SPORT TK: Revista Euroamericana de Ciencias del Deporte, vol. 9 n.º 1, (Supl. 1).
Monográfico: Turismo de aventura y deportes al aire libre, 21-26
Recibido: Octubre 2018
Aceptado: Agosto 2019

ISSN edición web (*http://revistas.um.es/sportk*): 2340-8812

Can lab and field testing be complementary in defining physiological effort through the Serra da Estrela routes?

¿Pueden las pruebas de laboratorio y de campo ser complementarias para definir el esfuerzo fisiológico por las rutas de Sierra da Estrella?

Raul F. Bartolomeu[1, 2*], José A. Bragada[3], Natalina Casanova[1, 2], Jorge Casanova[1, 2], and Mário J. Costa[1, 2, 4]

[1] *Research Unit for Inland Development, UDI*
[2] *Polytechnic Institute of Guarda (Portugal)*
[3] *Polytechnic Institute of Bragança (Portugal).*
[4] *Research Centre in Sport Sciences, Health Sciences and Human Development, CIDESD*

Abstract: Background: The current classification of the hiking trails using an agreement between lab and field test is inexistent. The aim of this study was to characterize a single route in a physiological basis. **Methods:** Twenty-nine subjects underwent a 11km hike. The velocity and heart rate (HR) were monitored continuously. In a separate day, all subjects underwent a laboratory test to measure both HR and Oxygen uptake (VO_2). Linear regressions between net HR (HRnet) vs %VO_2 reserve were computed. **Results:** The mean coefficients of determination were very high (R^2=0.98). The calculated %VO_2reserve mean values for this route were 42%. **Conclusions:** This route elicited light-to-moderate intensities. When hiking in this or in similar round routes, the formula %VO_2reserve=0.64+0.77*HRnet can be used to assess the hiking intensity. The complementarity of the field and lab tests proved to be useful and reliable in defining the energetic demands of the hike.
Keywords: hiking; HRnet; exercise intensity; active tourism.
Resumen: Introducción: La clasificación actual de las rutas de senderismo utilizando una combinación entre testes de laboratorio y de campo es inexistente. El objetivo de este estudio fue caracterizar una única ruta en una base fisiológica, para dar a los practicantes una visión más profunda sobre las demandas energéticas. **Metodología:** Veintinueve sujetos experimentaron un sendero de 11 km. La velocidad y la frecuencia cardíaca (FC) se monitorizaron continuamente. En un día separado, todos los sujetos se sometieron a una prueba intermitente y progresiva en una cinta de correr para medir tanto la FC como el consumo de oxígeno (VO_2). Se calcularon las regresiones lineales entre la FC neta (FCnet) y la %VO_2 reserva. **Resultados:** Los coeficientes de determinación medios fueron muy altos (R^2 = 0.98). Los valores medios calculados de %VO_2res para esta ruta fueron del 42%. **Conclusiones:** esta ruta mostró ser adecuada para quienes buscan caminatas de intensidad leve a moderada. Al caminar a diferentes velocidades en esta ruta o en rutas redondas similares, se puede usar la fórmula %VO_2res = 0.64 + 0.77 * FCnet para evaluar la intensidad de la caminata. La complementariedad de las pruebas de campo y de laboratorio demostró ser útil y confiable para definir las exigencias energéticas de la caminata.
Palabras clave: senderismo; FCnet; intensidad del ejercicio; turismo activo.

