COMPARISON OF RESULTS OF SPIROERGOMETRY ON RUNNING AND BICYCLE ERGOMETER OF ATHLETES WITH RUNNING AND CYCLING SPECIALIZATION

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ABSTRACT

Purpose: A choice between a running or bicycle ergometer is not possible in every laboratory. Significant differences may appear in measuring results of ergometers with different load specificity. The objective of our paper is to determine a difference in values measured during a spiroergometry test on a bicycle ergometer and a running ergometer in adolescent endurance sportsmen, with different specializations, for mountain cyclists and middle- and long-distance runners.
Methods: The experiment involved 10 cyclists and 10 runners at the national top level. The cyclists and runners were divided in two groups: one half of the tested group completed the first test on a running ergometer and the other on a bicycle ergometer. The test on the other ergometer was taken after three days' time. The progressed load test up to "vita maxima" was used for both ergometers. The examined parameters included values of VO_{2max}, V_T, VE, BF, HR_{max} and WR_{max}. Results were evaluated in terms of both statistical and substantial significance. Statistical significance was ascertained by means of t-test at the level $\alpha = 0.05$. Cohen's d was used to evaluate substantial significance.
Results: The results showed substantially significant differences for runners in all examined parameters. A substantially significant difference in measurement results of cyclists was discovered for parameters VO_{2max}, V_T, VE and WR_{max}. In runners, the mean of values for the most important parameter VO_{2max} reached 60.6 ± 4.24 ml.min^{-1}.kg^{-1} when running, and 56.0 ± 5.34 ml.min^{-1}.kg^{-1} when cycling; values reached by cyclists were 56.6 ± 5.16 ml.min^{-1}.kg^{-1} when running, and 61.30 ± 4.47 ml.min^{-1}.kg^{-1} when cycling. The only parameter not to correspond with the sportsmen's specializations was V_T, as it revealed larger values on a bicycle also for runners.
Conclusion: Results confirmed the correspondence between the load specificity according to the ergometer selected and the specificity of sports pursued. It was proven that it is necessary to select a suitable type of appliance for determining VO_{2max} according to the sports pursued.

Keywords: VO_{2max}; runners; cyclists; adolescents; ergometer

Introduction

Functional load diagnostics, as an objective tool, makes it possible to assess motor fitness and sports performance. Generally, the purpose of functional load diagnostics is to examine the physiological response and adaption of the body to load (Bartůňková et al., 2013). There exist an array of procedures and methods enabling the assessment of fitness and performance. Laboratory tests, whether directly or indirectly determining the maximum oxygen uptake, rank among those most frequently applied. The maximum oxygen uptake constitutes the basic parameter of human fitness and performance, since this parameter represents the upper limit of aerobic load tolerance. The maximum oxygen uptake signifies not only the lung capacity, ability of the heart and blood to transport oxygen to muscles at work, but also the utilization of oxygen in muscles under load (Heller, 2018).

According to Heller (2018) the value of the maximum oxygen uptake (VO_{2max}) stands at approximately 73 $ml.kg^{-1}.min^{-1}$ in mountain cyclists and about 71 $ml.kg^{-1}.min^{-1}$ in middle and long distance runners. In adolescence, the development of VO_{2max} continues, in both training and non-training population (Neumann, Pfützner, & Berbalk, 2000). The development of VO_{2max} in adolescent runners is examined e.g. by Daniels, Oldridge, Nagle, & White (1978) and Bahenský, & Bunc (2018).

The test of maximum oxygen uptake, VO_{2max} test, is most commonly carried out by means of running or bicycle ergometers (Noakes, 2002). Load-testing laboratories are most often equipped with bicycle ergometers as these are considerably cheaper than their running counterparts. These ergometers are characterized by considerable differences worth mentioning. The main difference lies in measurement results on account of different movement stereotypes (Bunc, 2012). A running treadmill and a bicycle ergometer have unique mechanical features and different physiological effects (Smodlaka, 1982).

