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AEROBIC FITNESS OF ELITE FEMALE AND MALE WRESTLERS

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Abstract. Aim: The purpose of this study was to assess the aerobic fitness of elite female wrestlers, and to determine whether there are gender differences in the physiological response to graded exercise. Materials and Methods: Ten female and ten male freestyle wrestlers volunteered for the study. They all performed a graded exercise test on the treadmill until exhaustion. To measure lactate concentration capillary blood was taken from the finger tip at the end of every workload and after 3, 5 and 7 minutes of recovery. Anaerobic threshold was defined as the running velocity associated with 4 mmol/l during the incremental exercise test (AT_4) and as the individual anaerobic threshold (IAT). Results: Maximal oxygen consumption (VO_2max) normalized to body mass or to fat free mass was significantly higher in male than in female wrestlers (59.8 and 49.7 ml/min/kg and 72.7 and 63.9 ml/min/kg FFA, respectively). Total oxygen uptake at the anaerobic thresholds (AT_4 and IAT) was similar in men and women, but when expressed as $\%VO_2max$, it was significantly higher in females. The peak blood lactate concentration was significantly higher in male than in female wrestlers (14.1 and 10.5 mmol/l, respectively). Conclusion: This study was the first to assess the aerobic fitness of female wrestlers. It demonstrated that there are significant gender related differences between female and male wrestlers. Possibly the lower VO_2max in the female wrestlers was compensated by their higher oxygen utilization at the anaerobic threshold. This result indicates that AT_4 method is sufficiently reliable for measuring anaerobic threshold for female and male wrestlers.

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Key words: Graded exercise test - Anaerobic threshold - Female and male wrestlers

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Introduction

The physiological demands of a wrestling match strain both anaerobic and aerobic systems. The high intensity of such a match is indicated by the high mean blood lactate concentration achieved i.e. 20 mmol/l [20]. The aerobic system contributes to sustained effort throughout the match and during the recovery period [6]. It is well known that endurance training improves lactate removal following anaerobic exercise, and enhances phosphocreatine restoration [26]. Considering that a wrestling match may last as long as 7 min 30 s (according to the rules modification after the 2004 Olympic Games in Athens) the development of well-conditioned physiological capacities in athletes is critical for success.

The physiological profile of male wrestlers has been relatively well described [12,28]. Until now data on female wrestlers performance level have been scarce, because women's wrestling has only became a mandatory sport since the 2004 Olympic Games in Athens. Hübner-Woźniak *et al.* [14] evaluated anaerobic performance of female wrestlers and demonstrated that their response to 30 s Wingate tests for arm cranking and leg cycling was similar to female judo athletes. However there are no data available concerning the aerobic fitness of female wrestlers.

Maximal oxygen uptake (VO_2max) is one of the most common measurements in exercise physiology, and it is frequently used to indicate the aerobic fitness of an individual [4]. It has been noted that maximal oxygen consumption is higher in men when compared with women [2]. However, it is well known that the anaerobic threshold (AT), regardless of its precise definition, represents the subject's aerobic work capacity in a more accurate way than VO_2max, especially in well trained athletes [1]. Number of methods have been developed to define the lactate deflection point from an incremental test [18]. This point is crucial because it indicated when one switches from mostly aerobic to mostly anaerobic metabolism [7]. It is well known that anaerobic threshold has been used to establish and to predicting performance capacity or to prescribing training intensities [18].

The primary purpose of the present study was to assess the aerobic fitness of elite female wrestlers. A secondary purpose was to compare the selected physiological (VO_2max, %VO_2max at anaerobic threshold, heart rate) and metabolic (blood lactate concentration) variables between female and male wrestlers, and to determine whether there are any gender differences in physiological response to graded treadmill exercise until exhaustion. The third aim of the study was to compare the indices obtained at anaerobic threshold calculated using two different methods.

