

Analysis and relationship between the anthropometric and somatotype characteristics and cardiovascular capacity in amateur mountain runners: a pilot study

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Summary

Purpose: The aim of this study was to describe the anthropometrical and cardiovascular characteristics of short course trail runners and analyze the associations, if any, between both anthropometric and cardiovascular features of amateur trail runners. **Material and method:** Anthropometrical evaluation and an incremental maximum test with 10% of grade on a treadmill were performed on a group of 10 short distance amateur trail runners.

Results: Significant negative correlations were found between the body mass index (BMI) and the speed at VT1 (Vel_{VT1}) ($r = -0,95$, $p < 0,001$), or the time to reach VT1 ($r = -0,91$, $p = 0,002$) and between the body fat percentage and the respiratory exchange ratio at VT2 ($r = -0,80$, $p = 0,016$) or the time to reach VT2 ($r = -0,83$, $p = 0,01$). Calf circumference was also found to be positively associated with oxygen consumption at VT1 ($r = 0,74$, $p = 0,037$), at VT2 ($r = 0,90$, $p = 0,002$) and with the maximal oxygen uptake ($r = 0,85$, $p = 0,007$).

Conclusions: Results indicate that both body fat percentage and calf circumference could be related to the performance on an incremental test protocol with inclination in amateur trail runners.

Key words:

Body composition.
Oxygen consumption.
Physiological thresholds.
Trail running. Kinanthropometry.

Análisis y asociación entre las características antropométricas, somatotipo y capacidad cardiovascular en corredores de montaña de categoría amateur: un estudio piloto

Resumen

Objetivo: Los objetivos del presente estudio fueron describir las características antropométricas y la capacidad cardiovascular de corredores *amateurs* de *trail running* de corta distancia y analizar si existe asociación entre las características antropométricas y la capacidad cardiovascular en los corredores de montaña.

Material y método: A un grupo de 10 corredores de *trail running* de corta distancia de categoría amateur se les realizó un análisis antropométrico y un test incremental máximo con un 10% de inclinación en tapiz rodante.

Resultados: Se encontraron correlaciones significativas y negativas entre el índice de masa corporal (IMC) y la velocidad alcanzada al primer umbral ventilatorio (Vel_{VT1}) ($r = -0,95$, $p < 0,001$), así como con el tiempo en alcanzar el VT1 (t_{VT1}) ($r = -0,91$, $p = 0,002$) y entre porcentaje (%) de grasa corporal y el índice de intercambio respiratorio al segundo umbral ventilatorio (RER_{VT2}) ($r = -0,80$, $p = 0,016$) así como con el tiempo en alcanzar el VT2 (t_{VT2}) ($r = -0,83$, $p < 0,01$). También se encontraron correlaciones significativas y positivas entre el perímetro de pierna y el consumo de oxígeno al VT1 (VO_{2VT1}) ($r = 0,74$, $p = 0,037$), el consumo de oxígeno al VT2 (VO_{2VT2}) ($r = 0,90$, $p = 0,002$) y el consumo máximo de oxígeno (VO_{2max}) ($r = 0,85$, $p = 0,007$).

Conclusiones: Los resultados obtenidos en el presente estudio ponen de manifiesto que tanto el % de grasa corporal como el perímetro de la pierna pueden estar asociados al rendimiento en una prueba incremental con inclinación en los corredores amateur de montaña participantes en el estudio.

Palabras clave:

Composición corporal.
Consumo de oxígeno.
Umbral fisiológico. Trail running.
Cineantropometría.

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Introduction

Trail running (mountain running) is a sports discipline that involves races along mountain tracks of varying distances ranging from 1 km to more than 100 km, in which important elevation gains and losses need to be overcome through different types of terrain and in variable weather conditions¹. Due to the characteristics of the races, this type of sport places high demands on participants at both a neuromuscular² and cardiovascular³ level. Therefore, *trail running* races are highly demanding from a physiological point of view. Possibly due to this high demand and the athletic challenge involved, the practice of *trail running* has become increasingly popular over the last few years, with regard to the number of races, competitions and participants, primarily at an amateur level⁴⁻⁶. This considerable boom has led mountain running to be recently recognised by the World Athletics and to have its own world championship⁷. However, despite this boom, in practice the existing scientific literature relating to this sport is still limited and even more so for runners at an amateur level. Consequently, there is a need for more scientific studies to analyse this sports discipline and the characteristics of its participants.

