Journal of Physical Education and Sport ® (JPES), Vol. 22 (issue 7), Art 224, pp. 1799 - 1803, July 2022
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Comparative analysis of perceived exertion and objective physiological standards of load intensity in the exercise test among skilled cross-country skiers

ANASTASIA S. BAKHAREVA[1], ALBERT S. AMINOV[2], VADIM S. CHEREPANOV[3], ELVIRA F. LATYPOVA[4], DMITRIY S. STEPANOV[5]
[1,2,3,4,5]South Ural State University, Chelyabinsk, RUSSIA

Published online: July 31, 2022
(Accepted for publication July 15, 2022)
DOI:10.7752/jpes.2022.07224

Abstract
Aim. The paper aims to compare the measurements of perceived exertion with those of objective physiological norms of load intensity by using the lactate (La) data obtained in the ski ergometer test and the treadmill test with respect to the five-zone aerobic intensity scale (Table 1). **Materials and methods.** The athletes were asked to participate in a psychophysiological assessment based on the Borg scale. The assessment included five stages, three minutes each. Each stage also assumed an increase in load intensity in accordance with the five-zone aerobic intensity scale. The Concept2 SkiErg (USA) training tool with the system of continuous motion and the Assault Runner (USA) treadmill with the Stryd power meter synchronized with the PerfPRO (USA) training software (ANT + system) were used for the purpose of the study. The exercise test was performed with simultaneous lactate (La) measurement. The study sample consisted of 20 skilled cross-country skiers (n = 20; age (M ± δ) - 19.65 ± 0.80 years; body weight - 69.78 (M ± δ) ± 6.14 kg; body length (M ± δ) - 176.14 ± 6.09 cm; fat mass (M ± δ) - 10.41 ± 4.23%; BMI (M ± δ) - 22.51 ± 1.99). Statistical analysis of the study results was carried out using the IBM SPSS Statistics v. 23. The study took place at the Institute of Sport, Tourism and Service of the South Ural State University (Russia, Chelyabinsk) at the beginning of the preparatory period (May). **Results:** statistical assessment of the results obtained with the Shapiro-Wilk test allowed to identify that the lowest values of the SkiErg exercise test were found at the anaerobic threshold (AnT, intensity zone 4) (W, p = 0.054) and within the aerobic intensity zone 1 (W, p = 0.008). **Conclusion:** a 10-point scale with evenly distributed lactate values can be used for subjective assessment of aerobic physical activity. The inability of athletes to assess themselves in terms of functional fitness allowed to identify their tactical level and expected physical performance. From a physiological point of view, further improvement of aerobic performance can be achieved through the increase of aerobic power of arm, trunk and leg muscles.
Keywords: Borg scale, exercise test, cross-country skiers, load intensity, lactate, perceived exertion.

Introduction

Physical activity of different intensity results in physiological and psychological changes (Cherepov, E. A et al, 2019), which cause the so-called subjectively perceived exertion (SPE). The ability of an athlete to evaluate load intensity with respect to his/her abilities reflects his/her adequate self-assessment in terms of physical fitness, self-regulation and stress coping skills, which contributes to the correct assessment of the psychophysiological status and accurate prediction of competitive performance (Kilpatrick, M.W. et. al, 2009; Scherr, J. et. al, 2013; Stolyarova, N.V. et. al, 2021).

There are various scales and methods for the assessment of perceived exertion (Daniel A. Hackett et. al, 2012; Buckley, John P. et. al, 2022; Fontes, E.B., et. al, 2010; Goosey-Tolfrey, V. et. al, 2010; Zamunér, A. R. et. al, 2011), which allow to quantify the sensory and subjective responses of an athlete during muscular activity. Heart rate monitors (an external physiological parameter) and portable hematology analyzers (an internal physiological parameter) are the most common ways to control the intensity of physical activity.

The ski ergometer exercise test allows to measure functional performance, excluding the psychological component. Therefore, psychophysiological tests based on the Borg scale are becoming more and more popular (Borg, G.A., 1982; Williams, N., 2017).

The 20-point Borg scale makes it possible to match perceived exertion data with heart rate measurements (PE x 10 = HR) only in people with a heart rate of approximately 200 bpm. The relationship between objective and subjective assessments is described by the linear regression equation ($\%HR_{max} = 1.01\ PE - 0.77$), which theoretically ensures the correspondence between the numerical values of these indicators. Previously, it was found that the subjective assessment of load intensity during exercise test was directly dependent on power. The correlation coefficient between perceived exertion and power was 0.96. There was also a close correlation between perceived exertion and absolute heart rate with a correlation coefficient of 0.93 (Akimov, E.B., et. al, 2008).

