and MP.

Multiple stepwise regression equations were developed to estimate mean and peak power from BW$(X)_1$, TV(X_2) and LBM(X_3) for males and females. The male equation for PP ($Y=252X_1 + 46.6X_2 + 321.9$) yielded an R^2 of 0.53 and for MP ($Y = 3.58X_1 + 38.3X_2 + 127.7$) the R^2 was 0.48 using using only BW and TV as dependent variables. The females' equation for PP ($Y = 735X_1 + 159.0$) resulted in $R^2 = 0.66$ and included only BW whereas that for MP ($Y = 608X_1 + 28.7 X_2 - 5.07X_3 + 69.4$) utilized all 3 variables and resulted in $R^2 = 0.76$. The dependent variables, however, are highly intercorrelated.

Discussion

In a study comparing male and female power output values during anaerobic cycle ergometer exercise, Ben Ari et al (1976) reported an absolute difference of 30.5% for a 30-40 year old age group. This is slightly less than that found herein where a younger group of subjects was studied. This difference, however, is most likely attributable to sampling fluctuation as Ben Ari et al also found similar power output values in a 19-20 year old age group. Furthermore, Cumming (1972) reported a gender difference of 26% in anaerobic power as measured during a 30s supramaximal cycle ergometer test in subjects aged 12-17 years. These data suggest, therefore, that following puberty females attain an average of 25% to 35% lower absolute anaerobic power than males.

These gender differences in anaerobic power are similar to those which have been documented for other physiological measures of exercise performance. Laubach (1976) reviewed the comparison of isometric muscular strength between men and women and found females to have 28% lower absolute strength in the lower extremities compared to males. Similarly, Vogel et al (1977) reported that maximal isometric strength for knee flexors was 34% lower and for knee extensors 23% lower in females than males. Differences in aerobic power between genders have been reviewed by Astrand and Astrand (1978) where women's $\dot{V}O_2max$ was shown to be 25% to 38% of men's values on an absolute basis. When corrected for body weight this range was 15% to 25%. Thus, the percentage differences in anaerobic power between genders on both an absolute and relative basis are similar to what has been found for maximal isometric strength and aerobic power.

The results of the present study favor the use of relative measures to compare anaerobic power output of males and females during the WT. Of the variables tested, watts•kg LBM^{-1} is the best relative measure on which to base a comparison since TV and BW account for less of the variability between the genders. Although expressing power output values relative to LBM considerably reduces the difference between males and females, the males' PO remains significantly higher than that of the females'. In the WT, power output is a function of both the pedalling frequency (revolutions•sec^{-1}) and the force (resistance setting) applied at the flywheel. The present data indicate that pedal revolutions•sec^{-1} are significantly lower in females at the same relative force throughout the entire 30s of the WT. This finding suggests that possible differences in central or peripheral factors controlling muscular performance may exist between genders. Indeed, Komi and Karlsson (1979) found opposite results between males and females when relating muscle power to FT muscle fibers; a positive correlation existed for males whereas a negative relationship was found for females. They suggested different control mechanisms for regulating muscle performance between the genders. In another study relating fibre type and muscle lactate to performance of the Wingate test in females, Jacobs and Tesch (1981) revealed very conflicting results in terms of what is known to occur in males. They suggested that gender related differences may exist in the interrelationships among anaerobic power output indices from the WT and fibre type, muscle lactate concentrations, and fatigue.

Although relative measures of anaerobic power significantly reduce the variablility between genders, this effect is less marked within each gender. Lower correlation coefficients were found for males and females seperately; however, it is interesting that thigh volume is the most significantly correlated variable for both genders. During the first 30 s of a 2 min anaerobic cycle test, Katch(1974) reported very low correlation coefficients for leg volume ($r<0.25$) and body weight ($r<0.30$) for 30 male subjects. These measures, however, became more important as the test continued reaching peak coefficients at 54 s of 0.64 and 0.68 for leg volume and body weight, respectively. These data are very similar to the present results for mean power of males, i.e., correlations of 0.64 and 0.67 for thigh volume and body weight, respectively. It is possible that anthropometric factors such as thigh volume and body weight do not contribute significantly to power output until the exercise intensity is either supramaximal such as in the WT or at a constant heavy intensity for at least 1 min.

