Croatian Journal of Education
Vol:15; Sp.Ed.No.4/2013, pages:
Original research paper
Paper submitted: 5th April 2011
Paper accepted: 11th October 2011

Physiological Responses in Male and Female 400m Sprinters

Matej Plevnik[1], Vlatko Vučetić[2], Goran Sporiš[2], Fredi Fiorentini[3], Zoran Milanović[4] and Mladen Miškulin[5]
[1]*Institute for Kinesiology Research, Science and Research Centre Koper, University of Primorska*
[2]*Faculty of Kinesiology, University of Zagreb*
[3]*FC Hajduk, Split*
[4]*Faculty of Sport and Physical Education, University of Niš*
[5] *Department of Orthopaedics, Clinical Hospital Sveti Duh*

Abstract

The primary objective of this study was to determine the differences between male and female athletes competing in the 400m running event, in the parameters for the assessment of not only aerobic and anaerobic energy capacity but also other physiological parameters. Trained 400m (14 male and 14 female) track athletes volunteered to take part in this study. All subjects performed an incremental treadmill test (1 km/h speed increase per minute, 1.5% gradient). The parameters FVC and FEV1S in the male athletes were of higher values than in the female athletes, while there were no significant differences in FEV1S%. A statistically significant difference was found in the parameters for the assessment of aerobic energy capacity in favour of male athletes. Significantly higher values of anaerobic capacity were found in male sprinters (5.7 km/h) compared to female sprinters (4.5 km/h). In other physiological parameters such as HRmax values and HR at VT there were no statistically significant differences. It can be concluded that it is necessary to determine whether there are differences in these parameters between male and female sprinters which will result in a more organized plan for the collective training process. Studies like this can help coaches develop athletes' performance according to their abilities.

Key words: *athletes; metabolic differences; ventilation*

Introduction

Track and field runners are specialized for and adapted to a wide range of running speed and track lengths. Moreover, they represent an optimum subject sample for establishing the relationship between physiological responses, that is the prevalence of various energy systems - from anaerobic alactate (sprinters in the 100m) and lactate (to 400m sprinters) to aerobic (long distance runners). Aerobic and anaerobic systems operate simultaneously but in different proportions, depending on the intensity of activities as well as track and field depending on the racing discipline. The results of energy contribution in the sprinting events have been the subject of numerous body of research. Martin and Coe (1997) have examined the proportion of energy sources in a variety of sprinting disciplines. Thus, in the discipline of 400 meters, the following was the percentage of energy contribution - anaerobic lactate was 60% and aerobic was 30%, while in the 800m discipline this ratio (anaerobic – aerobic) was 38-57%. Duffield et al. (2005), studying the energy contribution to the sprinting events at 400 meters, stated that contribution of aerobic energy system in the 400-meter male sprinters was

41% compared to 59% of anaerobic, while in the female runner it was 45% compared to 55% of anaerobic. Spenser and Gastin (2001) found that during 400m trials (49s) aerobic contribution was 43%, which was comparable to the 37-44% (sprint trained) and 46-50% (endurance trained) aerobic contribution found in 49-57s of exhaustive treadmill running (Nummela & Rusko, 1995; Medbo & Sejersted, 1985). The sprint treadmill allows the runners to sprint at a speed similar to the one developed on the track, while also permitting the same instantaneous variations in speed that occur during the actual sprinting (Lakomy, 2000). Nummela, Hämäläinen, Rusko (2007) in a study in which they wanted to examine whether the treadmill was a valid means of measurement for sprinters drew the conclusion that the results of measuring the track speed are connected and that they simultaneously match the results achieved on a treadmill.

Several authors have found the differences between men and women in the absolute and mass-corrected estimates of maximum aerobic power (McArdle, Katch, & Katch, 1991) as well as in anaerobic power and capacity (Evans & Quinney, 1981; Froese & Houston, 1987; Murphy, Patton, & Frederick, 1986). Hill and Smith (1993) concluded that the use of total work in 30s as a measure of anaerobic capacity of men and women may actually underestimate the gender difference in the anaerobic capacity, because women make a relatively larger aerobic contribution during short-term exercise than men do. From a practical perspective, there are many issues that must be taken into consideration when conducting gender comparative studies. First, the average female has a higher percentage of body fat (5-10%) and lower muscle mass compared to the average male (Tarnopolsky, et al., 2001; Tarnopolsky, MacDougall, Atkinson, Tarnopolsky, & Sutton, 1990; Carter, Renbie, & Tarnopolsky, 2001). Therefore, it is important to express indicators of fitness (i.e. maximum aerobic capacity, VO2max) relative to fat-free mass (Tarnopolsky & Saris, 2001).

Getting acquainted with the energy capacity (anaerobic and aerobic) could greatly assist coaches in creating optimum training sessions. In this particular paper, we are going to obtain the results with different parameters for the assessment of not only the aerobic but also the anaerobic energy capacity. Thus, for instance, the results of the absolute and relative maximum oxygen are going to aid us in assessing the aerobic energy capacity, while the parameter range of the anaerobic zone will be used as a parameter in estimating the anaerobic zone. In addition, the interest in the possible emergence of any kind of difference in these parameters between the male and female sprinters will certainly assist in defining the appropriate intensity of training for individual athletes. The primary objective of this study was to analyse whether the male and female athletes, competing in the 400m running event, have statistically significant differences in the parameters for the assessment of not only aerobic and anaerobic energy capacity but also other physiological parameters.

Methodology

Subjects

Trained 400m (14 male and 14 female) track athletes (descriptive characteristics are presented in Table 1) volunteered to take part in this study. The participants ranged in ability from club level to the national level athletes with the average age for male athletes 19.96 (s=3.60) and for female athletes 19.13 (s=3.20). Besides the results, the basic anthropometric parameters (Body height and Body weight) and the age of the participants were registered in the study protocol. All subjects performed an incremental treadmill test (1 km/h speed increase per minute, 1.5% grade) to volitional exhaustion, and walked at 5 km/h during the first two minutes of recovery. The measurement procedures and potential risks were verbally explained to each subject prior to obtaining a written informed consent according to the Helsinki Declaration. The study was approved by the Ethics Committee of the Faculty of

Kinesiology, University of Zagreb. Subjects were admitted in the study if they had a minimum training age of 3 years, if they were engaged in strenuous training at least 10 h per week and if they were currently active in competition.