Introduction

In the last couple of decades, the practice of physical activity using natural resources increased remarkably. This kind of physical activity takes part of the active tourism and has been pointed out as a new slope to increase the knowledge of protected green areas and develop social/economic backgrounds of less populated villages. The hiking is one of the outdoor activities that mobilizes a larger number of participants and has potential in terms of promoting healthy lifestyles (Alencoão et al., 2011). "Hiking" or "rambling" has been defined as the act of walking in non-flagged trails through countryside or mountain over a long period of time (Funollet, 1994). It is also a low cost and easy access activity that can be practiced by people of different ages, in trails with different features (Gabriel, Moreira, & Faria, 2010). Previous studies that focused in walking on green spaces of high natural and heritage value, showed health benefits. Hiking promotes a reasonable improvement in perceived health, fitness level and mood state (Strauss-Blasche et al., 2004). It is also beneficial for elderly with increased cardiac risk (Gatterer et al., 2015) or metabolic syndrome (Mair, 2008). However, long-term hiking can sometimes induce postural deficits (Vieira, 2015) and traumatic lower leg injuries, mostly ankle sprain (Loob, 2004). Recently, the French Ministry of Health and Sports has updated the number of hiking participants for 5 million (EG, 2009). In other European countries, such as Italy or United Kingdom, the number of people that experience hiking can reach from 3 to 10 million, respectively (Kouchner & Lyard, 2001). Until this day, the number of hiking participants in Portugal seems unknown. However, unpublished reports demonstrate that hiking in Portugal is increasing. The numbers reveal an increase of 61% from 2007 to 2009, with 34 organized activities each weekend in the national territory (Tovar & Carvalho, 2010).

The hiking trails can be classified in "easy", "medium" or "hard". The previous approaches that created this standard

Dirección para correspondencia [Correspondence address]: Raul F. Bartolomeu. E-mail: rfbartolomeu@gmail.com

classification, just used geographical and/or spatial-temporal information to set the trail difficulty. None of the previous studies used physiological data collected in a rigorous controlled environment such as lab testing. From our point of view, both field and lab protocols can be used simultaneously to define trail difficult and give a new insight to trails classification. This will serve as a diagnose tool defining trails exigency and health safety in an individual background, and helping the participants to choose the most appropriate trails according to their age and physical level.

The aim of this study was to characterize a single route in a physiological basis, to give practitioners a deeper insight about its energetic demands. It was hypothesised that high coefficients of determination between lab and field tests, would allow for both to be complementary in the evaluation of the hiking intensity.

Methods

Participants

With institutional approval, twenty-nine subjects (20 males and 9 females) ageing between 21 and 55 (28.04±10.79 years), with a mean of 1.73±0.09 m and 69.59±11.00 kg participated in this study. The participation was voluntary, and those who volunteered signed a consent form. The inclusion criteria were: i) not having any skeletal muscle injury in the previous 6 months; ii) being clinically healthy; iii) have completed at least 2 hikes in the past year. The mean values at rest were 64 bpm for heart rate (HR) and 4.8 ml·kg^{-1}·min^{-1} for Oxygen uptake (VO_2).

Study overview

The main goal of this study is to characterize a single route in a physiological basis. This characterization will be made not only by collecting physiological data in the field, but in a laboratory as well. It was hypothesised that physiological data collected in the lab would have high coefficient correlation between each other in order to be extrapolated to the field physiological characterization.

Procedures

Field testing

All subjects underwent at the same time an 11km hike in a previously homologated circular route. This route was divided into 9 stages according to the terrain characteristics (Figure 1). The velocity was monitored continuously with a GPS device (Fenix 5, Garmin, USA) to ensure a consistent 5.5 km·h^{-1} pace. During the hike, no stops were allowed, and the participants informed that those who stopped for more than 1min for any reason, would be removed from the sample. Every subject used a watch with HR monitor and GPS tracking (Fenix 5, Garmin, USA) throughout the hike. At the end of each one of the 9 stages, one “lap” was marked in the watch. The mean HR value from each stage was given by the watch from the instantaneous values recorded between laps.