Although thigh volume was the most significantly correlated anthropometric variable in the present study, the correlations were only moderate indicating that thigh volume is not a good predictor of anaerobic power. The measure of thigh volume includes not only muscle mass but also fat and bone. The question arises as to whether the use of thigh muscle mass would correlate more highly with power output values from the WT and further reduce the difference between or within the genders. Davies(1971) related thigh muscle mass determined by soft tissue radiographs to anaerobic power output during the Margaria stair climb test on 47 male subjects. This correlation, however, was only slightly greater ($r=0.74$) than that of the present study where thigh volume was measured by water displacement. In addition, the correlations of anaerobic power to BW and LBM were also higher in Davies' study ($r=0.79$ and 0.86, respectively) indicating that the improved correlation using thigh muscle mass may only be a reflection of sampling fluctuation or sample size.

In summary, although relative measures, particularly LBM, reduce the difference in anaerobic power between genders , a significant portion remains which can only be attributed to physiological differences between the genders.

Within each gender these relative measures are less effective in accounting for variability among individuals. As suggested by other investigators (Jacobs & Tesch, 1981; Komi & Karlsson, 1979) different mechanisms may exist for power production in males and females. Furthermore, because thigh volume is the most highly correlated relative measure for both males and females, further study should investigate the efficacy of using thigh muscle mass to predict anaerobic power within each gender.

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Human Research

Human subjects participated in these studies after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 on Use of Volunteers in Research.

References

Astrand I, Astrand PO (1978) Aerobic work performance, a review. Environmental Stress: Industrial Adaptations, L.J. Folinsbie, et al (ed) NY Academic Press, pp. 149-163.

Bar-Or O (1978) A new anaerobic capacity test: characteristics and applications. XXI World Congress in Sports Medicine. Brasilia. Sept. 6-12.

Ben Ari E, Inbar O, Bar-Or O (1976) The anaerobic capacity and maximal anaerobic power of 30-40 year old men and women. Int. Cong. Phys. Act. Sci. Quebec City, pp 427-433.

Buskirk E, Taylor HL (1957) Maximum oxygen intake and its relation to body composition with special reference to chronic physical activity and obesity. J. Appl. Physiol. 11:72-78.

Cumming GR (1972) Correlation of athletic performance and aerobic power in 12 to 17 year old children with bone age, calf muscle, total body potassium, heart volume and two indices of anaerobic power. In Bar-Or O (ed.): Proceedings of the 4th International Symposium on Pediatric Work Physiology. Wingate Institute. pp. 109-134.

Davies CTM (1971) Human power output in exercise of short duration in relation to body size and composition. Ergonomics 14: 245-256.

Drillis R, Contini R (1965) Body segment parameters. United States Air Force, WADCA Technical Report No. 1166.03.

Durnin JV, Womersley J (1974) Body fat assessment from total body density and its estimation from skinfold thickness. Measurements on 481 men and women aged from 16 to 72 years. Brit. J. Nutrition. 32:77-79.

Evans JA, Quinney HA (1981) Determination of resistance settings for anaerobic power testing. Can. J. Appl. Sport Science. 6:53-56.

Frederick FA, Langevin RC, Miletti J, Sacco M, Murphy MM, Patton JF (1983) Development and assessment of the Monark cycle ergometer for anearobic muscular exercise. USARIEM Technical report T6/83.

Jacobs I (1980) The effects of thermal dehydration on performance of the Wingate anaerobic test. Int. J. Sports Med. 1:21-24.

Jacobs I, Tesch P (1981) Short time, maximal muscular performance: relation to muscle lactate and fibre type in females. Med. Sci. Sports 14:125-132.

Jones PM, Pearson J (1969) Anthropometric determination of leg fat and muscle plus bone volumes in young male and female adults. J. Physiol. 204: 63-66.

Kaczkowski W, Montgomery DL, Taylor AW, Klissouras V (1982) The relationship between muscle fibre composition and maximal anaerobic power and capacity. J. Sports Med. 22:407-413.

Katch V (1974) Body weight, leg volume, leg weight and leg density as determinators of short duration work performance on the bicycle ergometer. Med and Sci in Sports and Exerc. 6:267-270.