Procedures

Laboratory assessments were carried out at the Faculty of Kinesiology, University of Zagreb, Croatia. Each athlete's anthropometrics were measured by an experienced tester prior to the measurement of ventilation and metabolic parameters. Body mass was assessed to the nearest 0.1 kg using beam balance scale with the athletes wearing minimum clothing. Body height was assessed to the nearest 0.1 cm using portable stadiometer. The stadiometer and the scales were calibrated periodically during the study.

Experiment Protocols

The subjects were asked to refrain from strenuous exercise for 24 h prior to the exercise test. Each athlete had previous experience of treadmill running and testing. After a warm-up and stretching, based upon the subject's habits, the incremental protocol on a calibrated treadmill (Run Race 900, Technogym, Italy) with 1.5% inclination was applied.

Ramp Treadmill Test Protocol

The initial speed was 3 km/h, with speed increments of 1 km/h every 60 seconds. The subjects walked the first three steps (up to 7 km/h), and continued running from 8 km/h, until volitional exhaustion. During recovery after the test protocol, the subjects walked at 5 km/h for 2 minutes. The last half or full stage the subject could sustain (for either 30 or 60 s) was defined as the subject's maximum speed.

Expired Gas Analysis

The expired gas was sampled continuously and O_2 and CO_2 concentrations in expired gas were determined using the stable and fast Zirconium Oxygen and NDIR Carbon Dioxide analyzers (breath-by-breath gas exchange system Quark b^2, COSMED, Italy) which were calibrated prior to and following each test, using precision reference gases. The system was calibrated before each test using gases of known concentrations. The heart rate (HR) was monitored continuously during the tests using telemetric heart rate monitor (Polar Electro, Kempele, Finland), and stored in PC memory. The testing was performed during the morning hours (between 9 a.m. and 11 a.m.) in thermo-neutral conditions. The expired airflow was measured with a digital turbine flow meter (COSMED, Italy), which was calibrated prior to and following each test using a 3l syringe at a flow rate and volumes in the expected physiological range. The temperature and humidity of expired gas were measured using a rapidly-responding sensor (Quark b^2, COSMED, Italy). After the test completion, all measured parameters were averaged at 30 second intervals.

Determination of Anaerobic Threshold

Ventilation thresholds were detected visually by combining a 3-segment model (McLellan 1985), V-slope methods (Beaver, Wasserman, Whipp, 1986) and ventilatory equivalent method (Davis, Whipp, Wasserman, 1980). Ventilatory aerobic threshold (VT_1) was defined as the time point which corresponded with an initial departure from linearity in V_E and the onset of the systematic rise in V_E/VO_2, and the fraction of expired O_2 (F_EO_2). Ventilatory anaerobic threshold (VT_2) was determined by combining two common methods: 1) ventilatory equivalent method (the first rise in the ventilatory equivalent of oxygen without a concurrent rise in the ventilatory equivalent of carbon dioxide) (Davis et al., 1980), and 2) V-slope method (the point at which a steeper increase of VCO2as compared to VO_2 occurred) (Beaver et al., 1986). Briefly, two experienced experimenters assessed each subject's graphic data. Values for VO2VT were determined by simultaneously evaluating graphs of the data plotted for each of the two methods. The evaluators used both graphs to assess concurrent break points. The end-of-test criteria for the determination of maximum oxygen uptake (VO_{2max}) included two of the following: 1) volitional exhaustion, 2) achieving a plateau in VO_2 (highest values were calculated as arithmetic means of the two consecutive highest 30s values), and 3) HR ≥ 90% of age-predicted maximum.

The Variables of the Test are:

VO_{2max} and RVO_{2max} – the maximum oxygen uptake (ml·kg/min and l/min); VO_{2VT} and RVO_{2VT} - oxygen uptake at the anaerobic ventilation threshold (ml·kg/min and l/min); $\%VO_2$ - % of the maximum oxygen uptake at the anaerobic ventilation threshold (%); HR_{max} – the maximum heart rate achieved in the test (beats/min); HR_{VT} - heart rate at the anaerobic ventilation threshold (beats/min); v_{max} – the maximum running speed (km/h); v_{VT} - running speed at the anaerobic ventilation threshold (km/h); v_{AN} - anaerobic speed range (km/h) = v_{max} – v_{VT}; *FVC* - forced vital capacity; *FEV1S* – forced expiratory volume in 1 second; *FEV1%* - Tiffeneau index (%); VE_{max} - maximum voluntary ventilation (l/min); FD_{max} - maximum breathing frequency (breaths/min); TD_{max} – Tidal volume (l).

Data Analysis

The collected data were stored and analyzed via Windows statistical software (Statistica for Windows 7.0). The descriptive statistics was calculated for all experimental data. The T-test for independent variables was used in order to determine if there were statistically significant differences between male and female sprinters among the tested variables. The statistical significance was set at $p<0.05$.

Results

Table 1 shows descriptive characteristics of the subjects. The results of the analysis of differences (Table 2) showed a statistically significant difference ($p <0.05$) for the variables of Body height and Body weight, where the male sprinters were taller and heavier than the female sprinters. Male sprinters' average age (mean 19.96) did not differ significantly from that of female sprinters (mean 19.13). Statistically significant differences were obtained by spirometry parameters used to measure pulmonary ventilation function (Table 2). The parameters FVC and FEV1S in male athletes were of greater values than in the female athletes, while there were no significant differences in FEV1S%.