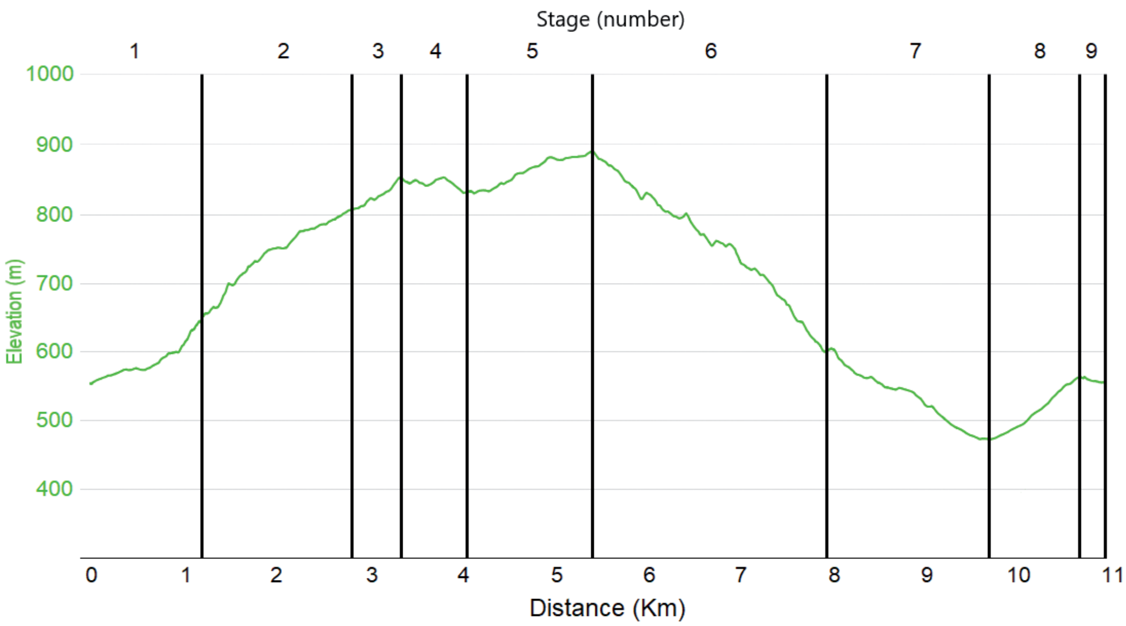

Figure 1. Hike course characterization by elevation, distance and stages.

Lab testing

In a different day, the same subjects underwent an intermittent and progressive submaximal test of 5 steps of 5 min each in a treadmill at progressive velocities (4.5, 6.5, 8.5, 10.5 and 12.5 km·h^{-1}). Those who reported to be very tired at 10.5 km·h^{-1} were exempted from the 5th step. Both HR and VO_2 were measured continuously using a breath by breath system (MetaMax 3B, Cortex, Germany). Resting values were collected for 15 minutes with the participants lying silent in a dimly lit room, although not being allowed to fall asleep. Individual metabolic equivalent of task (MET) was calculated beforehand according to the procedures described by Lopes et al. (Lopes et al, 2009). Tanaka's equation (Tanaka, Monahan, & Seals, 2001) was considered to estimate maximum HR, and the obtained value was then used to estimate the maximum VO_2 (VO_2max). For that purpose, it was assumed that for the same intensity, the percentage of HR reserve (%HRres) equals the percentage of VO_2 reserve (%VO_2res), as described elsewhere (Lounana et al., 2007; Swain & Leutholtz, 1997; Dalleck & Kravitz, 2006). Thus, knowing the estimated HRmax and calculating the %HRres that corresponds to the maximum measured value at the end of each test step, it was assumed that the %VO_2res at this same level is equal to the %HRres previously calculated. Linear regressions between net HR (HRnet) vs %VO_2res were computed to make the link between field and lab tests, and predictive equations where retrieved. Also, the Metabolic Equivalent of the Task (MET) was calculated for each one of the 9 stages of the route, dividing the VO_2 value by its value at rest. Then, intensity was classified according to ACSM's guidelines (ACSM, 2018).

Statistical Procedures

The Shapiro Wilk's test was used to evaluate the normality of the distributions. A student's t-test (independent samples) was used to evaluate the differences between sexes ($p \leq 0.05$). Linear regression models were used to describe the assess the relationships between HRnet and %VO_2res. Coefficient of determination was selected as effect size index and interpreted as: (1) small effect size if $0.04 \leq R^2 < 0.25$; (2) moderate effect size if $0.25 \leq R^2 < 0.64$ and (3) strong effect size if $R^2 \geq 0.64$ (Ferguson, 2009).