Values measured by a running ergometer are generally higher than those gained by a bicycle ergometer (Bunc, 2009; Bartůňková et al., 2013). Hermansen, & Saltin (1969) studied the values measured by running and bicycle ergometers for 55 male probands at the ages between 19 and 68, where the values measured in running were higher by 7% than those measured on a bicycle. In testing male students, statistically higher values of the maximum oxygen consumption were measured in favour of a running ergometer (Miyamura, & Honda, 1972; McArdle, Katch, & Pechar, 1973). The problems of different results for spiroergometry of runners and cyclists were dealt addressed e.g. by Římák, Fiala, Kunzová, & Kaňovský (2012), who discovered higher values of the maximum oxygen consumption during a test on a bicycle ergometer, specifically by 12% in cyclists, and a statistically insignificant value 4.6% in runners. On the contrary, the research of Pannier, Vrijens, & Van Cauter (1980) and Verstappen, Huppertz, & Snoeckx (1982) yielded statistically higher values of runners during a test on a running ergometer. The maximum oxygen uptake of top sportsmen is usually measured at their specific load (Máček & Radvanský, 2011; Verstappen, Huppertz, & Snoeckx, 1982).

The objective of our study is to determine the dependence of results of spiroergometry tests by means of running and bicycle ergometers in adolescent categories of runners and cyclists.

Methods

The study involved 20 adolescent boys, out of which 10 were middle and long distance runners, and 10 were cyclists in MTB category. The average age of cyclists was 16.90 ± 1.75 years, weight 72.90 ± 5.61 kg and height 181.30 ± 2.86 cm. All cyclists are members of Česká spořitelna Specialized Junior MTB team. At the average, probands spend 13 hours per week cycling and complete at the average 7,170 ± 1,438 km on an annual basis. As regards runners, the average age was 15.80 ± 1.24 years, average weight 65.40 ± 9.73 kg and height 179.90 ± 7.80 cm. All members of the research group of runners undergo 6 and more training units per week. The performance level of the tested runners reaches that of the Czech youth top runners, four probands are members of the youth national team and won medals in youth categories of the Championship of the Czech Republic. The number of kilometres completed by running by the tested group of runners reached 2092 ± 492 km per year. The tested probands had experience in taking load tests, of the same type as in case of our experiment. The author of the present paper has no conflict of interest in connection with this study. The research was performed with consent of the Ethics Committee, Faculty of Education, University of South Bohemia, Ref. No.: 001/2018. All procedures conducted within the study comply with ethical standards of the Institutional Research Committee and the Helsinki Declaration.

Protocol

In the course of the study, probands of the both sports disciplines were tested using two different ergometers, i.e. running and bicycle ergometers. All probands underwent a test on both ergometers, with a three-day interval between the tests. The three-day interval enabled the probands to recover after the first test to an adequate extent, while eliminating different results due to a worse or better performance after the second test. Importantly, the probands undertook the test on the same level of physical and mental tiredness: for this reason, the same training plan was set up before both tests. The possibility of influencing the results due to different levels of tiredness was also eliminated by a "plan with cross-classification and repetition of measurement" (Hendl, 2004). The plan with cross-classification consisted in random division of the runners' and cyclists' group into two halves, whereas the first half undertook the first test on a running ergometer and the other half was tested on a bicycle ergometer. The parameters examined included values VO_{2max}, V_T, VE, HR_{max}, BF and WR_{max}. Resultant values were compared between the ergometers and both groups.

The maximum functional parameters were determined by means of a progressed-load test up to "vita maxima". The running ergometer test was preceded by a four-minute running warm-up at the speed of 6 $km.h^{-1}$ and a subsequent two-minute break. The initial speed of the treadmill was set up individually according to the test results conducted three months before, and increased by 1 $km.h^{-1}$ every minute until the test was stopped by the proband himself. Throughout the test, the constant inclination was set up at 5%. The test was followed by a three-minute walking phase at the pace of 4 $km.h^{-1}$; this phase does not affect test results.

A two-minute cycling warm-up with resistance of 25 W and the cadence of 80–100 $n.min^{-1}$ preceded the test on a bicycle. All 10 cyclist as well as runners were tested 3 months before our study so the initial resistance of the test itself was set up in line with the individual fitness level of the given proband (approximately 2.5 $W.kg^{-1}$) and increased by 20 W every minute until the test was terminated by the proband himself. The same protocol is applied e.g. by Bahenský, & Malátová (2018). The cadence during the test stood at 98–102 $n.min^{-1}$. The "cool-down" phase with resistance of 25 W and cadence of 60 $n.min^{-1}$ followed the termination of the test; this phase does not affect test results.