Table 1. Descriptive characteristics of the subjects

	Total (n=28)	Female (n=14)	Male (n=14)
Age (years)	19.54±3.37	19.13±3.20	19.96±3.60
Body height (cm)	174.19±8.80	167.23±6.16	181.16±4.27
Body weight (kg)	63.96±10.52	55.21±4.94	72.71±6.36

Legend: Values are means, ± standard deviation

A further analysis of ventilation and metabolic parameters showed a statistically significant difference in the parameters for the assessment of the aerobic energy capacity (Table 2). In other words, VO2max and VO2 values at VT (ventilation threshold) were higher for males than females. In line with this RVO2max and RVO2max values at VT also showed a higher value for the male athletes in comparison with female athletes. However, there was no statistically significant difference in VO2VP between male and female 400m sprinters. The male sprinters achieved statistically greater maximum speed on a treadmill as well as in the parameter that showed the achieved speed at the anaerobic threshold compared to the females. In this study, significantly higher values of anaerobic capacity were found in male (5.7 km/h) compared to female sprinters (4.5 km/h). In other physiological parameters such as HRmax values and HR at VT there were no statistically significant differences. The analysis also revealed that there were no statistically significant differences between males and females in the maximum breathing frequency (FDmax).

Table 2. Differences between male and female sprinters

Variables	Male (Mean±SD)	Female (Mean±SD)	t-value	p
Age (years)	19.96±3.60	19.13±3.20	0.64	0.53
Body height (cm)	181.16±4.27	167.23±6.16	6.95	0.00
Body weight (kg)	72.71±6.36	55.21±4.94	8.13	0.00
FVC (l)	6.16±0.58	4.06±0.40	11.08	0.00
FEV1S (l)	5.03±0.43	3.61±0.42	8.85	0.00
FEV1% (%)	79.76±8.59	89.33±7.15	-3.20	0.00
HR_{max} (beats/min)	200.43±7.11	196.00±5.48	1.85	0.08
HR_{VT} (beats/min)	181.50±10.19	179.43±9.36	0.56	0.58
V_{max} (km/h)	19.50±0.78	17.11±1.32	5.84	0.00
V_{VT} (km/h)	13.82±1.01	12.57±1.41	2.70	0.01
V_{AN} (km/h)	5.68±0.72	4.54±0.58	4.62	0.00
VO_{2max} (l/min)	4.34±0.34	2.94±0.25	12.20	0.00
RVO_{2max} (ml/k·min)	59.95±3.60	53.39±3.65	4.79	0.00
VO_{2VT} (l/min)	3.78±3.78	2.49±0.26	10.81	0.00
RVO_{2VT} (ml·/kg·min)	52.12±3.65	45.28±4.34	4.51	0.00
$\%VO_{2VT}$ (%)	86.96±3.56	84.73±4.52	1.45	0.16
VE_{max} (l/ min)	161.34±24.70	104.67±13.72	7.50	0.00
FD_{max} (breaths/min)	62.30±8.27	58.23±9.08	1.24	0.23
TD_{max} (l)	2.70±0.31	1.93±0.35	6.24	0.00

FVC - forced vital capacity, FEV1S – forced expiratory volume in 1 second, FEV1% - Tiffeneau index (%), HRVT - heart rate at the anaerobic ventilation threshold, v_{max} - maximum running speed, v_{VT} - running speed at the anaerobic ventilation threshold, v_{AN} - anaerobic speed range, VO_{2VT} and RVO_{2VT} - oxygen uptake at the anaerobic ventilation threshold, $\%VO_2$ - % of VO_{2max} at the anaerobic ventilation threshold, VE_{max} - maximum voluntary ventilation, FD_{max} - maximum breathing frequency, TD_{max} – Tidal volume

Discussion and Conclusion

The average values of Body height and Body weight for the tested sprinters were similar to the values found by other researchers (Khosla, 1978; Khosla & McBroome, 1985; Uth, 2005). The male sprinters were taller and heavier than the female sprinters, which was expected due to the greater muscle mass (Table 2). It is interesting to note that female sprinters who were of the same height, leg length and stride length as male sprinters, recorded times in a 100m race that were about 1s slower than the performance of men. According to Hoffman (1972), this difference is attributed to the lower stride frequency of the female sprinters. In addition, male sprinters perform better then female because they have larger muscle mass (Cureton, Collins, Hill, & McElhannon, 1988) and the muscle-building hormone, testosterone, that is essential for the anaerobic working potential (Kraemer et al., 1991). The male and female 400m sprinters did not differ significantly in age (Table 2) which was of great importance for the other measurements taken during this study.

Statistically significant differences were obtained by spirometry parameters used to measure pulmonary ventilation function. The parameters FVC and FEV1S were greater for male athletes than for the females, while the obtained parameter values FEV1S% were lower, which may be interpreted more as a knowledge of forced respiratory techniques than the actual change in the ability of respiratory muscles (Table 2).

The further analysis of ventilation and metabolic parameters showed a statistically significant difference in the parameters for the assessment of aerobic energy capacity. In other words, VO2 max and VO2 values at VT (ventilatory threshold) were higher in males, which had been expected. In line with this RVO2max and RVO2max at VT also showed higher values for the male runners in comparison with the female runners. Regardless of higher values in male runners, both groups should work on developing the aerobic and anaerobic capacity due to the great importance of both capacities in the result at 400m. Although the anaerobic energy contribution in male and female 400m race is greater (about 60% for male runners and 70% for female runners), the aerobic component is of great importance, which was confirmed by Duffield, Dawson, Goodman (2005). Duffield et al. (2005) also stated in their research that the energy system contribution to the 400m event was calculated as 41% of the aerobic energy system for male (59% anaerobic) and 45% of the aerobic energy system for female sprinters (55% anaerobic). By increasing the length of the event, the participation of the aerobic system raises, so at 800m, the percentages of energy will be opposite. This wide range of values previously found is due to the fact that different measurement protocols had been used and thus different ways of determining the relative energy system contribution had been used as well.

Table 2 shows that there is no statistically significant difference between male and female sprinters for the % of $VO2_{VT}$, but both exceed the anaerobic threshold of about 85% VO2max, which is consistent with the data obtained in research on athletes in all racing disciplines (Vučetić, 2007). Comparing the results for achieved maximum speed on a treadmill, there is a statistically significant difference in favour of the male runners ($p<0.05$). In addition, the result for the parameter that shows the achieved speed at the anaerobic threshold was greater in male sprinters. These results are consistent with the results and the differences between athletes in the 400m event, where male sprinters achieve significantly better results.
Looking at the parameter for the assessment of anaerobic energy capacity, endurance in anaerobic zone (V_{AN}), males had significantly higher values (5.7 km/h) compared to females (4.5 km/h). Thus, it could be concluded that male sprinters have greater anaerobic capacity than female sprinters.