Results

The field HRnet values ranged from 10 to 102 bpm and the correspondent %VO_2res and MET values ranged from 7.6 to 90% and 1.8 to 9.7 respectively. No significant differences were found between genders. The mean of the individual coefficients of determination presented a strong effect size (R^2=0.98). The overall values for HRnet, %VO_2res and MET of the 9 stages are presented in table 1.

Table 1. Mean HRnet values measured at each stage, and its correspondent calculated %VO2res and MET values.

Stages	HRnet	%VO2res	MET
1	59	47	5,3
2	67	54	6,0
3	65	52	5,8
4	49	39	4,6
5	55	44	5,1
6	41	32	4,0
7	40	32	3,9
8	68	54	6,0
9	49	39	4,6
Overall route	53	42	5,0

In the laboratory test, the HRnet values ranged from 14.5 bpm to 129 bpm, 15% to 97% and 2.4 to 11.3 HRnet, %VO_2res and MET, respectively. The overall values for HRnet, %VO_2res and MET of the 5 laboratory test steps are presented in table 2.

Table 2. Mean HRnet, %VO2res and MET values measured during the lab test protocol.

Test steps	HRnet	%VO2res	MET
0 (rest)	0	0	1
1 (4,5 Km/h)	27	22	2,9
2 (6,5 Km/h)	48	38	4,5
3 (8,5 Km/h)	83	70	7,3
4 (10,5 Km/h)	100	80	8,4
5 (12,5 Km/h)	118	93	9,4

The overall correlation between HRnet and %VO_2res can be represented by the equation: %VO_2res = 0.64 + 0.77*HRnet.

Discussion

The aim of this study was to analyse a hiking route from a physiological point of view, to help the hiking enthusiasts to better understand its demands so it can be done by those with suitable age and physical level. At this point we tried to putt together physiological data from both field and lab tests. Main variables recorded were HR in field and HR plus VO_2 in laboratory. As stated earlier, the relationship between HR and VO_2 is well known (specifically between %HRres and %VO_2res). However, in the present study the best relationship between HR and VO_2 values were those expressed in HRnet vs. $\%VO_2$res, with an overall coefficient of determination of 0.95 (vs the 0.94 of the relationship %HRres/$\%VO_2$res). Besides having a higher coefficient of determination, this approach presents an advantage when compared with the usage of the %HRres values, because it does not need the HRmax value, that was estimated, mitigating the associated bias.

In the present study, HRnet values ranging from 40 to 68 bpm were found throughout the course's stages, and an overall course value of 53bpm. In a study conducted in by Simpson et al. (2011) in fifteen women, it was reported mean HR values of 108 bpm in an 8 km outdoor/indoor mixed circuit at 6.1 $km{\cdot}h^{-1}$. Despite the velocity of the hike in the present study was lower, the mean HR values were slightly higher (117 bpm), probably because of the numerous trail ascents. In the other hand, in a treadmill, a study by Bragada et al. (2009) assessed the HRnet for seventy-nine subjects, divided into two groups. The results for the HRnet values presented in his study however are much lower compared to those in the present study (at 4.5 $km{\cdot}h^{-1}$, 32.9 and 43.1 bpm in group 1 and 2, vs 27 bpm). This is probably due to the difference in the mean age, that was around 60 years old while in the present study was 28 years old. To the best of our knowledge, no other studies reported HRnet values in hiking nor in any outdoor or indoor walking/running activity.

The minimum and maximum $\%VO_2$res calculated were 32 and 54%, respectively. These values represent a light to moderate effort intensity as described by the ACSM's guidelines. ACSM (2018) report a threshold of 20 to $39\%VO_2$res as main reference to exercise at light intensity, and 40 to $59\%VO_2$res as main reference to exercise at moderate intensity. While hiking, practitioners usually self-select the pace according to the terrain characteristics. The walking velocity influences the exercise intensity and it is expected to change HR and VO_2 values. Thus, it is important to remark that, in the present study, both HR and VO_2 reflect a 4.5 $km{\cdot}h^{-1}$ velocity (13.3 $min{\cdot}km^{-1}$ pace), which may differ from similar studies.