Corresponding Author: ANASTASIA S. BAKHAREVA, E-mail: bakharevaas@susu.ru

In skilled athletes, HR_{max} is an individual parameter, which depends on the functional state of the autonomic nervous system (Sylta, Ø. et. al, 2014). At the same time, lactate concentration is the most reliable in exercise tests (Beneke R., et. al, 2011; Schmidt, F., et. al, 2018). Lactate concentration can be easily correlated using the 10-point Borg scale and the five-zone aerobic intensity scale (Dias, M.R. et. al, 2014; Morishita, S. et. al, 2018).

Thus, the ability to compare objective external and internal physiological parameters with subjectively perceived exertion is an important criterion for the effectiveness of training and competitive activities (Cherepov, E. et. al, 2016). Therefore, higher psychophysiological growth is believed to underlie better athletic performance (Herzog, T. et. al, 2018, Dopsaj, M. et. al, 2020).

Materials and methods.

The athletes were asked to participate in a psychophysiological assessment based on the Borg scale. The assessment included five stages, three minutes each. Each stage also assumed an increase in load intensity in accordance with the five-zone aerobic intensity scale. Perceived exertion and the objective level of load intensity was matched by the data of lactate concentration. Therefore, the athletes had to fall within the lactate limits of the five-zone aerobic intensity scale (Table 1) in terms of perceived exertion or the 10-point Borg scale. The Concept2 SkiErg (USA) training tool with the system of continuous motion and the Assault Runner (USA) treadmill with the Stryd power meter synchronized with the PerfPRO (USA) training software (ANT + system) were used for the purpose of the study. The exercise test was performed with simultaneous lactate (La) measurement. La concentration (mmol/l) was measured by using the Lactate Plus (USA) portable lactate test analyzer in the first minute after each stage of the test.

The study sample consisted of 20 skilled cross-country skiers (n = 20; age (M ± δ) - 19.65 ± 0.80 years; body weight - 69.78 (M ± δ) ± 6.14 kg; body length (M ± δ) - 176.14 ± 6.09 cm; fat mass (M ± δ) - 10.41 ± 4.23%; BMI (M ± δ) - 22.51 ± 1.99). Statistical analysis of the study results was carried out using the IBM SPSS Statistics v. 23. Since the size of the survey sample is considered small (n<30) (Ivanovsky, R.I., 2010), the relevance of parametric methods (Student's t-test) data normality was checked with the Shapiro-Wilk test, W (Shapiro, S. S. et. al, 1965). To check sample homogeneity, the coefficient of variation (CV, %) was calculated. The study took place at the Institute of Sport, Tourism and Service of the South Ural State University (Russia, Chelyabinsk) at the beginning of the preparatory period (May).

Table 1 – A multistage test combined with the five-zone aerobic intensity scale and the Borg scale (Morishita, S. et. al, 2018)

1 stage	2 stage	3 stage	4 stage	5 stage
I zone	II zone	III zone	IV zone	V zone
% of HR_{max}	% of HR_{max}	% of HR_{max}	% of HR_{max}	% of HR_{max}
60 – 72 %	73 – 82 %	83 – 87 %	88 – 93 %	94 – 100 %
La, mmol/l	La, mmol/l	La, mmol/l	La, mmol/l	La, mmol/l
0.8 –1.5	1.6 – 2.5	2.6 – 4.0	4.1– 6.0	6.1 <
RPE 1–10	RPE 1–10	RPE 1–10	RPE 1–10	RPE 1–10
1– 2 points	3 – 4 points	5 – 6 points	7 – 8 points	9 – 10 points
Very low	Low	Moderate	High	Very high

Results

The results of the normality test and the calculation of the coefficient of variation are presented in Table 2.