Although with regard to other endurance disciplines, it has been reported that body composition is a determining factor in athletic performance^{3,9-12}, due to the characteristics of *trail running*, in which athletes must overcome important elevation gains, the anthropometric characteristics of the runners could take on even greater importance in order to achieve sporting success³. Prior investigations have studied the body composition of mountain runners, analysing the anthropometric characteristics of long-distance runners (42 km – more than 217 km)^{9,14}. However, given that studies made on the anthropometric characteristics of short-distance runners (<42 km) are limited^{15,16}, it could be of interest to conduct further studies in this regard, in order to obtain scientific evidence on the anthropometric profile of short-distance mountain runners.

On the other hand, as in other endurance disciplines¹⁷⁻²⁰, an analysis has also been made of the physical performance and physiological characteristics of the runners taking part in *trail running*^{3,6,8,15,16,21-24}. It is common to use laboratory tests to measure the cardiovascular capacity of runners^{3,8,15,16} analysing maximal and submaximal aerobic performance markers that make it possible to determine the physiological characteristics of the athletes and to subsequently prescribe, monitor and assess training. Most of the in-laboratory protocols used with mountain runners have been conducted with no incline²⁶⁻²⁸. However, given the fact that a considerable part of the *trail running* races takes place on uphill terrain and that it has been reported that the running economy or the energy cost of the runners could be different depending on whether they are running on level terrain or uphill²¹, further studies are needed in order to analyse the physiological characteristics of trail runners using protocols with an incline^{3,29-31}.

Prior studies conducted with endurance athletes analysed the relationship between body composition and physiological performance

in a laboratory test^{11,32-35}. However, for trail runners, the knowledge available on the influence of the anthropometric characteristics of the runners on physiological performance in a standardised laboratory test is very limited. Despite the fact that some studies have reported that the anthropometric characteristics of mountain runners have a significant correlation with performance in competition^{9,16,37}, we have found no studies that analyse the relationship between body composition and performance in laboratory-based incremental running tests. Knowledge of whether or not anthropometric characteristics are related to the physiological characteristics of the trail runners could be relevant to understanding the extent to which the results obtained in an incremental test, which are generally used to monitor the adaptations induced by the training process, could in some way be influenced by changes in body composition.

Considering the importance of evaluating the anthropometric characteristics and cardiovascular capacity of mountain runners using protocols with an incline, with a view to designing personalised training programs, the objectives of this study were to firstly describe the anthropometric characteristics, somatotype and cardiovascular capacity of short-distance (< 42 km) *trail runners* and, secondly, to analyse whether there is any relationship between the anthropometric characteristics and the cardiovascular capacity of mountain runners at an amateur level.

Material and method

Participants

10 mountain runners took part in this study, who were competing in short-distance races at an amateur level (38.0 ± 9.5 years, 174.0 ± 8.1 cm, 65.21 ± 9.52 kg, 8.58 ± 2.28 % fat, 21.44 ± 1.96 kg·m⁻²) with a valid federation membership, of which there were 9 men and 1 woman. In order to take part in the study, participants were required to have at least one year of experience in mountain races, at least 5 years of experience in an endurance sport as a member of a federation, and not to have suffered an injury in the 5 months prior to the study. Before the study started, all participants were informed of the objectives and methodology to be used during the investigation and they had the possibility to freely withdraw and with no penalty at any stage of the investigation. Before taking part in the study, they signed an informed consent form. The investigation followed the guidelines established by the Declaration of Helsinki (2013) and was approved by the Ethics Committee for Research on Human Subjects (CEISH) of the University of the Basque Country (UPV/EHU) (Ceid Ref. No. : M10/2017/200).

Procedure

During the competition season, and always one month before an important race, the participants were evaluated in a single session, in which an analysis was made of their anthropometric profile as well as a laboratory-based maximal incremental running test performed on a treadmill. The runners were familiar with tests of this nature, having

performed them previously as part of their training program. They were asked not to alter their daily routine with regard to diet and training in the days prior to the investigation in order to maintain their normal condition. For the tests, the participants were asked to come well-rested and hydrated, to have performed low-intensity exercise (<90 min at <70% of the maximum individual heart rate, FC_{max}) during the days prior to the test, to have spent at least 4 days resting since the last competition (to ensure glycogen replenishment) and not to eat anything in the 2 h prior to the tests. Of the 10 mountain runners taking part, the results of 2 runners in the laboratory-based incremental test were not included in the analysis. This was either due to problems with the measurement of the study variables or to logistics problems when conducting the test.