The purpose of MET system is to know how many times above rest a certain subject is exercising (Jette, Sidney, & Blümchen, 1990). In the present study, the minimum MET value was 3.9, the maximum was 6.0, and the overall was 5.0 MET. In the Compendium of Physical Activity, Ainsworth et al. (2011) classified the Hiking activity as promoting a 6.0 MET effort. Discrepancy between our results and the data reported by Ainsworth et al. (2011) may rely on walking velocity. At different speeds the exercise intensity is also different, and the velocity is not stated in the compendium, unlike in the present study that was stable at 5.5 $km{\cdot}h^{-1}$. This able to add a connotation for data analysis retrieving the real individual physiological effort. So, despite two practitioners demonstrate different fitness levels, both experience five times the energetic expenditure compared to rest while doing an activity of 5 MET. However, if their fitness levels are different, it means that the maximum exercise intensity (maximum MET value) supported by each one is also different. Thus, regarding exercise prescription, MET system should be used carefully in order to avoid an under/overestimation of exercise intensity. The best way to avoid this is calculating, through linear regression, the METmax value from 100%VO2res. In the present study, the mean METmax value was 10.3, meaning, according to ACSM guidelines (ACSM, 2018), that our MET values (3.9 to 6 MET) fall under the light-to-moderate intensity (2.4 to 4.7 and 4.8 to 7.1 MET, respectively).

As previously stated, the velocity is known to influence the HR. Because it is hard to keep a steady pace during a hike, a predictive equation was created that allows the practitioners to estimate exercise intensity (expressed in $\%VO_2$res) based on their HRnet values. The predictive equation is $\%VO_2res = 0.64 + 0.77{*}HRnet$. This equation is best applied in this route as well as other similar round routes, and practitioners can use it to estimate the exercise intensity in a specific instant, during a segment or/and in the whole route.

Conclusions

Engaging in a physical activity is a must do when it comes to health and physical fitness. In accordance with previous studies, hiking proved to be an activity that elicit the adequate intensity of exercising, according to the recommendations, to improve both health and physical fitness. However, the decision to take one route instead of another should not be taken lightly, especially to special populations such as elderly, physical injured or sedentary people. The complementarity of the field and laboratory tests that proved to be useful and reliable in defining the energetic demands of the hike. Thanks to this complementarity, the present route in Serra da Estrela proved to be for sure suitable for both general and special population, since the physiological demands to overcome its terrain are low to moderate.

References

1. ACSM. (2018). *ACSM's Guidelines for Exercise Testing and Prescription. 10th ed*. Philadelphia: Wolters Kluwert.
2. Ainsworth, B. E., Haskell, W. L., Herrmann, S. D., Meckes, N., Bassett Jr, D. R., Tudor-Locke, C., & Leon, A. S. (2011). 2011 Compendium of Physical Activities: a second update of codes and MET values. *Medicine & science in sports & exercise*, *43*(8), 1575-1581.
3. Alencoão, A., Gomes, E., Quaresma, L., Sousa, L., & Gabriel, R. (2011). *Percursos Pedestres. O valor natural e a promoção da saúde*. Vila Real: Universidade de Trás-os-Montes e Alto Douro.
4. Bragada, J. A., Pedro, P. M., Vasques, C. S., Tiago, M. B., & Vítor, P. L.

(2009). Net heart rate to prescribe physical activity in middle-aged to older active adults. *Journal of sports science & medicine*, *8*(4), 616-621.