Table 2 - The results of the normality test (Shapiro-Wilk test) for the data obtained in the exercise test for cross-country skiers based on the Borg scale

La, mmol/l	Ski-Erg (n = 20)			Afr (n = 20)		
	M ± δ	W, p*	Cv, %	M ± δ	W, p*	Cv, %
1 stage	2.14 ± 0.71	0.522	33.44	1.43 ± 0.69	0.008	47.98
2 stage	2.61 ± 0.67	0.746	25.73	1.48 ± 0.74	0.124	49.81
3 stage	3.91 ± 0.91	0.788	23.22	2.48 ± 1.29	0.401	52.14
4 stage	6.36 ± 1.51	0.054	23.73	4.90 ± 1.40	0.731	34.66
5 stage	10.68 ± 2.71	0.665	25.03	10.68 ± 2.80	0.727	26.17

*Note. Low p values presume the erroneous assumption of normality.

The results presented in Table 2 show that the distribution of La values at different stages of the test (for both the ski ergometer and treadmill) can be considered normal. The coefficient of variation showed a large scatter in lactate values at stage 1 in the SkiErg test (Cv > 20%) and from stages 1 to 4 in the Afr test (Cv > 20%), which indicated a strong variability in La values at these stages.

Comparative analysis of the La data obtained in the Ski-Erg and Afr tests is presented in Table 3.

Table 3 - The results of a comparative analysis of the La data obtained at the stages of the Ski-Erg and Afr tests (T-test)

La at different stages, mmol/l		Pair differences		t-test	p*
		95% confidence interval for the difference			
		Lower	Higher		
La 1	Ski-Erg / Afr	0.35888	1.20362	3.942	0.001
La 2	Ski-Erg / Afr	0.42510	1.57490	3.708	0.002
La 3	Ski-Erg / Afr	0.52046	2.06704	3.566	0.003
La 4	Ski-Erg / Afr	-0.00999	2.07249	2.111	0.052
La 5	Ski-Erg / Afr	-1.26165	1.74915	0.345	0.735

*Note: p< 0.05 – significant differences; p< 0.01 and < 0.001 – highly significant differences.

Table 3 shows significant differences in La levels during the first three stages of Ski-Erg and Afr tests. Thus, at stage 1, the difference in La concentration between Ski-Erg and Afr tests was 0.71 mmol/l (p<0.01), at stage 2 – 1.13 mmol/l (p<0, 01), at stage 3 – 1.43 mmol/l (p <0.01), at stage 4 – 1.46 mmol/l (p > 0.05), at stage 5 peak average La values were equal between two tests.

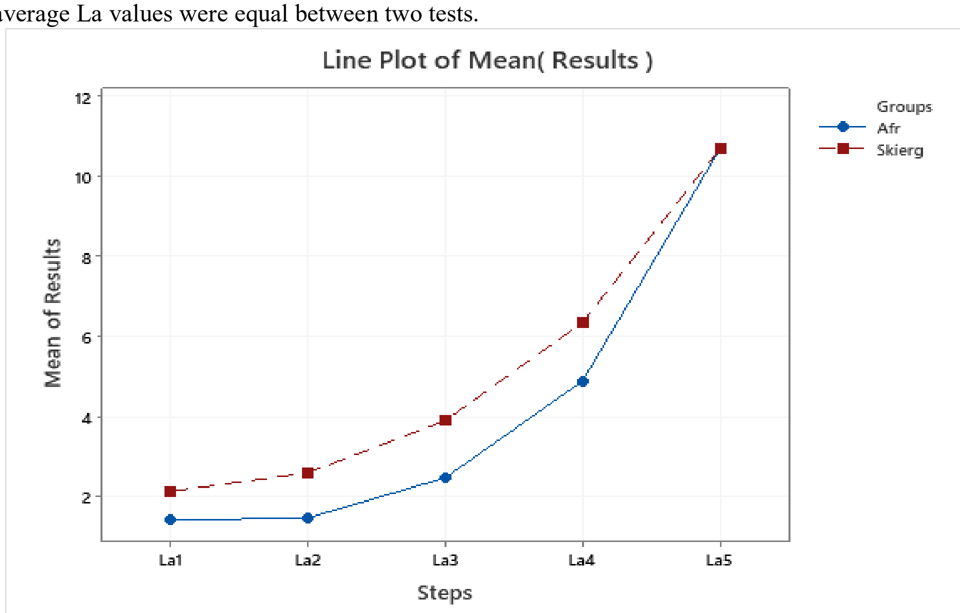

Figure 1 – The dynamics of La concentration (mmol/l) among cross-country (Ski-Erg and Afr tests)

Figure 1 shows that during the SkiErg test La concentration increased faster than during the Afr test. It was found that, in the SkiErg test, averaged subjective perceived exertion values were increased at the first stage, and La concentration turned out to be 30% higher (p <0.01) compared with an objective indicator of zone I. When it comes to the second stage, perceived exertion values did not correspond to those of zone II, since La concentration exceeded reference values by 1.20% (p> 0.05), at the third stage, perceived exertion data perfectly matched that of zone III. When it comes to the treadmill test, averaged perceived exertion values during the first three stages of the test were increased, since La concentration was lower than reference values by 3.33% (p > 0.05), 48% (p < 0.01) and 45 % (p<0.01), respectively.