Komi PV, Karlsson J (1979) Physical performance, skeletal muscle enzyme activities and fibre types in monozygous and dizygous twins of both sexes. Acta Phys Scand. suppl 462:1-28.

Laubach LL (1976) Comparative muscular strength of men and women: a review of the literature. Aviat Space Environ Med 47:534-542.

McArdle WD, Katch FI, Pechar GS (1973) Comparison of continuous and discontinuous treadmill and cycle ergometer test protocols for eliciting maximal oxygen intake. Med Sci Sports and Exerc. 5:156-160.

Vogel JA, Ramos MU, Patton JF (1977) Comparisons of aerobic power and muscle strength between men and women entering the US Army. Med Sci Sports 9:58.

TABLE 1. Physical characteristics of the subjects (mean ± SD).

	Males (n = 19)	Females (n = 18)
Age, yrs	25.1 ± 8.8	24.3 ± 3.9
Height, cm	176.8 ± 4.1	163.7 ± 6.4
Weight, kg	75.5 ± 10.5	59.0 ± 7.5
Body Fat, %	17.0 ± 4.1	23.5 ± 3.7
Lean Body Mass, kg	62.4 ± 6.4	45.0 ± 5.0
Thigh Volume, ℓ	5.5 ± 1.0	4.7 ± 1.0
$\dot{V}O_2max, \ell \cdot min^{-1}$	3.52 ± 0.32	2.60 ± 0.53

TABLE 2. Power output values of males and females in watts (W) and relative to thigh volume (TV), body weight (BW) and lean body mass (LBM) (Mean ± SD).

	Males	Females	% Diff
Peak Power			
W	770 ± 94	503 ± 93	35 **
$W \cdot \ell TV^{-1}$	141 ± 19	109 ± 16	23 **
$W \cdot kgBW^{-1}$	10.3 ± 1.1	8.5 ± 1.1	17 **
$W \cdot kgLBM^{-1}$	12.4 ± 1.2	11.2 ± 1.6	10 *
Mean Power			
W	555 ± 89	334 ± 59	40 **
$W \cdot \ell TV^{-1}$	101 ± 15	73 ± 10	28 **
$W \cdot kgBW^{-1}$	7.3 ± 0.9	5.7 ± 0.6	23 **
$W \cdot kgLBM^{-1}$	8.9 ± 1.1	7.4 ± 0.9	17 **
Power Decrease			
$W \cdot s^{-1}$	16.3 ± 3.4	10.7 ± 2.7	34 **
$W \cdot s^{-1} \cdot \ell TV^{-1}$	3.0 ± 0.7	2.3 ± 0.4	23 **
$W \cdot s^{-1} \cdot kgBW^{-1}$	0.22 ± 0.04	0.18 ± 0.04	18 **
$W \cdot s^{-1} \cdot kgLBM^{-1}$	0.26 ± 0.06	0.24 ± 0.06	8
Mean Force, kg	5.7 ± 0.8	4.4 ± 0.6	23 **
Mean Pedal $Rev \cdot s^{-1}$	1.66 ± 0.20	1.29 ± 0.13	22 **

* $p<.05$; ** $p<.001$

TABLE 3. Correlation coefficients between power output variables and anthropometric measures.

	Peak Power (W)	Mean Power (W)	Power Decrease ($W.s^{-1}$)
Males (n = 19)			
TV, ℓ	0.70 **	0.64 **	0.38
BW, kg	0.66 **	0.67 **	0.32
LBM, kg	0.60 **	0.62 **	0.10
Females (n = 18)			
TV, ℓ	0.81 **	0.84 **	0.71 **
BW, kg	0.72 **	0.81 **	0.51 *
LBM, kg	0.58 *	0.68 **	0.39
All Subjects (n = 37)			
TV, ℓ	0.73 ***	0.69 ***	0.67 ***
BW, kg	0.84 ***	0.86 ***	0.63 ***
LBM, kg	0.87 ***	0.89 ***	0.68 ***

* $p<.05$; ** $p<.01$; *** $p<.001$

Figure 1. Absolute and relative power output values for each 5s of the Wingate test for both males and females.