5. Dalleck, L. C., & Kravitz, L. (2006). Relationship between % heart rate reserve and% VO2 reserve during elliptical crosstrainer exercise. *Journal of sports science & medicine*, *5*(4), 662-671.
6. EG. 2009, "Trek & Trail – L'outdoor garde le ritme", Sport Première Magazine, Julho/Agosto de 2009, pp. 3-4.
7. Ferguson, C. J. (2009). An effect size primer: A guide for clinicians and researchers. *Professional Psychology: Research and Practice, 40*(5), 532–538. doi:10.1037/a0015808
8. Funollet, F. (1994), "Actividades En El Médio Natural. Tipos, Clasificaciones Y Recursos", Organización De Actividades Físicas En La Naturaleza. Tema 14, Barcelona: Inde.
9. Gabriel, R., Moreira, H., & Faria, J. (2010). "Pedestrianismo, Biomecânica E Prevenção De Lesões", In Ronaldo Gabriel (Eds), Pedestrianismo – Uma Abordagem Multidisciplinar: Ambiente, Aptidão Física E Saúde, Pp. 83 – 109, Utad, Vila Real.
10. Gatterer, H., Raab, C., Pramsohler, S., Faulhaber, M., Burtscher, M., & Netzer, N. (2015). Effect of weekly hiking on cardiovascular risk factors in the elderly. *Zeitschrift für Gerontologie und Geriatrie, 48*, 150-153.
11. Jette, M., Sidney, K., & Blümchen, G. (1990). Metabolic equivalents (METS) in exercise testing, exercise prescription, and evaluation of functional capacity. *Clinical cardiology*, *13*(8), 555-565.
12. Kouchner, F., & Lyard, J. (2001). A valorização do turismo de passeio pedestre nos territórios rurais – Guia pedagógico para a elaboração e execução de um projeto de passeio pedestre", Inovação em Meio Rural, Caderno n.º 12, Observatório Europeu Leader.
13. Loob, B. (2004). Load Carriage For Fun: A Survey Of New Zealand Trampers: their activities and injuries. *Applied Ergonomics, 35*(6), 541-547.
14. Lopes, V. P., Magalhaes, P., Bragada, J. A., & Vasques, C. (2009). Actigraph calibration in obese/overweight and type 2 diabetes mellitus middle-aged to old adult patients. *Journal of Physical Activity & Health 6*(Suppl. 1), S133–S140.
15. Lounana, J., Campion, F., Noakes, T. D., & Medelli, J. (2007). Relationship between %HRmax, %HR reserve, %VO2max, and %VO2 reserve in elite cyclists. *Medicine and Science in Sports and Exercise, 39*(2), 350-357.
16. Mair, J., Hammerer-Lercher, A., Mittermayr, M., Klingler, A., Humpeler, E., Pachinger, O., & Schobersberger, W. (2008). 3-week hiking holidays at moderate altitude do not impair cardiac function in individuals with metabolic syndrome. *International Journal of Cardiology, 11*, 123(2), 186-188.
17. Simpson, K. M., Munro, B. J., & Steele, J. R. (2011). Effect of load mass on posture, heart rate and subjective responses of recreational female hikers to prolonged load carriage. *Applied ergonomics*, *42*(3), 403-410.
18. Strauss-Blasche, G., Riedmann, B., Schobersberger, W., Ekmekcioglu, C., Riedmann, G., Waanders, R., Fries, D., Mittermayr, M., Marktl, W., & Humpeler, E. (2004). Vacation at moderate and low altitude improves perceived health in individuals with metabolic syndrome. *Journal of Travel Medicine, 11*(5), 300-304.
19. Swain, D. P., & Leutholtz, B. C. (1997) Heart rate reserve is equivalent to %VO2 reserve, not to %VO2max. *Medicine and Science in Sports and Exercise, 29*(3), 410-414.
20. Tanaka, H., Monahan, K. D., & Seals, D. R. (2001). Age-predicted maximal heart rate revisited. *Journal of the American College of Cardiology, 37*(1), 153-156.
21. Tovar, Z., & Carvalho, C. (2010). *Pedestrianismo e Percursos Pedestres em Portugal: paisagens, património e desenvolvimento.* Actas do XII Colóquio Ibério de Geografia, 1-11.
22. Vieira, M., de Avelar, I., Silva M., Soares, V., & Lobo da Costa P. (2015). Effects of four days hiking on postural control. *PLoS One,* 10(4), e0123214. doi: 10.1371/journal.pone.0123214