Materials and Methods

Subjects: Ten female and ten male freestyle wrestlers, all members of the Polish national team, volunteered for the study. Their physical characteristics are shown in Table 1. A detailed description of the study as well as an explanation of the risks and benefits of participation was provided, and all participants gave their informed consent, in accordance with and with prior approval of the Ethics Committee of the University of Physical Education, in compliance with the Helsinki Declaration. Athletes reported to the laboratory in the morning, between 9 and 11 am after a standardized breakfast (840 kJ) consumed 2 hours before the start of exercise. A physician performed a physical examination on all female and male wrestlers to confirm that there were no medical reasons for their exclusion from this study. Initially, the height and body mass of athletes were measured, then the percentage of body fat was estimated using the method given by Durnin *et al.* [8], by measuring skinfold thickness at the biceps, triceps, suprailiac and subscapular sites with a Harpender caliper. Two measurements were made at each site and the mean was used for the assessment of the percent of body fat. The measurements were taken on the right site of the body with the athletes in standing position. Fat free mass (FFM) was calculated from body mass and percentage of body fat.

Test protocol: All participants performed a graded exercise test on the treadmill (Saturn, H-P-Cosmos, Germany) for the determination of maximal oxygen uptake (VO_2max) and anaerobic threshold. Women were tested with no respect to their menstrual cycle. Menstrual cycle phase was not controlled, given that previous research suggested that maximal VO_2 is not affected by menstrual cycle phase [5]. All athletes were familiarized with the testing equipment and procedures prior to the commencement of testing. Velocity on the treadmill started at 6 and 8 km/h for women and men respectively, and was increased every 3 minutes by 2 km/h at 0 degrees inclination. Running velocity was increased until the athlete reached volitional exhaustion. Gas exchange analysis, using breath-by-breath system, was used to improve VO_2max estimation. During exercise oxygen uptake and carbon dioxide production were measured continuously utilizing a Sensormedic (USA).

The gas analysis system was calibrated according to the manufacturer's recommendation before each test using gases of known concentration. Criteria according to Howley *et al.* [13] were applied to verify that each athlete attained VO_2max. Heart rate was monitored throughout the exercise duration using a polar telemetric monitor (Polar Vantage NV, Finland). At the end of every workload capillary blood was taken from the finger tip to measure lactate concentration using a Dr Lange analyzer, calibrated with 4 and 10 mmol/l lactate standard solutions.

The coefficient of variation for lactate determination was 4.4%. Blood lactate concentration was also determined at 3, 5 and 7 min after cessation of exercise to assess the peak lactate accumulation (LA_{peak}). The anaerobic threshold (AT) was calculated using two different methods. One of them was the onset of blood lactate accumulation which is defined as the running velocity associated with 4 mmol/l during the incremental exercise test (AT_4). It was assessed by plotting blood lactate concentration (mmol/l) against VO_2 (ml/min/kg) for all work intensities, and defined as the VO_2 at which blood lactate concentration attained 4 mmol/l [19]. The second one was the individual anaerobic threshold (IAT), which was determined from the changes in blood lactate both during and after incremental treadmill test. Individual data points for both the exercise and recovery lactate concentrations (LA) were plotted as a continuous function against velocity. The increasing portion of the exercise LA curve was fit with a third order polynomial which minimized the residual sum of squares and the IAT coordinates were defined by the line passing through the recovery coordinates [27].

Statistical analysis: Data were reported as mean (x) and standard deviation (SD). Conventional descriptive statistical methods were used to compare physiological and biochemical indices between female and male wrestlers. Shapiro-Wilk's test did not reveal significant deviation from normal distribution for each variable. The differences were determined using Student's t test for independent data. Significant levels were established at $p<0.05$.

Results

Anthropometric data from the present study revealed gender differences. The male wrestlers were significantly taller, heavier, and had a lower percentage of body fat than female wrestlers (Table 1). The significantly higher average BMI value of men as compared with women was probably the consequence of better musculature of male wrestlers. Compared with the women, the men were significantly older and had longer training experience.