Measurements

Anthropometric and somatotype characteristics The measurements of the anthropometric characteristics were taken following the guidelines established by the International Society Advancement Kinanthropometry (ISAK)³⁸. A scale with measuring rod (Seca, Bonn, Germany) was used to measure the height and body mass with an accuracy of 1 mm and 0.05 kg respectively. The height and body mass measurements were then used to calculate the Body Mass Index (BMI). The skin folds (biceps, triceps, subscapular, abdomen, iliac crest, supraspinale, anterior thigh and medial calf) were measured using a skinfold calliper (Holtain, Crymych, United Kingdom) and the sum of the 8 folds was calculated (Σ folds). The percentage of body fat was calculated using the Yuhaz formula³⁹. The circumferences [(relaxed arm, flexed and contracted arm, waist (minimum)), hip (maximum) were measured using a non-flexible tape measure graduated in millimetres (Holtain 110P-98606, Crymych, United Kingdom). The circumferences were used to calculate the ratio between the waist circumference and the hip circumference (waist-hip index). Furthermore, a sliding calliper (HLT-100, Holtain Ltd., Crymych, United Kingdom) was used to measure the biepicondylar (humerus) and bicondylar (femur) widths. Finally, a calculation was made of the somatotype component⁴⁰ of each mountain runner taking part.

Laboratory-Based Maximal Incremental Running Testing: The participants performed a continuous Maximal Incremental Running Test on a treadmill (ERGelek™ EG2, Vitoria-Gasteiz, Spain) using the protocol with incline described above for mountain runners³¹. The test started at 6 km·h⁻¹, always with an incline of 10%. Every 2.5 min, the speed was increased by 1 km·h⁻¹. The aforementioned treadmill, which had been calibrated by the manufacturer prior to the start of the study, was used to continuously record the running speed and the test time. At the end of each stage and on completion of the test, the heart rate (HR) was measured with a heart rate monitor (Polar™ Electro Oy, Kempele, Finland). The following ventilatory variables were analysed: ventilation (VE), oxygen uptake (VO_2) and carbon dioxide production (VCO_2), which were recorded throughout the entire test using a gas analyser (Medisoft™ Ergocard, Medisoft Group, Sorinnes, Belgium). Furthermore, the Respiratory Exchange Rate (RER) was calculated as the ratio between

$VCO_2:VO_2^{-1}$ ^{41,42}. Apart from the HR; the variables were obtained at the ventilatory threshold 1 (VT1), which was considered to be the moment at which the ventilation-volume of oxygen ratio ($VE:VO_2^{-1}$) and the end-tidal oxygen tension (PETO2) started to increase without the corresponding increase in the end-tidal carbon dioxide tension (PETCO2)^{44,45} and at ventilatory threshold 2 (VT2), which is considered as the moment when the values of both equivalents ($VCO_2:VE^{-1}$ and $VO_2:VE^{-1}$) increased with a drop in PETCO2⁴⁶, and the maximum values (Max). The test was considered to be maximum when two of the following three criteria were met: a) the VO_2 ceased to increase despite the increase in the speed demanded, b) 90% of the heart rate was exceeded (HR_{max}) estimated according to age (220-age), c) the RER was greater than 1.15.

Statistical analysis

The results are shown as a mean ± standard deviation of the mean. In order to determine the magnitudes of the relationships between the anthropometric variables and the variables obtained in the laboratory-based incremental running test, the Pearson (r) correlation was used with confidence intervals (CI) at 95%. The interpretation of the correlations was made through the following magnitude scale: trivial (r <0.1), low (r = 0.10-0.30), moderate (r = 0.31-0.50), high (r = 0.51-0.70), very high (r = 0.71-0.90) and almost perfect (r >0.9)⁴⁷. The statistical analysis was made with the Statistical Package for Social Sciences (SPSS™ Inc, version 23.0 for Windows, Chicago, IL, EE.UU.). The statistical significance cut-off was set at p <0.05.

Table 1. Results of the anthropometric and somatotype characteristics of mountain runners (n=10).