In other physiological parameters such as values HRmax and HR at VT there were no statistically significant differences. The analysis also revealed that male sprinters did not differ significantly in the maximum breathing frequency (FDmax) compared to female sprinters ($p>0.05$). Male sprinters achieved significantly higher values in the parameters of maximum voluntary ventilation (VEmax) and maximum respiratory volume (TDmax). These results can be explained firstly by the fact that male athletes have larger lung capacity than females and secondly, because males achieve greater maximum speed and higher pH value. Having that in mind, the fundamental task of the lungs is ventilating correction, through the breathing centre that is located in an extended cord; as a consequence we have the increase in the ventilation. These physiological parameters do not estimate the energy capacity, but are closely related to the intensity of the training and therefore the results will help us in programming and controlling the training process.

In this paper, the research was conducted on elite Croatian athletes involved in the 400m discipline in order to become better acquainted with their level of performance through ventilation and metabolic parameters that are necessary for planning, programming and the analysis of the training process.

Also, it was necessary to determine whether there were differences in these parameters between male and female sprinters, which will result in a more organized plan for the collective training process. Gender differences in sprint have received very limited attention, despite the fact that the smallest performance differences between male and female are actually observed at 100m to 400m events (Cheuvront, Carter, Deruisson, & Moffatt, 2005). Studies like this can help coaches to improve athlete's performance according to their abilities. Also, the coaches should involve their athletes more in such diagnostic tests and by the interpretation of ventilation and metabolic parameters they will obtain a significantly "wider range" of data that are required for planning, programming and control of training. This will ultimately lead to better results.

References

Beaver, W.L., Wasserman, K., & Whipp, B.J. (1986). A new method for detecting anaerobic threshold by gas exchange. *J Appl Physiol*, *60*, 2020–2027.

Carter, S.L., Renbie, C., & Tarnopolsky, M.A. (2001). Substrate utilization during endurance exercise in men and women after endurance training. *Am J Physiol Endocrinol Metab, 280,* 898-907.

Cheuvront, S.N., Carter, R., Deruisseau, K.C., & Moffatt, R.J. (2005). Running performance differences between men and women: an update. *Sports Med, 35*(12), 1017-24.

Cureton, K.J., Collins, M.A., Hill, D.W., & McElhannon, F.M. (1988). Muscle hypertrophy in men and women. *Med Sci Sports Exerc, 20*(4), 338-344.

Davis, J.A., Whipp, B.J. & Wasserman, K. (1980). The relation of ventilation to metabolic rate during moderate exercise in man. *Eur J Appl Physiol Occup Physiol, 44*, 97–108.

Duffield, R., Dawson, B., & Goodman, C. (2005). Energy system contribution to 400 - metre and 800 – metre track running. *J Sports Sci, 23*(3), 299-307.

Evans, J.A. & Quinney, H.A. (1981). Determination of resistance settings for anaerobic power testing. *Can J Appl Sport Sci, 6*, 53-6.

Froese, E.A. & Houston, M.E. (1987). Performance during the Wingate anaerobic test and muscle morphology in males and females. *Int J Sports Med, 8*, 35-9.

Hill, D.W. & Smith, J.C. (1993). Gender difference in anaerobic capacity: role of aerobic contribution. *Br J Sports Med, 27*(1), 45-48.

Khosla, T. & McBroom, V.C. (1985). Age, height and weight of female Olympic finalists. *Br J Sports Med, 19*, 96-99.

Khosla, T. (1978). Standards on age, height and weight in Olympic running events for men. *Br J Sports Med, 12*, 97-101.

Kraemer, W.J., Gordon, S.E., Fleck, S.J., Marchitelli, L.J., Mello, R., Dziados, J.E., Friedl, K., Harman, E., Maresh, C. & Fry, A.C. (1991). Endogenous anabolic hormonal and growth factor responses to heavy resistance exercise in males and females. *Int J Sports Med, 12,* 228-235.

Lakomy, H.K.A. (2000). Physiology and biochemistry of sprinting. In J. A. Hawley (Ed), *Running: Handbook of Sports Medicine and Science,* (pp. 1-14). Oxford: Blackwell Science.

Martin, D.E. & Coe, P.N. (1997). *Better Training for Distance Runners*. *2nd ed*. Champaign, IL: Human.

McArdle, W.D., Katch, F.I. & Katch, V.L. (1991). *Exercise Physiology: Energy, Nutrition, and Human Performance, 3rd ed*. Philadelphia, Pennsylvania, USA: Lea and Febiger.

McLellan, T. (1985). Ventilatory and plasma lactate response with different exercise protocols: a comparison of methods. *Int J Sports Med, 6*, 30-35.

Medbo, J. & Sejersted, O. (1985). Acid-base and electrolyte balance after exhausting exercise in endurance-trained and sprint-trained subjects. *Acta Physiol Scand, 125*, 97–109.

Murphy, M.M., Patton, J.F., & Frederick, F.A. (1986). Comparative anaerobic power of men and women. *Aviat Space Environ Med, 57*, 636-41.

Nummela, A., Hämäläinen, I., & Rusko, M. (2007). Comparison of maximal anaerobic running tests on treadmill and track. *J Sports Sci, 25*(1), 87-96.

Nummela, A., Rusko, H. (1995). Time course of anaerobic and aerobic energy expenditure during short term exhaustive running in athletes. *Int J Sports Med, 16*(8), 522 – 527.

Spencer, M.R. & Gastin, P.B. (2001). Energy system contribution during 200 to 1500m running in highly trained athletes. *Med Sci Sports Exerc, 33*(1), 157-162.