Statistical analysis

Material significance of differences in values gained on both ergometers was determined by Cohen's *d*, which can be applied to evaluate the effect between two independent variables (Blahuš, 2000). The size of coefficient *d* was established according to Hendl (2004), specifically as follows:

- $d \geq 0.80$ – large effect,
- d = 0.50 to 0.80 – medium effect,
- d = 0.20 to 0.50 – slight effect.

The values were compared also in terms of statistical significance, using t-test at the level $\alpha = 0.05$.

Results

Table 1 presents resultant parameters of runners on both ergometers. Runners achieved larger values of VO_{2max} in running; this difference is materially significant, with a large effect ($d = 0.903$). The statistical importance of the difference in parameter VO_2max was also proven ($p < 0.01$). Parameter V_T was found to reveal a materially significant difference ($d = 0.325$) in favour of the bicycle test. The difference of V_T values was statistically insignificant. Runners reached higher VE values in running. The difference of VE values is materially significant, with a medium effect ($d = 0.614$). Statistical significance was not proven. Breathing frequency in runners was greater in case of the test on a running treadmill, with a materially significant difference ($d = 0.541$), yielding a medium effect. Statistical significance was not proven. The difference of values of HR_{max} in runners was materially ($d = 0.656$) and statistically ($p < 0.05$) significant, in favour of the running treadmill. As to parameter WR_{max}, runners achieved larger values when running on the running treadmill. The difference was both materially ($d = 1.115$) and statistically ($p < 0.01$) significant.

Table 1 *Resultant values of runners on the running treadmill and bicycle*

	VO_{2max}	V_T	VE	BF	HR_{max}	WR_{max}
	[ml.min^{-1}.kg^{-1}]	[l]	[l.min^{-1}]	[n.min^{-1}]	[n.min^{-1}]	[W]
Running ergometer	60,6 ± 4,2	2,34 ± 0,5	143,45 ± 11,1	63,8 ± 11,4	196 ± 8,1	402 ± 68,9
Bicycle ergometer	56,0 ± 5,3	2,52 ± 0,5	135,68 ± 12,7	56,60 ± 13,6	189 ± 10,2	334,5 ± 37,3

VO_{2max}: Maximum oxygen uptake; V_T: Tidal volume; VE: Pulmonary ventilation during exercise; BF: Breathing frequency; HR_{max}: Maximum heart rate; WR_{max}: Maximum work rate

Table 2 shows resultant values of cyclists on both ergometers. Cyclists reached greater values of VO_{2max} in the bicycle ergometer test; the difference of the values is both materially (d = 0.923), and statistically ($p < 0.01$) significant. In the case of parameter V_T, a materially (d = 0.871) and statistically ($p < 0.01$) significant difference between both ergometers was determined. The difference of the values as to parameter VE was materially significant (d = 0.795), with medium effect. Statistical significance was not proven for this parameter. Parameter BF was not found to have a materially or statistically significant difference between both ergometers in the cyclists. The difference of values of parameter HR_{max} was not statistically or materially significant in cyclists. Cyclists achieved higher WR_{max} values in riding a bicycle ergometer. The difference of values between the ergometers was materially (d = 1.543) and statistically ($p < 0.01$) significant.

Table 2 *Resultant values of cyclists on the running treadmill and bicycle*

	VO_{2max}	VT	VE	BF	HR_{max}	WR_{max}
	[ml.min^{-1}.kg^{-1}]	[l]	[l.min^{-1}]	[n.min^{-1}]	[n.min^{-1}]	[W]
Running ergometer	56,6 ± 5,1	2,51 ± 0,4	156,80 ± 13,2	63,3 ± 9,6	195,2 ± 8,9	411,1 ± 36,4
Bicycle ergometer	61,3 ± 4,4	2,90 ± 0,4	172,13 ± 22,2	61,5 ± 11,5	195,5 ± 8,9	473,2 ± 39,7

VO_{2max}: Maximum oxygen uptake; V_T: Tidal volume; VE: Pulmonary ventilation during exercise; BF: Breathing frequency; HR_{max}: Maximum heart rate; WR_{max}: Maximum work rate

Discussion

Both ergometers reveal differences in measurement results (Bunc, 2012); our results confirm this assertion. The research of Pannier, Vrijens, & Van Cauter (1980) and Verstappen, Huppertz, & Snoeckx (1982) revealed statistically higher values of runners in case of the test on a running ergometer.. Also in the research of Basset & Boulay (2000), groups of triathlets, runners and cyclist had significantly ($P < 0.05$) higher values of VO_{2max} on the treadmill compared with the cycle ergometer; our data comply with this assertion for runners group. All of the ten participants of the study in the runners' group reached higher values of VO_{2max} on the running ergometer, specifically by a significant value of 8.21%. Contrariwise, cyclists were found by Římák, Fiala, Kunzová, & Kaňovský (2012) to reach higher values of the maximum oxygen consumption in the test on a bicycle ergometer, specifically by 12%. All of the ten participants of the study in the cyclists' group accomplished higher values of VO_{2max} when riding the bicycle ergometer. The value of VO_{2max} was higher by 8.30% at the average on a bicycle ergometer in case of cyclists.