	Minimum	Maximum	Mean ± SD
<i>Skin folds</i>			
Triceps (mm)	4.30	16.70	8.58 ± 3.76
Subscapular (mm)	5.80	12.20	8.20 ± 1.95
Biceps (mm)	2.40	5.70	3.48 ± 1.20
Iliac crest (mm)	5.90	15.00	9.12 ± 3.30
Supraspinale (mm)	3.80	12.50	6.44 ± 2.59
Abdomen (mm)	4.50	21.50	11.30 ± 5.72
Thigh (mm)	3.70	23.60	10.78 ± 5.50
Calf (mm)	3.40	10.00	5.74 ± 2.22
Σ of 8 folds (mm)	38.30	109.60	62.65 ± 21.89
Body fat (%)	5.70	12.60	8.58 ± 2.28
<i>Circumferences</i>			
Relaxed arm (cm)	22.80	30.50	27.43 ± 2.43
Contracted and flexed arm (cm)	25.50	33.10	29.83 ± 2.55
Waist (cm)	66.70	84.00	74.44 ± 4.93
Hip (cm)	86.00	99.70	92.82 ± 4.10
Leg (cm)	32.30	40.50	36.60 ± 2.50
Waist-Hip index	0.76	0.85	0.80 ± 0.04
<i>Widths</i>			
Humerus (cm)	5.50	37.90	9.83 ± 9.88
Femur (cm)	8.00	11.20	9.75 ± 0.93
<i>Somatotype</i>			
Endomorph	1.40	3.30	2.20 ± 0.76
Mesomorph	2.80	5.90	4.62 ± 1.16
Ectomorph	1.80	4.50	3.16 ± 0.87

ST = standard deviation; Σ = sum

Table 2. Results obtained in the laboratory-based maximum incremental test by the mountain runners (n=8).

	Minimum	Maximum	Mean \pm SD
VT1			
VE _{VT1} (L·min ⁻¹)	60.52	83.54	71.36 \pm 8.63
VO _{2VT1} (L·min ⁻¹)	2.32	3.22	2.86 \pm 0.27
VO _{2VT1} (mL·kg ⁻¹ ·min ⁻¹)	38.57	51.62	43.98 \pm 4.33
VCO _{2VT1} (L·min ⁻¹)	2.16	2.94	2.67 \pm 0.23
RER _{VT1}	0.89	0.96	0.93 \pm 0.02
Vel _{VT1} (km·h ⁻¹)	7.00	8.00	7.44 \pm 0.53
t _{VT1} (min:s)	3:15	6:45	5:10 \pm 1:19
VT2			
VE _{VT2} (L·min ⁻¹)	103.37	165.18	134.02 \pm 17.65
VO _{2VT2} (L·min ⁻¹)	3.35	5.14	4.10 \pm 0.55
VO _{2VT2} (mL·kg ⁻¹ ·min ⁻¹)	55.93	71.32	63.02 \pm 4.65
VCO _{2VT2} (L·min ⁻¹)	3.49	5.77	4.48 \pm 0.65
RER _{VT2}	1.04	1.23	1.09 \pm 0.06
Vel _{VT2} (km·h ⁻¹)	10.00	13.00	11.56 \pm 0.88
t _{VT2} (min:s)	10:45	18:15	15:03 \pm 2:13
Max			
VE _{max} (L·min ⁻¹)	114.15	180.81	147.53 \pm 23.14
VO _{2max} (L·min ⁻¹)	3.42	5.59	4.23 \pm 0.70
VO _{2max} (mL·kg ⁻¹ ·min ⁻¹)	56.48	77.50	64.66 \pm 6.41
VCO _{2max} (L·min ⁻¹)	3.77	6.09	4.73 \pm 0.70
RER _{max}	1.09	1.24	1.12 \pm 0.05
Vel _{max} (km·h ⁻¹)	11.00	13.00	12.33 \pm 0.71
t _{agot} (min:s)	12:38	18:58	16:42 \pm 1:58
HR _{max} (p·min ⁻¹)	160	202	184.90 \pm 11.73

SD = Standard deviation, VT1 = first ventilation threshold, VT2 = second ventilation threshold, Max = max values, VE = lung ventilation, VO₂ = oxygen consumption (absolute and relativized to body mass), VCO₂ = carbon dioxide production, RER = respiration exchange rate, Vel = velocity, t = time, tagot = time to exhaustion, HRmax = maximum heart rate.