Tarnopolsky, L.J., MacDougall, J.D., Atkinson, S.A., Tarnopolsky, M.A. & Sutton, J.R. (1990). Gender differences in substrate for endurance exercise. *J Appl Physiol, 68*, 302-308.

Tarnopolsky, M.A. & Saris, W.H.M. (2001). Evaluation of gender differences in physiology: an introduction. *Curr Opin Clin Nutr Metab Care, 4*, 489-492.

Tarnopolsky, M.A., Zawada, C., Richmond, L.B., Carter, S., Shearer, J., Graham, T. & Phillips, S.M. (2001). Gender differences in carbohydrate loading are related to energy intake. *J Appl Physiol, 91*, 225-230.

Uth, N. (2005). Anthropometric comparison of world-class sprinters and normal. *J Sports Sci Med, 4*, 608-616.

Vučetić, V. (2007). Razlike u pokazateljima energetskih kapaciteta trkača dobivenih različitim protokolima opterećenja [Differences in the energy capacity parameters among runners obtained with different load protocols]. (Unpublished PhD thesis, University of Zagreb). Zagreb: Faculty of Kinesiology University of Zagreb

Matej Plevnik
Institute for Kinesiology Research, Science and
Research Centre Koper, University of Primorska,
Garibaldijeva 1, 6000 Koper, Slovenia
matej.plevnik@zrs.upr.si

Vlatko Vučetić
Faculty of Kinesiology ,University of Zagreb
Horvaćanski zavoj 15, 10000 Zagreb, Croatia
vvuceticif.hr

Goran Sporiš
Faculty of Kinesiology, University of Zagreb
Horvaćanski zavoj 15, 10000 Zagreb, Croatia
gsporisif.hr

Fredi Fiorentini
FC Hajduk
Mediteranskih igara 2, 21000 Split, Croatia
fredi.fio@gmail.com

Zoran Milanović
Faculty of Sport and Physical Education, University of Niš
Univerzitetski trg 2, 18000 Niš, Serbia
zoooro_85@yahoo.com

Mladen Miškulin
Department of Orthopaedics, Clinical Hospital Sveti Duh
Sveti Duh 64, Zagreb, Croatia
mladen.miskulin@zg.t-com.hr

Fiziološke reakcije muških i ženskih sprintera na 400m

Sažetak

Primarni cilj ovog istraživanja bio je utvrditi razlike između muških i ženskih atletičara koji se natječu u trčanju na 400 m, u parametrima koji procjenjuju ne samo aerobni i anaerobni energetski kapacitet već i druge fiziološke parametre. Trenirani atletičari na 400 m (14 muških i 14 ženskih) dragovoljno su sudjelovali u ovom istraživanju. Svi ispitanici izvodili su inkrementalni treadmill *test (1 km/h povećanje brzine u minuti, 1,5% nagib). Parametri FVC i FEV1S su kod muških atletičara većih vrijednosti nego u ženskih atletičarki, dok nije bilo značajne razlike u FEV1S%. Statistički značajna razlika pronađena je u parametrima za procjenu aerobnog kapaciteta energije u korist muških atletičara. Značajno više vrijednosti anaerobnog kapaciteta pronađene su kod muških (5,7 km/h) sprintera u odnosu na ženske (4,5 km/h). U drugim fiziološkim parametrima, kao što su HRmax vrijednosti i HR na VT nema statistički značajne razlike. Može se zaključiti da je potrebno utvrditi postoje li razlike u tim parametrima između muških i ženskih sprintera, koje će rezultirati organiziranijim planiranjem kolektivnog procesa obuke. Studije kao što je ova mogu pomoći trenerima razvijati atletičareve performanse u skladu s njihovim sposobnostima.*

Ključne riječi*: atletičari, metaboličke razlike, ventilacija*

Uvod

Atletičari trkači specijalizirani su i u širokom rasponu prilagođeni brzini trčanja i dužini staze. Štoviše, oni predstavljaju optimalan uzorak za uspostavljanje odnosa između fizioloških reakcija, u kojem prevladavaju različiti energetski sustavi – od anaerobnih alaktatnih (sprinteri na 100 m) i laktatnih (do 400 m) do aerobnih (dugoprugaši). Aerobni i anaerobni sustavi rade istovremeno, ali u različitim omjerima, ovisno o intenzitetu aktivnosti, kao i u atletici, ovisno o disciplini utrke. Rezultati energetskog doprinosa u sprintu dosta su istraživani. Martin i Coe (1997) istražili su udio energetskih izvora u različitim sprinterskim disciplinama. Tako je u disciplini 400 metara postotak doprinosa energije – anaerobnih laktata 60% i 30% aerobnog, dok je u disciplini 800 metara taj odnos (anaerobni – aerobno) iznosio 38% prema 57%. Duffield i sur. (2005) istraživali su energetski doprinos kod sprintera na utrkama 400 metara i navode da je doprinos aerobnog energetskog sustava kod muških sprintera na 400 metara 41% u odnosu na 59% anaerobni, dok je kod ženskih sprintera bio 45% u odnosu na 55% anaerobnog. Spenser i Gastin (2001) utvrdili su da je tijekom utrke na 400 m (49 s) aerobni doprinos bio 43%, što je usporedivo s 37-44% (sprinterski trening) i 46-50% (trening izdržljivosti) aerobni doprinos nalazi u 49 – 57 sekundi kod iscrpnog trčanja na pokretnoj traci (Nummela i Rusko, 1995; Medbo i Sejersted, 1985). Sprint na pokretnoj traci omogućuje trkaču da sprinta sličnim brzinama s onima postignutim na stazi, a također istovremeno dopuštajući iste trenutne promjene u brzini koje se javljaju tijekom stvarnog sprinta (Lakomy, 2000). Nummela, Hämäläinen, Rusko (2007) u studiji u kojoj su željeli ispitati je li na pokretnoj traci bio valjan način mjerenja za sprintera, došli su do zaključka da su rezultati mjerenja brzine na stazi povezani i istovremeno odgovaraju postignutim rezultatima na pokretnoj traci. Nekoliko autora našlo je razlike između muškaraca i žena u apsolutnom i masovno korigiranim procjenama maksimalne aerobne snage (McArdle, Katch, Katch, 1991) te u anaerobnoj snazi i kapacitetu (Evans i Quinney, 1981; Froese i Houston, 1987 , Murphy, Patton i Frederick, 1986). Hill i Smith (1993) zaključili su da se korištenjem ukupnog rada od 30 sekundi, kao mjere anaerobnog kapaciteta muškaraca i žena, zapravo može podcjenjivati razlika među spolovima u anaerobnom kapacitetu jer žene čine relativno veći aerobni doprinos tijekom kratkotrajnog vježbanja nego muškarci. S praktičnog aspekta, postoje mnoga pitanja koja treba uzeti u obzir, kad je riječ o spolu, prilikom provođenja komparativne studije. Prvo, prosječna žena ima veći postotak tjelesne masti (5-10%) i niže mišićne mase u usporedbi s prosječnim muškarcem (Tarnopolsky et al 2001;. Tarnopolsky, MacDougall, Atkinson, Tarnopolsky, Sutton, 1990, Carter, Renbie , Tarnopolsky, 2001). Zbog toga je važno izraziti pokazatelje sposobnosti (tj. maksimalni aerobni kapacitet, VO2max) u odnosu na nemasne mase (Tarnopolsky i Saris, 2001).

