Can lab and field testing be complementary in defining physiological effort through the Serra da Estrella 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. Bartolomeu1,2,*, José A. Bragada3, Natalina Casanova1,2, Jorge Casanova1,2, and Máximo J. Costa1,2,4

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 nonexistent. 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 (VO2). Linear regressions between net HR (HRnet) vs %VO2 reserve were computed. Results: The mean coefficients of determination were very high (R2=0.98). The calculated %VO2 reserve 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 %VO2 reserve=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.

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 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 (Alencóaro 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...
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 (VO₂).

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

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 VO₂ 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 VO₂ (VO₂max). For that purpose, it was assumed that for the same intensity, the percentage of HR reserve (%HRres) equals the percentage of VO₂ reserve (%VO₂res), 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 %VO₂ res at this same level is equal to the %HRres previously calculated. Linear regressions between net HR (HRnet) vs %VO₂ res 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 VO₂ 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 ≤ 0.05). Linear regression models were used to describe the assess the relationships between HR net and %VO₂ res. Coefficient of determination was selected as effect size index and interpreted as: (1) small effect size if 0.04 ≤ R² < 0.25; (2) moderate effect size if 0.25 ≤ R² < 0.64 and (3) strong effect size if R² ≥ 0.64 (Ferguson, 2009).

Results

The field HRnet values ranged from 10 to 102 bpm and the correspondent %VO₂ res 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 (R²=0.98). The overall values for HRnet, %VO₂ res and MET of the 9 stages are presented in table 1.

### Table 1. Mean HRnet values measured at each stage, and its correspondent calculated %VO₂ res and MET values.

<table>
<thead>
<tr>
<th>Stages</th>
<th>HRnet</th>
<th>%VO₂ res</th>
<th>MET</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>59</td>
<td>47</td>
<td>5.3</td>
</tr>
<tr>
<td>2</td>
<td>67</td>
<td>54</td>
<td>6.0</td>
</tr>
<tr>
<td>3</td>
<td>65</td>
<td>52</td>
<td>5.8</td>
</tr>
<tr>
<td>4</td>
<td>49</td>
<td>39</td>
<td>4.6</td>
</tr>
<tr>
<td>5</td>
<td>55</td>
<td>44</td>
<td>5.1</td>
</tr>
<tr>
<td>6</td>
<td>41</td>
<td>32</td>
<td>4.0</td>
</tr>
<tr>
<td>7</td>
<td>40</td>
<td>32</td>
<td>3.9</td>
</tr>
<tr>
<td>8</td>
<td>68</td>
<td>54</td>
<td>6.0</td>
</tr>
<tr>
<td>9</td>
<td>49</td>
<td>39</td>
<td>4.6</td>
</tr>
</tbody>
</table>

The overall correlation between HRnet and %VO₂ res can be represented by the equation: %VO₂ res = 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 put together physiological data from both field and lab tests. Main variables recorded were HR in field and HR plus VO₂ in laboratory. As stated earlier, the relationship between HR and VO₂ is well known (specifically between %HRres and %VO₂ res). However, in the present study the best relationship...
between HR and VO₂ values were those expressed in HR-
net vs. %VO₂,res, with an overall coefficient of determination
of 0.95 (vs the 0.94 of the relationship %HRres/%VO₂,res).
Besides having a higher coefficient of determination, this ap-
proach 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 over-
all course value of 53bpm. In a study conducted in by Simp-
son 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·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·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 %VO₂,res calculated were
32 and 54%, respectively. These values represent a light to
moderate effort intensity as described by the ACSM’s guide-
lines. ACSM (2018) report a threshold of 20 to 39%VO₂,res
as main reference to exercise at light intensity, and 40 to
59%VO₂,res as main reference to exercise at moderate in-
tensity. 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 VO₂ values. Thus, it is important to remark that,
in the present study, both HR and VO₂ reflect a 4.5 km·h⁻¹
velocity (13.3 min·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 ve-
locity. At different speeds the exercise intensity is also differ-
ent, and the velocity is not stated in the compendium, unlike
in the present study that was stable at 5.5 km·h⁻¹. This able to
add a connotation for data analysis retrieving the real indi-
vidual physiological effort. So, despite two practitioners dem-
onstrate different fitness levels, both experience five times the
energetic expenditure compared to rest while doing an activ-
ity 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, regard-
ing exercise prescription, MET system should be used care-
fully 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, mean-
ing, 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 %VO₂,res) based
on their HRnet values. The predictive equation is %VO₂,res
= 0.64 + 0.77*HRnet. This equation is best applied in this
route as well as other similar round routes, and practition-
ers 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 stud-
ies, 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 reli-
able 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

Physical Activities: a second update of codes and MET values. Medicine
& science in sports & exercise, 43(8), 1575-1581.
Real: Universidade de Trás-os-Montes e Alto Douro.
Can lab and field testing be complementary in defining physiological effort through the Serra da Estrela routes?