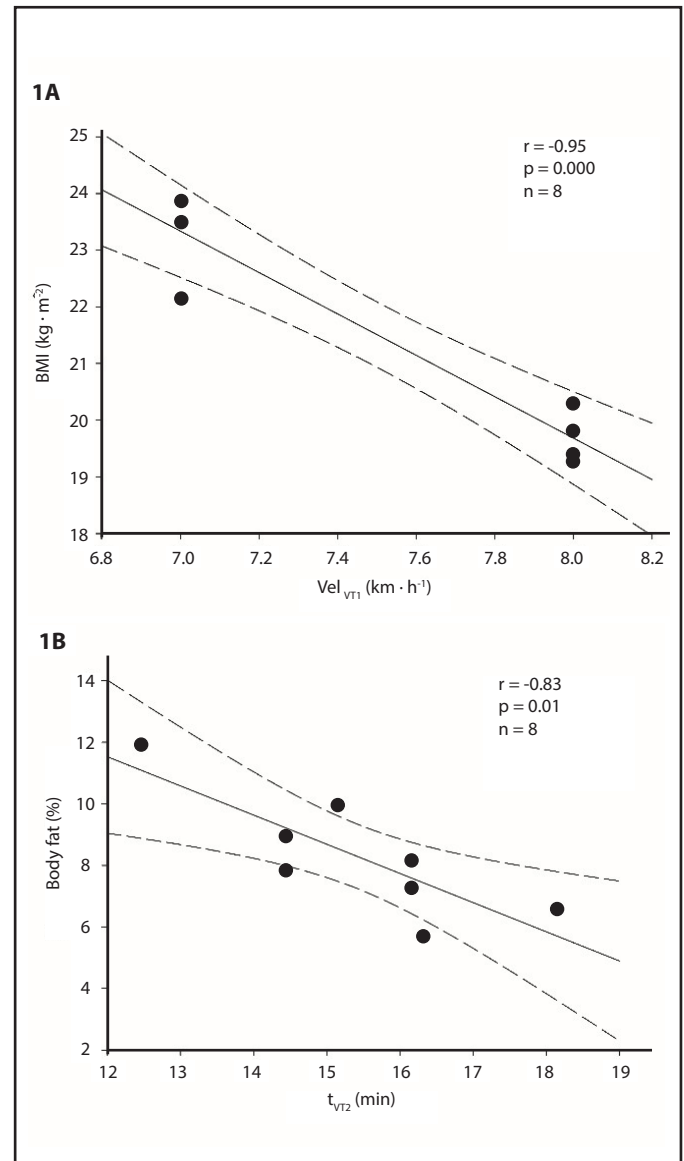
Results

Table 1 shows the results of the anthropometric characteristics (skin folds, circumferences, widths and estimated variables) and of the somatotype of the mountain runners taking part in the study.

Table 2 gives the results obtained by the mountain runners taking part in this study in the laboratory-based maximal incremental running test, for the values obtained at VT1, VT2 and also the maximum values.

With regard to the relationship between the anthropometric characteristics and the results obtained in the laboratory-based incremental test, significant negative correlations were found between the BMI and Vel_{VT1} ($r = -0.95$, $p < 0.001$, *almost perfect*) (Figure 1A), the BMI and t_{VT1} ($r = -0.91$, $p = 0.002$, *almost perfect*), between the percentage of body fat and the RER_{VT2} ($r = -0.80$, $p = 0.016$, *very high*) and between % of fat and t_{VT2} ($r = -0.83$, $p = 0.01$, *very high*) (Figure 1B). Significant positive correlations were also found between the circumference of the calf and VO_{2VT1} ($r = 0.74$, $p = 0.037$, *very high*), the VO_{2VT2} ($r = 0.90$, $p = 0.002$, *almost perfect*) (Figure 2A) and VO_{2max} ($r = 0.85$, $p = 0.007$, *very high*) (Figure 2B).