Upoznavanje s energetskim kapacitetom (anaerobnim i aerobnim) uvelike može pomoći trenerima u kreiranju optimalnog treninga. U ovom radu željeli smo dobiti rezultate s različitim parametrima za procjenu ne samo aerobnih već i anaerobnih energetskih kapaciteta. Stoga će nam, primjerice, rezultati apsolutnog i relativnog maksimalnog primitka kisika pomoći u procjeni aerobnih energetskih kapaciteta, dok će se parametar raspona anaerobnih područja koristiti kao parametar procjene anaerobnog područja. Osim toga, interes za moguću pojavu bilo kakve razlike u tim parametrima između muških i ženskih sprintera zasigurno će pomoći u definiranju odgovarajućeg intenziteta treninga za pojedine sportaše. Primarni cilj ovog istraživanja bio je utvrditi postoji li statistički značajna razlika u parametrima za procjenu ne samo aerobnih i anaerobnih energetskih kapaciteta već i drugih fizioloških parametara kod muških i ženskih atletičara koji se natječu u trčanju na 400 metara.

Metode

Uzorak

U istraživanju su sudjelovali trenirani atletičari (14 muških i 14 ženskih) na 400 metara (deskriptivne karakteristike prikazane su u tablici 1.). U istraživanju su sudjelovali ispitanici u rasponu sposobnosti od klupske razine do nacionalne razine prosječne dobi za atletičare 19,96 (s = 3,60) i atletičarke 19,13 (s = 3,20). Osim rezultata, u studiji su zabilježeni i osnovni antropometrijski parametri (tjelesna visina i težina tijela) i dob sportaša. Svi ispitanici izvode inkrementalni test na pokretnoj traci (1 km/h povećanje brzine u minuti, 1,5% stupanj) do iscrpljenosti, i hodaju 5 km/h tijekom prve dvije minute za oporavak. Mjerni postupci i potencijalni rizici usmeno su objašnjeni svakom ispitaniku prije nego što su dobili pismeni pristanak prema Helsinškoj deklaraciji. Studija je odobrena od Etičkog povjerenstva Kineziološkog fakulteta, Sveučilišta u Zagrebu. Ispitanici su bili primljeni u studiju ako su imali minimalni trening od 3 godine i ako su sudjelovali u napornom treningu najmanje 10 sati tjedno i trenutno su aktivni u natjecanju.

Postupak

Laboratorijske procjene izvršene su na Kineziološkom fakultetu Sveučilišta u Zagrebu, Hrvatska. Svakom atletičaru iskusni su mjeritelji izmjerili antropometriju, a zatim ventilacijske i metaboličke parametre. Masa tijela procijenjena je vagom, s točnošću od 0,1 kg, a sportaši su bili minimalno odjeveni. Visina tijela procijenjena je s točnošću od 0,1 cm korištenjem prijenosnog stadiometra. Stadiometar i vaga kalibrirani su periodično tijekom istraživanja.

Eksperimentalni protokol

Ispitanici su zamoljeni da se suzdrže od naporne vježbe 24 sata prije testiranja. Svaki atletičar imao je prethodna iskustva trčanja na pokretnoj traci i testiranja. Nakon zagrijavanja i istezanja, na temelju ispitanikove navike, inkrementalni protokol namješten je na traci (Run Race 900, Technogym, Italija) s 1,5% nagiba.

Protokol izvođenja na pokretnoj traci

Početna brzina je 3 km/h, s povećanjem brzine od 1 km/h svakih 60 sekundi. Ispitanici su hodali prva tri koraka (do 7 km/h), a zatim nastavili trčanje s 8 km/h, do iscrpljenosti. Za vrijeme oporavka nakon testa ispitanik hoda 5 km/h 2 minute. Posljednja polovina ili puna faza koju ispitanik može održati (bilo za 30 ili 60 a) definirana je kao ispitanikova maksimalna brzina.

Analiza izdahnutih plinova

Izdahnuti plinovi su uzorci O_2 i CO_2 , tj. koncentracije plinova koji je izdahnut i određuje se s pomoću stabilnog i brzog Zirconium Oxygen and NDIR Carbon Dioxide analizatora (dah po dah sustava razmjene plinova Quark b2, COSMED, Italija) koji su precizno namješteni prije i provjereni nakon svakog testa korištenjem referentnih plinova. Sustav je namješten tako da se prije svakog testa koriste plinovi poznatih koncentracija. Otkucaji srca (HR) prikupljani su kontinuirano tijekom ispitivanja koristeći se telemetrijskim monitorom za otkucaje srca (Polar Electro, Kempele, Finska), i pohranjeni su u memoriju računala. Testiranje je provedeno u jutarnjim satima (između 09:00 i 11:00 sati) u termo-neutralnim uvjetima. Protok zraka koji je istekao mjeren je digitalnom turbinom protoka (COSMED, Italy), koja je namještena prije početka i nakon svakog testa s pomoću 3 l šprice na protok i volumen u očekivanom fiziološkom rasponu. Temperatura i vlažnost plina izmjerene su vrlo brzo s pomoću reakcije senzora (Quark b2, COSMED, Italija). Nakon završetka testa, svi su izmjereni parametri kompletirani u prosjeku od 30 sekundi.