We anticipated that, due to the specificity of the load, cyclists would reach higher values of VO_{2max} when riding the bicycle, when compared with the runners on a treadmill; however, a greater difference was expected for runners, not cyclists. We proceeded from the theory that running – which is included in most sports preparations – would not present as a big problem for cyclists as a bicycle riding technique for runners. The reason for the greater difference between values of VO_{2max} could consist in the fact that cyclists might not have coped with higher speed of the running treadmill, that reason not being the exhaustion of the respiratory, circulatory and metabolic systems. This issue is addressed e. g. by Bartůňková et al. (2013).

Our resultant values of VO_{2max} comply with the studies of Máček, & Radvanský (2011) and Verstappen, Huppertz, & Snoeckx (1982). Top sportsmen achieved higher values of VO_{2max} under their specific load.

Runners accomplished higher V_T values when riding a bicycle, i.e. by 7.96%. The lower V_T may have been caused by a poorer coordination of the upper torso when running at higher speed, with the result of worse breathing stereotype and breathing economy. An explanation may also be found in the engagement of abdominal muscles in running: these muscles are engaged to a great extent in inspiration. These muscles may tire during running, whereby decrease the value V_T and the overall breathing economy.

The difference between V_T values was even more distinct in cyclists than in runners. Cyclists achieved higher values by 15.88% in riding on a bicycle. These results may contribute to the theory mentioned above in the case of runners. When running at higher speed, the problems with body coordination may be even more noticeable in cyclists; as a result, this may evidently disrupt their breathing stereotype. The breathing stereotype may, however, be influenced by targeted training (Bahenský, Malátová, & Bunc 2019).

In the study of Tanner, Duke, & Stager (2014), 22 trained males underwent a progressed-load test up to maximum on two ergometers, running and bicycle. V_E did not differ between the individual ergometers. Our results do not tally with the above study. The resultant V_E values in runners, despite the lower V_T, were higher on a running ergometer, specifically by a materially significant value 5.73%. The lower V_T was compensated in runners by the higher BF, which was larger on a running ergometer by 12.72%. Cyclists achieved higher values V_E in the test on a running ergometer, specifically by 9.78%. The difference between BF was not significant in the case of cyclists.

Runners reached higher values of HR_{max} on a running ergometer. This result may be explained by the engagement of larger muscle groups in running and most probably also by a higher work intensity, in a sports activity structurally the same or similar to the sport practised by the given individual. The difference between values of HR_{max} was not significant in the case of cyclists. This might be explained by the above theory proclaiming a higher number of engaged muscle groups, and also a great probability of reaching HR_{max} in a sports activity that is the same in terms of structure as that in the sport pursued by the given individual.

Runners were found to achieve higher values of WR_{max} on a running ergometer, contrariwise, these values were higher in cyclists on a bicycle ergometer. The difference for runners and cyclists was 20.18% and 15.11%, respectively.

Conclusion

Our study proved that the appliance used does influence the value of VO_{2max} in the case of using a running ergometer and a bicycle ergometer for runners and cyclists. All of the ten participating runners were found to achieve a higher value of VO_{2max} in the test on a running ergometer. All of the ten participating cyclists were found to a higher value of VO_{2max} in the test on bicycle ergometer. As a consequence of a poor coordination at higher speed of running and a more considerable engagement of abdominal muscles, the breathing stereotype may be disrupted and V_T value may decrease. Runners and cyclists alike achieved higher V_T values in running on a bicycle ergometer. Higher values of VE and WR_{max} were reached by both runners and cyclists in the test when it came to their specific activities. The difference in parameters BF and HR_{max} was significant only in runners, who achieved higher values when running. It is suitable to test highly trained sportsmen on an appliance on which the nature of the physical activity performed comes as closest as possible to that in the sportsmen's specific load.

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