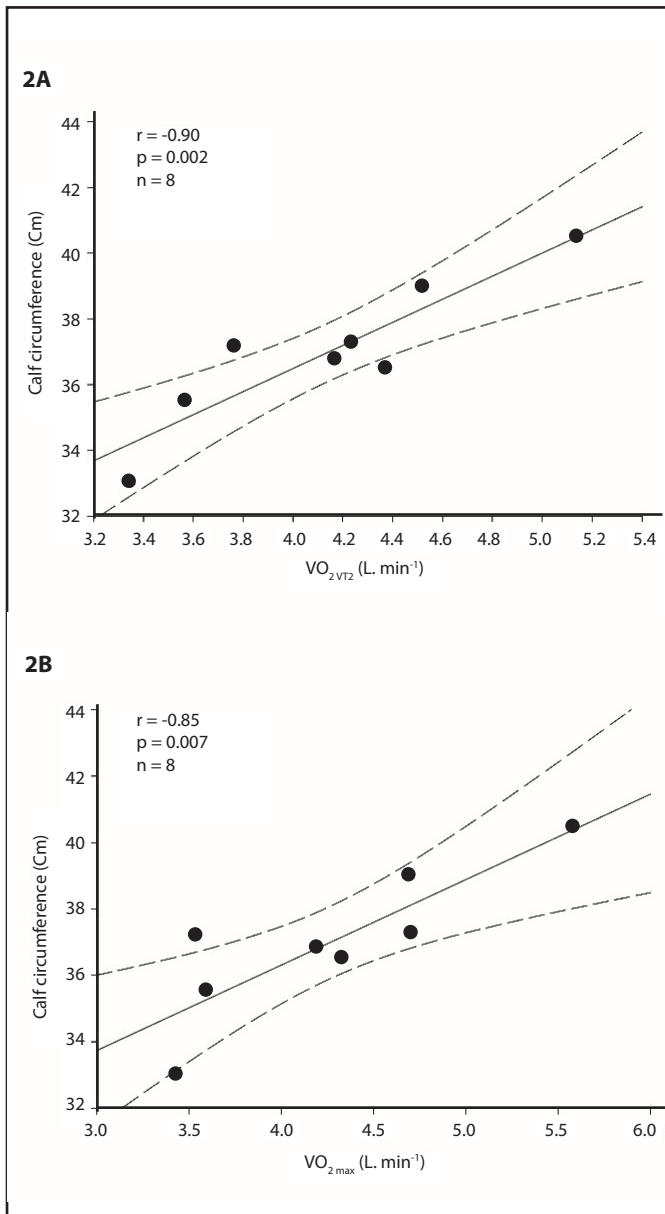
Figure 1. Correlation between the body mass index (BMI) and the velocity achieved at the first ventilation threshold (Vel_{VT1}) (1A) and between the percentage (%) of fat and the time employed to reach the second ventilatory threshold (t_{VT2}) (1B). Solid black lines = linear regression lines. Dashed black lines = confidence intervals of 95%.



Discussion

The study objectives were, on the one hand, to describe the anthropometric characteristics and the performance in a standard laboratory-based maximal incremental running test of mountain runners at an amateur level and, on the other hand, to analyse the relationship between the anthropometric characteristics of these runners and their cardiovascular performance. Based on the scientific literature consulted, this study is the first to analyse the relationship between the anthropo-

Figure 2. Correlation between the calf circumference and oxygen consumption at the second ventilatory threshold (VO_{2VT2}) (2A) and maximal oxygen consumption VO_{2max}) (2B). Solid black lines = linear regression lines. Dashed black lines = confidence intervals of 95%.



metric characteristics and the performance obtained in a laboratory test with an incline, for trail runners in an amateur category who regularly compete in short-distance mountain races (<42 km). Considering the increasing popularity of amateur trail running over the last few years, an in-depth knowledge of this relationship could be extremely helpful for sports coaches and for the athletes themselves, in order to optimise the training process.

The anthropometric characteristics of endurance runners has been extensively discussed in scientific literature^{29,48–50}, possibly due