Određivanje anaerobnog praga

Ventilacijski pragovi otkriveni su vizualno, kombiniranjem 3-segmentarnog modela (McLellan 1985), V-nagib metode (Beaver, Wasserman, Whipp 1986) i ventilacijsko ekvivalentne metode (Davis, Whipp, Wasserman 1980). Respiracijskoj aerobni prag (VT_1) je definiran kao vremenska točka koja odgovara početnom odlasku iz linearnosti u V_E i početku sustavnog rasta V_E/VO_2, a dio je istekao O_2 (F_EO_2). Respiracijsko-anaerobni prag (VT_2) određen je kombinacijom dvije uobičajene metode: 1) respiracijski jednakovrijedne metode (prvi uspon u respiracijskoj ekvivalenti kisika bez istodobnog porasta ugljičnog dioksida) (Davis i sur., 1980), i. 2) V-nagib metodom (točka u kojoj se dogodio jači porast VCO_2 u odnosu na VO_2) (Beaver i sur. 1986). Ukratko, dvoje iskusnih eksperimente svakog subjekta procjenjuju grafičkim podatcima. Vrijednosti za VO_{2VT} utvrđene su istodobno kod procjene grafova podataka i ucrtane za svaku od dvije metode. Ocjenjivači koriste oba grafikona za procjenu istovremenih kontrolnih točki. *End-of-test* kriterija za određivanje maksimalnog primitka kisika (VO2max) uključuje dva sljedeća: 1) voljnu iscrpljenost, 2) postizanje platoa VO2 (najviša se vrijednost izračunava kao aritmetička vrijednost s pomoću dvije uzastopne od najviše 30 sekundi), i 3) HR $\geq$ 90% u dobi od predviđene maksimalne.

Varijable u testu su:

VO_{2max} i RVO_{2max} – najveći unos kisika (ml kg/min i L/min); VO_{2VT} i RVO_{2VT} – unos kisika na anaerobni prag ventilacije (ml kg/min i L/min); % VO_2 -% od maksimalnog unosa kisika na anaerobni prag ventilacije (%);HRmax - maksimalni broj otkucaja srca postignut u testu (otkucaja/min); HR_{VT} – broj otkucaja srca pri anaerobnom pragu ventilacije (otkucaja/min); V_{max} – maksimalna brzina trčanja (km/h); V_{VT} – brzina trčanja pri anaerobnom pragu ventilacije (km/h); V_{AN} – anareobni raspon brzine (km/h) = $v_{max} – v_{VT}$; *FVC* – prisilan vitalni kapacitet; *FEV1S* – prisiljeni izdisajni volumen u 1 sekundi; *FEV1%* – Tiffeneau index (%); VE_{max} – maksimalna spontana ventilacija (l/min); FD_{max} – maksimalna frekvencija disanja (udisaj/min^1); TD_{max} – Tidal volumen (l).

Analiza obrade podataka

Prikupljeni podaci pohranjeni su i analizirani s pomoću Windows statističkog programa (Statistica for Windows 7.0). Za sve dobivene podatke izračunati su deskriptivni statistički parametri. T-test za nezavisne uzorke korišten je kako bi se utvrdilo postojanje statistički značajne razlike između muških i ženskih sprintera u testiranim varijablama. Statistička značajnost postavljena je na razini $p<0,05$.

Rezultati

Tablica 1. prikazuje deskriptivne parametre ispitanika. Rezultati analize razlika (tablica 2) pokazuju statistički značajnu razliku ($p <0,05$) za varijable tjelesna visina i tjelesna težina, i pokazuje da su muški sprinteri viši i teži od ženskih sprintera. Prosječna dob muških sprintera (srednja vrijednost 19.96) ne razlikuje se statistički značajno od ženski sprintera (srednja vrijednost 19.13). Statistički značajne razlike dobivene su kod spirometrijskih parametara koji se koriste za mjerenje plućne ventilacije (Tablica 2). Parametri FVC i FEV1S su kod muških atletičara većih vrijednosti nego kod atletičarki, dok nije bilo značajne razlike u FEV1S%.

Tablica 1.

Daljnja analiza ventilacijskih i metaboličkih parametara pokazala je statistički značajnu razliku u parametrima za procjenu aerobnoga energetskog kapaciteta (Tablica 2). Drugim riječima, VO2max i VO2 vrijednosti na VT (ventilacija prag) bili su veći kod muškaraca nego kod žena. U skladu s tim RVO2max i RVO2max vrijednosti kod VT također su pokazale više vrijednosti za atletičare u usporedbi s atletičarkama. Međutim, nije bilo statistički značajne razlike u VO2VP između muških i ženskih sprintera na 400 m. Muški sprinteri postižu statistički veće maksimalne brzine na pokretnoj traci, kao i u parametru koji pokazuje postignutu brzinu kod anaerobnog praga u odnosu na ženske sprintere. U ovoj studiji značajno veće vrijednosti anaerobnog kapaciteta pronađene su kod muških (5,7 km/h) sprintera u odnosu na ženske (4,5 km/h). U ostalim fiziološkim parametrima kao što su HRmax vrijednosti i HR pri VT nema statistički značajne razlike. Analiza je također pokazala da nema statistički značajne razlike između muškaraca i žena u maksimalnoj frekvenciji disanja (FDmax).

Tablica 2.