Discussion

A 10-point scale with evenly distributed lactate values can be used for subjective assessment of aerobic physical activity. Large production of La by the arm muscles can also be associated with a greater involvement of high-threshold muscle fibers with low oxidative capacity (Bakhareva, A.S. et al, 2018; Popov, D. V. et al, 2014). The lowest values of the Shapiro-Wilk test were found at the level of anaerobic threshold (W, p = 0.054, SkiErg test) and at the level of zone I (W, p = 0.008, Afr test). Anaerobic threshold plays an important role in the performance of cross-country skiers, it reflects the aerobic reserves of muscle cells, the effectiveness of adaptive changes, the buffer capacity of blood (Bakhareva, A.S. et al, 2020; Bennett, H. et al, 2019; Ghosh, A. K., 2004;

Gusakov, I.V. et al, 2020). Performance in zone I does not produce any effect on the body, however, it creates prerequisites for the further development of physical fitness, namely, the network of blood vessels in the skeletal and cardiac muscles expands, and the performance of other functional systems is activated (Isaev, A.P. et al, 2018; Nogaev, B.T. et al, 2018).

Conclusion.

Thus, from a psychological point of view, incorrect assessment of perceived exertion indicates a misunderstanding and ignorance of the real level of physical fitness, as well as irrational use of one's efforts. From a physiological point of view, further improvement of aerobic performance can be achieved through the increase of aerobic power of arm, trunk and leg muscles.

References

Akimov, E.B., Alekseev, V.M. (2008). Lactate and subjectively perceived exertion during muscle work of different power in athletes. *Collection of abstracts of international congress "Modern Olympic and Paralympic sport and sport for all XII"*, T. 2, P. – 197. [in Russian].

Bakhareva, A.S., Aminov A.S., Latypova E.F., Savinykh E.Y., Cherepanov V.S. (2021). Ski-erg training for enhancing anaerobic glycolysis in cross-country skiers. Journal of Physical Education and Sport. V. 21(4). P.1919-1923. DOI: 10.7752/jpes.2021.04243

Bakhareva, A.S., Cherepanov, V.S., Bykov E.V., Budanov G.V. (2020). Determination of anaerobic threshold power during the ski ergometer step test with increasing load using heart rate data. *Human Sport Medicine*, Vol. 20 (4), pp. 25 – 30. DOI: 10.14529/hsm200402.

Beneke, R., Leithäuser, R.M., Ochentel, O. (2011). Blood lactate diagnostics in exercise testing and training. *Int J Sports Physiol Perform*, no 6(1), pp. 8 –24. DOI:10.1123/ijspp.6.1.8.

Borg, G.A. (1982). Psychophysical bases of perceived exertion. *Med Sci Sports Exerc,* Vol. 14, pp. 377– 381.

Buckley, John P., Roger Eston. (2022). Ratings of perceived exertion. *In book: Sport and Exercise Physiology Testing Guidelines*, p. 10. DOI: 10.4324/9781003045267-21.

Cherepov, E. A., Eganov, A. V., Aminova, A. S., & Savinykh, E. Y. (2019). Socially significant values of students aimed at maintaining and promoting health. *Journal of Physical Education and Sport*, 19(4), 2508-2511

Cherepov, E., Shaikhetdinov, R. (2016). Effectiveness of functional training during physical conditioning of students practicing martial arts. *Journal of Physical Education and Spor (JPES). Vol.* 16(2), Art 79. P. 510 – 512.