to the close relationship with athletic performance^{11,36,50,51}. Specifically, the anthropometric characteristics of trail runners have also been analysed^{9,12,14,16,48,52}, given that this could be particularly relevant to athletic performance in this discipline due to the fact that body mass may have a significant influence when running on terrain with elevation gains and losses¹⁶. The runners taking part in this study had a body fat percentage of $8.58 \pm 2.28\%$ and a BMI of $21.44 \pm 1.86 \text{ kg}\cdot\text{m}^{-2}$. These results are similar to those obtained in the previous study made with short-distance trail runners (< 42 km) by Alvero-Cruz *et al.*¹⁶ (% body fat = $9.96 \pm 1.35\%$, BMI = $22.67 \pm 1.62 \text{ kg}\cdot\text{m}^{-2}$). However, both the % of body fat and the BMI of the runners taking part in this study and in that of Alvero-Cruz *et al.*¹⁶ were less (45.9% for % of fat and 10.78% for BMI) than the values obtained for long-distance runners (> 42 km), for runners taking part in a 161 km race (% fat = $16.1 \pm 4.1\%$, BMI = $24.8 \pm 2.7 \text{ kg}\cdot\text{m}^{-2}$)¹², and also for those taking part in a 217 km race (% fat = $13.2 \pm 1.8\%$, BMI = $24.8 \pm 2.7 \text{ kg}\cdot\text{m}^{-2}$)⁹ as well as participants in 24-hour races (% fat = $16.1 \pm 4.1\%$, BMI = $23.1 \pm 1.8 \text{ kg}\cdot\text{m}^{-2}$)⁵². Contrary to what might be expected, long-distance runners had a higher % of body fat and a higher BMI than short-distance runners. *A priori*, it would be expected that long-distance runners would have lower fat percentages and BMI due to the fact that, in principle, the training performed to prepare for races of this type and the actual competitions ought to be longer and, consequently, with a greater use of energy substrates through lipid uptake⁵³, which would lead to a sharper drop in the % of fat and BMI in comparison to short-distance runners. It is possible that these contradictory results are due to the characteristics of the sample. Although amateurs, the runners taking part in this study were at a high competition level, while those runners taking part in the studies by Hoffman *et al.*¹² and Belli *et al.*⁹ were from extremely varied levels and included athletes who completed the race and those who did not. Another plausible explanation to account for the marked differences between the studies could be related to the different methodology used to estimate the body fat percentage. All the same, both Hoffman *et al.*¹² and Belli *et al.*⁹ found a positive relationship between the body fat percentage and race time. Therefore, in future investigations, it could be of interest to compare the fat % and the BMI of short- and long-distance runners of a similar competition level. Taking account of the fact that for both short-distance races^{3,16} and long-distance ones^{9,12} a positive relationship was observed between the % of body fat and the competition time, it seems reasonable to think that one of the de trail runners' objectives should be to reduce the body fat % and BMI in order to improve their competition performance. Nevertheless, the possible relationship between the fat % and competition performance may also be related to the fact that, in order to improve performance, more adequate training is required and, therefore, the actual training may lead to a change in the body fat %. However, bearing in mind that Hoffman³⁷ reported that in very long-distance races (161 km) a higher percentage of body fat measured prior to the race may not be a disadvantage in races with a high energy demand³⁷, considering that this type of competition may require high lipid demands. In this respect, further studies may be necessary for the different types of trail running.

Despite the fact that numerous studies have used laboratory tests to analyse the physiological characteristics of trail runners and have reported data for the maximal values obtained^{3,7,54}, few studies have focussed on analysing the submaximal values^{16,22,25}. The analysis of these values may help to better understand the characteristics of mountain runners and make it possible to better plan training sessions. Furthermore, taking account of the fact that a large part of the mountain running competitions involve significant elevation gains, the analysis of the physiological characteristics of the runners using protocols with an incline could be relevant^{23,25,55}. In this regard, the athletes taking part in our study achieved a relative $\text{VO}_{2\text{max}}$ of $64.66 \pm 6.41 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. These results are similar to the $\text{VO}_{2\text{max}}$ figures for high-level short-distance runners (27 km) ($61.1 - 69.7 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$)¹⁵ obtained by Alvero-Cruz *et al.*¹⁶ with trained runners ($67 \pm 7 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) and even to those obtained by Björklund *et al.*³, for elite runners ($68.1 \pm 5.8 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ in men). Likewise, the results obtained by Alvero-Cruz *et al.*¹⁶ for VO_2 at VT1 ($43 \pm 6 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) are very similar to those obtained in this study ($43.98 \pm 4.33 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$), although slightly lower (7.97 %) than those observed in $\text{VO}_{2\text{VT2}}$ ($58 \pm 5 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ vs $63.02 \pm 4.65 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$). Due to the fact that the studies analysed use different measurement protocols, different sampling characteristics with regard to age and sex and different competition levels, it is difficult to determine the influence of these variables on VO_2 performance. However, the results obtained herein with regard to $\text{VO}_{2\text{max}}$ are higher (13.04%) than those obtained by Wüthrich *et al.*³¹ ($57.2 \pm 6.1 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) for participants who were able to complete an ultra-distance race (110 Km), using the same protocol and also higher (12.65%) than the results obtained by Fornasiero *et al.*²² for ultra-distance amateur runners (65 km) with a protocol with an incline. These results could suggest that a high $\text{VO}_{2\text{max}}$ has no determinant influence on very long distance races. As previously described, for a 65 km race, VT1 is not exceeded during approximately 82% of the competition time and the average intensity of the race is approximately 77% of HR_{max} (approximately 66% of $\text{VO}_{2\text{max}}$)²². By contrast, for short-distance races (27 km) the average running intensity was reported to be approximately 89% of HR_{max} ¹⁵. As a result of these different race characteristics, the training of the runners may seek different goals and, therefore, different physiological adaptations.