Maximal oxygen consumption normalized to body mass was significantly higher in male as compared with female wrestlers (Table 2). This difference was maintained when VO_2max was normalized to fat free mass. Maximal heart rate (HR_{max}) was similar in both sexes. The blood lactate concentration after cessation of the graded exercise test was significantly higher in male than in female wrestlers. Oxygen uptake at the two calculated lactate thresholds (AT_4 and IAT) was similar in both men and women, but when expressed as %VO_2max, was significantly higher in female than in male athletes (Table 3). The current study

showed that at both AT_4 and IAT heart rate and $\%HR_{max}$ were significantly higher in women when compared to men, however running velocity did not differed. No statistically significant differences was found between the calculated indices at anaerobic threshold estimated as AT_4 or IAT.

Table 1
Physical characteristics of the female and male wrestlers (means ± SD)

Variable	Male wrestlers (n=10)	Female wrestlers (n=10)
Age (years)	27.5±5.0*	21.6±2.4
Body weight (kg)	85.2±17.6***	60.5±8.6
Body height (cm)	176.4±10.4**	164.9±5.4
Body mass index ($kg \cdot m^{-2}$)	27.0±2.6***	22.1±2.1
Body fat content (%)	17.7±4.5**	22.5±3.1
FFM[A] (kg)	69.5±10.9***	46.6±5.3
Training experience (years)	16.9±5.4***	8.1±2.6

[A] Fat free mass
Significantly different from female wrestlers: *p<0.05, **p<0.01, ***p<0.001

Table 2
Cardiorespiratory and metabolic measurements for male and female wrestlers (means ± SD)

Variable	Male wrestlers (n=10)	Female wrestlers (n=10)
VO_2max		
ml/min/kg	59.8±8.6**	49.7±2.7
ml/min/kg FFA	72.7±4.8*	63.9±9.3
Maximal heart rate (beats/min, HR_{max})	179.0±14.0	190.0±6.2
LA_{peak} (mmol/l)	14.1±2.6**	10.5±2.2

Significantly different from female wrestlers: *p<0.05, **p<0.01

Table 3
Physiological variables at AT_4 and IAT thresholds in male and female wrestlers (means ± SD)

Variable	Male wrestlers (n=10)	Female wrestlers (n=10)
AT_4		
VO_2 (ml/min/kg)	42.7±7.9	190.0±6.2
% VO_2max	70.7±14.0***	85.9±5.6
HR (beats/min)	153.1±11.6***	172.9±10.6
% HR_{max}	85.9±2.8*	90.7±5.7
V (km/h)	12.0±0.6	11.4±5.7
IAT		
LA (mmol/l)	4.2±0.7	3.9±0.9
VO_2 (ml/min/kg)	43.0±8.1	40.3±7.0
% VO_2max	71.7±11.8*	81.7±9.2
HR (beats/min)	155.8±15.7*	169.1±9.9
% HR_{max}	84.9±4.1*	88.9±5.4
V (km/h)	12.4±0.9	11.7±1.6

Significantly different from female wrestlers: *p<0.05, **p<0.01, ***p<0.001

Discussion

The main contribution of the present study is the evaluation of the aerobic capacity of female wrestlers. It has been demonstrated that their maximal oxygen consumption was 49.7 ml/min/kg (ranged from 38.8 to 66.5 ml/min/kg) and was higher when compared with senior female judoists (43.7 ml/min/kg) as reported by Little *et al.* [16] but similar to female judo athletes (49.9 ml/min/kg) from the Polish national team [3]. Compared to other reports the VO_2max achieved by male wrestlers in the present study (mean 58.9, ranged from 47.5 to 67.2 ml/min/kg) was greater than reported by Gale *et al.* [10] in the American Olympic team (mean 54.3 ml/min/kg). The present values of VO_2max were similar to those demonstrated by Yoon [5] in Korean wrestlers (60.0 ml/min/kg).