Diskusija

Prosječne vrijednosti visine tijela i tjelesne težine za testirane sprintere sličnih su vrijednosti pronašli i drugi istraživači (Khosla, 1978, Khosla i McBroome, 1985; Uth, 2005). Muški sprinteri su viši i teži od žena sprintera što se i očekuje s obzirom na veću mišićnu masu (Tablica 2). Zanimljivo je napomenuti da ženski sprinteri iste visine, dužine nogu i duljine koraka kao muški sprinteri imaju tijekom utrke na 100 metara oko 1 s sporije vrijeme od muškaraca. Prema Hoffman (1972) ta razlika pripisuje se sporijoj frekvenciji koraka ženskih sprintera. Osim toga, muški sprinteri uspješniji su od žena jer imaju veću mišićnu masu (Cureton, Collins, Hill, McElhannon, 1988) i zbog hormona testosterona koji izgrađuje mišiće i koji je neophodan za anaerobni radni potencijal (Kraemer i sur. 1991). Muški i ženski sprinteri ne razlikuju se značajno po dobi (Tablica 2), koja je od velike važnosti za druga mjerenja tijekom ove studije.

Statistički značajne razlike dobivene su kod parametra spirometrije koji se koriste za mjerenje funkcije plućne ventilacije. Parametri FVC i FEV1S bili su veći kod muških atletičara nego kod ženskih, a dobivene vrijednosti parametara FEV1S% bile su manje i mogu se tumačiti više kao poznavanje prisilne respiratorne tehnike od stvarne promjene u sposobnosti respiratornih mišića (Tablica 2). Daljnja analiza ventilacijskih i metaboličkih parametara pokazala je statistički značajnu razliku u parametrima za procjenu aerobnoga energetskog kapaciteta. Drugim riječima, VO2max i VO2 vrijednosti kod VT (ventilacijskog praga) bile su veće kod muškaraca, što je bilo i očekivano. U skladu s tim RVO2max i RVO2max kod VT također su pokazale više vrijednosti kod trkača u odnosu na trkačice. Bez obzira na veće vrijednosti kod trkača, obje skupine trebaju raditi na razvoju aerobnih i anaerobnih kapaciteta zbog velike važnosti oba kapaciteta u rezultatu na 400 m. Iako je anaerobni energetski doprinos u muškim i ženskim utrkama na 400 m veći (oko 60% muškaraca i 70% žena), i aerobna je komponenta od velike važnosti, što su potvrdili Duffield, Dawson, Goodman (2005). Duffield i sur. (2005) također navode u svojim istraživanjima da je doprinos energetskog sustava u utrci na 400 m bio izračunat kao 41% aerobnoga energetskog sustava za muške (59% anaerobni) i 45% aerobnog energetskog sustava za ženske sprintera (55% anaerobni). Povećanjem dužine utrke sudjelovanje aerobnih sustava povećava se, pa će na 800 m postoci energije biti suprotni. Taj široki raspon vrijednosti prethodno je utvrđen zbog činjenice da su korišteni različiti mjerni protokoli, a time su i korišteni različiti načini utvrđivanja relativnog doprinosa energetskog sustava. Tablica 2 pokazuje da ne postoji statistički značajna razlika između muških i ženskih sprintera za % $VO2_{VT}$, ali i veći anaerobni prag od oko 85% VO2max, što je u skladu s podacima dobivenim u istraživanju o atletičarima svih trkačkih disciplina (Vučetić, 2007). Uspoređujući rezultate za postignute maksimalne brzine na pokretnoj traci, utvrđeno je da postoji statistički značajna razlika u korist trkača (p <0,05). Osim toga, rezultati za parametar koji prikazuje postignutu brzinu u anaerobnom pragu bio je veći kod sprintera. Ti rezultati u skladu su s rezultatima i razlikama između atletičara u utrkama na 400 m, kada su sprinteri ostvarili znatno bolje rezultate. Gledajući parametar za procjenu anaerobnih energetskih kapaciteta, izdržljivost u anaerobnoj zoni (V_{AN}), muškarci su imali značajno veće vrijednosti (5,7 km/h) u odnosu na žene (4,5 km/h). Dakle, moglo bi se zaključiti da sprinteri imaju veći anaerobni kapacitet od sprinterica. U ostalim fiziološkim parametrima kao što su vrijednosti HRmax i HR kod VT nema statistički značajne razlike. Analiza je također pokazala da se sprinteri ne razlikuju značajno u maksimalnoj frekvenciji disanja (FDmax) u odnosu na sprintere (p> 0,05). Muški sprinteri postigli su značajno više vrijednosti u parametrima maksimalne spontane ventilacije (VEmax) i maksimalnog dišnog volumena (TDmax). Ti rezultati mogu se objasniti prije svega činjenicom da muški sportaši imaju veći kapacitet pluća od ženskih, i time što muškarci postižu veću maksimalnu brzinu i veće pH vrijednosti. Imajući to na umu, temeljna zadaća pluća je ventilacijska korekcija u centru disanja koji se nalazi u produženoj moždini, a posljedica je povećanje ventilacije. Ti fiziološki parametri nisu procjene energetskih kapaciteta, ali su tijesno vezane uz intenzitet treninga, a samim time rezultati će nam pomoći u programiranju i kontroli trenažnog procesa. U ovom radu istraživanje je provedeno na elitnim hrvatskim atletičarima koji se natječu u disciplini na 400 m, kako bismo se bolje upoznali s razinom svojih performansi kroz ventilaciju i metaboličke parametre potrebne za planiranje, programiranje i analizu treninga. Također je bilo potrebno utvrditi postoje li razlike u tim parametrima između muških i ženskih sprintera, što će rezultirati u boljem organiziranju planiranja za kolektivne treninge. Spolne razlike u sprintu dobile su vrlo ograničenu pažnju unatoč činjenici da je najmanja razlika performansi između muških i ženskih sprintera zapravo promatrana na utrci od 100 do 400 m (Cheuvront, Carter, Deruisson, Moffatt, 2005). Studije poput ove mogu pomoći trenerima da razvijaju performanse atletičara u skladu s njihovim sposobnostima. Isto tako, treneri bi trebali više uključivati svoje sportaše u takve dijagnostičke testove, a interpretacijom ventilacije i metaboličkih parametara mogu dobiti puno više ("širi spektar") podataka koji su potrebni za planiranje, programiranje i kontrolu treninga. To će u konačnici dovesti do boljih rezultata.