A number of prior studies conducted with asphalt runners analysed the relationship between the anthropometric characteristics and the laboratory test results^{11,29,34,36}. However, there is no evidence for trail runners in this regard. The results obtained in this study show that, despite the fact that no significant relationship was obtained between the anthropometric characteristics of the runners and the maximum values for VO_2 , significant negative correlations were observed between the BMI and Vel_{VT1} , the BMI and t_{VT1} , between the body fat % and RER_{VT2} and between the fat % and t_{VT2} . These results indicate that the runners with a greater fat % or BMI had a poorer submaximal performance for the test with a ramp. Despite the fact that there are no similar studies for *trail runners* in order to compare these results, these relationships

appear to indicate that the % of fat and BMI can play a very important role when running on a ramp. These results reveal that the BMI and fat % could have a better relationship with the submaximal values obtained in the laboratory test in comparison to the maximal values.

On the other hand, the results obtained in this study show significant positive correlations between the calf circumference and $\text{VO}_{2\text{VT1}}$, $\text{VO}_{2\text{VT2}}$ and $\text{VO}_{2\text{max}}$. Although a number of studies conducted with asphalt runners reported greater mass in the lower limbs (generally measuring the calf circumference) is related to poorer running economy⁵⁶⁻⁵⁸, leading to poorer performance on level or slightly sloping terrain, the results obtained herein show that this trend may be the opposite for races on sloping terrain. Vernillo *et al.*²⁴ reported that the power required for uphill terrain is greater than for level running given that, with the increase in the elevation profile, runners tend to run with a forefoot strike pattern²⁴, probably demanding more work from the ankle extensor muscles (gastrocnemius and soleus)⁵⁵. It is possible that these differences between level running and graded running can explain the contradictory results obtained when compared to previous studies. Along these same lines, previous studies have reported that the neuromuscular capacity could be a relevant performance factor in uphill races^{2,24}, a factor that could explain the relationship found between the calf circumference and the maximal and submaximal VO_2 values. In this regard, it could be of interest to determine whether the calf circumference is also related to performance in mountain races over the different distances.

Conclusions

The results obtained in this study, compared to previously published studies show that the fat % and the BMI of the short-distance trail runners appear to be lower than that of longer distance runners (>100 km). With regard to the physiological characteristics, the results obtained herein for the values for $\text{VO}_{2\text{max}}$, $\text{VO}_{2\text{VT1}}$ and $\text{VO}_{2\text{VT2}}$ are similar to those obtained in other studies with short-distance trail runners. However, the $\text{VO}_{2\text{max}}$ values of the runners taking part in this study, as well as those obtained in similar studies with short-distance runners, appear to be greater than those obtained for long-distance runners.

To the best of our knowledge, this is the first study to analyse the relationships between anthropometric characteristics and performance in a maximal continuous incremental incline test for short-distance amateur trail runners. It was observed that those study participants with a higher fat % and BMI achieved a lower Vel_{VT1} , lower t_{VT1} , lower RER_{VT2} and lower t_{VT2} , indicating that those runners with a higher fat % or BMI had a poorer submaximal performance with regard to the incremental incline test. Furthermore, significant positive correlations were observed between the between the calf circumference and $\text{VO}_{2\text{VT1}}$, $\text{VO}_{2\text{VT2}}$ and $\text{VO}_{2\text{max}}$. These results suggest that both fat % and BMI and the calf circumference could be determinant in performance in an incremental running incline test. Future studies, with a greater number of participants, could permit a multiple regression analysis and an in-depth study of the optimal combination of the different anthropometric variables in order to promote cardiovascular performance in standard laboratory-based incline incremental short-distance trail running tests.

Conflict of interest

The authors have no conflict of interest at all.

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