Dias, M.R., Simão, R., Machado, G.H., Furtado, H. (2014). Relationship of different perceived exertion scales in walking or running with self-selected and imposed intensity. V. 11. P. 149-157

Dopsaj, M., Zuoziene, I. J., Milić, R., Cherepov, E., Erlikh, V., Masiulis, N., . . . Vodičar, J. (2020). Body composition in international sprint swimmers: Are there any relations with performance? *International Journal of Environmental Research and Public Health*, 17(24), 1-14. doi:10.3390/ijerph17249464

Bennett, H., Slattery, F. (2019). Effects of Blood Flow Restriction Training on Aerobic Capacity and Performance: A Systematic Review. Journal of Strength and Conditioning Research.V.33(2). P. 572-583

Fontes, E.B., Smirmaul, B.P., Nakamura, F.Y. (2010). The relationship between rating of perceived exertion and muscle activity during exhaustive constant-load cycling. Int J Sports Med. V.31. P. 683-688

Ghosh, A.K. (2004). Anaerobic threshold: Its concept and role in endurance sport. Malaysian Journal of Medical Sciences. V.11(1). P.24-36

Goosey-Tolfre, V., Lenton, J., Goddard, J. (2010). Regulating intensity using perceived exertion in spinal cord-injured participants.Med Sci Sports Exerc. V. 42(3). P.608-613

Gusakov, I.V., Nurmukhanbetova, D.K., Kydyrbaeva, D.B. (2020). Modern trends in training of skilled swimmers. Proceedings of X international scientific conference of students and young scientists: university sport: health and prosperity of the nation. P.134-147

Herzog, T., Zavilla, S., Dupee, M., Stephenson, M. (2018). The Psychophysiology of Self-Regulation. Sport, Exercise and Performance Psychology. P. 174-175

Schmidt, R.F., Lang, F., Hekmann, M. (2019). Human physiology with the basics of pathophysiology. Laboratory of Knowledge. V. 2. P. 429-445

Ivanovsky, R.I. (2008). Theory of probability and mathematical statistics. Fundamentals and applied aspects with examples and tasks in Mathcad. 528 p.

Isaev, A.P., Erlikh, V.V., Bakhareva, A.S., Saraykin, D.A., Pavlova, V.I., Maleev, D.O. (2018). Effects of short- and long-term adaptation to the middle-altitude hypoxia on the condition of athletes practicing cyclic and acyclic sports. *Minerva ortopedica e traumatological*.T. 69(3S1), P. 31-42. DOI: 10.23736/S0394-3410.18.03873-0

Kilpatrick, M.W., Robertson, R.J., Powers, J.M. (2009). Comparisons of RPE before, during, and after Self-Regulated Aerobic Exercise. Sci Sports Exerc. V. 41(3). P. 682-687

Morishita, S., Tsubaki, A., Takabayashi, T. (2018). Relationship between the rating of perceived exertion scale and the load intensity of resistance training. Strength and Conditioning Journal. V. 40(2). P. 94-109

Nogaev, B.T., Shalbarbaev, A.M., Zhapparov, A.A, Keldosov, E.E. (2018). Zones of intensity of physical activity with respect to heart rate. Actual scientific research in the modern world. V. 6(42). P. 118-120

Popov, D.V., Grushin, A.A., Vinogradova, O.L. (2014). Physiological basis for assessing aerobic capabilities and the training loads selection in skiing and biathlon. Soviet Sport. 78 p.

Scherr, J., Wolfarth, B., Christle, J.W., Pressler, A., Wagenpfeil, S., Halle, M. (2013). Associations between Borg's Rating of Perceived Exertion and physiological measures of exercise intensity. V.113. P.147-155.

Shapiro, S.S., Wilk, M.B. (1965). An analysis of variance test for normality. V.52(3). P. 591-611

Stolyarova, N.V., Stovba, I.R., Petrozhak, O.L, Savinykh, E.Y. (2021). Psychophysiological potential and health level of foreign students. Journal of Physical Education and Sport. V.3. P. 2266–2271

Sylta, O., Tonnessen, E., Seiler, S. (2014) From heart-rate data to training quantification: A Comparison of 3 methods of training-intensity analysis. International Journal of Sports Physiology and Performance. V. 9(1). P.100-107

Williams, N. (2017). The Borg Rating of Perceived Exertion (RPE) scale. Occupational Medicine V. 67(5). P. 404-405

Zamuner, A.R., Moreno, M.M., Camarg, T.M. (2011). Assessment of Subjective Perceived Exertion at the Anaerobic Threshold with the Borg CR-10 Scale. J Sports Sci Med. V.10(1). P. 130 –136