There is little data available concerning oxygen uptake at the anaerobic threshold expressed as %VO_2max in male and female athletes. In both female and male marathon runners matched to training experience the percent of oxygen

uptake at the anaerobic threshold was similar and achieved above 80% [11]. However Little *et al.* [16] demonstrated gender differences in $\%VO_2max$ at the anaerobic threshold. They reported that female judo athletes had greater oxygen utilization at the anaerobic threshold than male judoists (85% and 79%VO_2max, respectively). Similar results have been presented by Maldonaldo-Martin *et al.* [17] which established that $\%VO_2max$ at the anaerobic thresholds estimated as AT_4 and IAT method were higher in female than in male middle distance runners with similar relative performance level. In the present study oxygen uptake at the anaerobic thresholds (AT_4 and IAT), expressed as $\%VO_2max$, was greater in female when compared with male wrestlers. This was unexpected, because females were significantly less experienced than male athletes (8.1 vs. 16.9 years of training). Many studies indicated that during endurance exercise fat metabolism is different in women and men. Jeukendrup *et al.* [15] suggested that at a similar exercise intensity females had a higher absolute rate of fat oxidation then males and this occurred at higher exercise intensity for the females then the males. However, investigation of the effect of gender on exercise substrate utilization yielded conflicting results. The mechanisms for these gender-based differences are still not fully understood, but it was postulated that substrate metabolism can be influenced by the catecholamines and female sex hormones [22], body fat content, percent of fiber type area and training experience [21]. Elis *et al.* [9] revealed that estradiol increases the availability of lipids to exercising muscle due to an increase in muscle lipoprotein lipase activity. A greater relative amount of body fat in women seems to be a potential basis for difference in substrate metabolism between men and women [26]. Moreover Helgerund [11] demonstrated that performance-matched men and women had a similar $\%VO_2max$ although the body fat was significantly higher in female compared to male athletes. A higher percentage of body fat could theoretically lead to a greater availability of fatty acids and to more fat oxidation at a given exercise intensity in women than in men. Another possible explanation of gender-based differences in the regulation of fat metabolism between men and women could be fiber area in skeletal muscle. Staron *et al.* [24] showed that although men and women have an overall distribution of fast and slow fiber types in the vastus lateralis, significant gender differences exist with regard to the total area occupied by each fiber type within the muscle. They revealed that slow fibers occupied a greater area in women, whereas the fast fibers occupied a greater area in men, and suggested that these differences in percentage fiber type area may result in differences in performance.

As follows from the current study the blood lactate concentration after cessation of graded exercise was significantly higher in male than in female wrestlers.

Similar findings, reflecting the gender difference, were reported by Sandoval *et al.* [22] after 5 min cycling corresponding to 60%VO_2max in recreationally active men and women, and they postulated that if women were using less glycogen during exercise than they would produce less lactate. Moreover Sargent *et al.* [23] noted that in untrained men lactate concentration reached higher values then in untrained women after cessation of incremental exercise test. It seems that in the present study the higher blood lactate in male than in female wrestlers resulted from higher intensity at the end of exercise test. It is suggested that more energy was provided through anaerobic glycolysis leading to lactate formation.

This study was the first to assess the aerobic fitness of female wrestlers. It was demonstrated that there are gender differences between female and male wrestlers in response to graded exercise. The maximal oxygen uptake normalized to total body mass or to fat free mass was significantly greater in male when compared to female athletes. However percentage of oxygen uptake at the anaerobic threshold was significantly higher in female as compared to male wrestlers, despite women's shorter training experience. It is possible that the lower VO_2max in the female wrestlers was compensated for by their higher oxygen utilization at the AT. It was also determined that blood lactate concentration, oxygen uptake, percentage of VO_2max, heart rate, percentage of HR_{max} and running velocity at anaerobic threshold was the same when measured with the AT_4 and IAT method in each group of wrestlers (male and female). This result indicates that AT_4 method is sufficiently reliable for measuring anaerobic threshold for female and male wrestlers. AT_4, as opposed to IAT, does not require the athlete to reach the maximal effort. It is therefore easier to apply, takes less time, and is less physically demanding to the athletes of study.

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