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EDUCATION & TRAINING

Use of Bioimpedianciometer as Predictor of Mountain Marathon Performance

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Abstract This study aimed to examine the relation among body composition, training experience and race time during a mountain marathon. Body composition and training pre-race experience analyses were conducted previous to a mountain marathon in 52 male athletes. A significant correlation between race time and mountain marathon with chronological age, body fat mass, percentage of body fat (BF), level of abdominal obesity, sport experience and daily training volume was revealed. In addition, BF and athlete's chronological age were negatively associated with race performance. In contrast, the daily training volume was positively associated with mountain marathon time. A regression analysis showed that race time could be predicted (R^2 = .948) by the daily training load, sports experience, age, body fat mass, BF and level of abdominal obesity. The comparison between performance groups regarding to body composition and training characteristics showed that the higher performance group was lighter with lower BF, fat mass and level of abdominal obesity, and with more days of training per week compared with the lower performance group ($p < .05$). Therefore, coaches and fitness trainers working with mountain marathon runners should develop exercise and nutritional strategies to reduce BF and consider increasing mean daily training volume to improve performance.

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Introduction

The association between athletes' anthropometric features and performance during an ultraendurance race has been mainly investigated in disciplines as swimming, cycling, triathlon and running [1, 2]. Specifically, in running events, depending on the distance and duration of the race, performance is influenced by several physiological, anthropometrical and training features [2]. Body mass was related with runners' performance [3] while body mass index (BMI), was related with marathon [4] and ultramarathon performance [1]. In addition, body fat percentage (BF) was shown to correlate with performance in elite runners in distances from 100 m to 10 km [5], marathon [6] and ultramarathon [7]. In contrast, Kenney and Hodgson [8] reported no association between BF and performance in a 5-km race. Conley & Krahenbuhl [9] also found that the sum of six skin folds was not related with performance in a 10 km race.

Another important factor related with running performance in endurance and ultraendurance races is the athletes' training background. In a 5-km race, peak running velocity during training was related with the athletes' performance [10]. Moreover, during a 10 km race runners with higher training frequency weekly training volume and longer running experience had higher performance [11]. Also, runners that trained more than 100 km per week presented faster race time over distances from 10 km to 90 km compared to athletes that trained less than 100 km per week [12]. During a marathon race training characteristics were the most important training factors related with performance [4]. In this line, top class marathoners trained more total km per week and with higher velocity compared with lower level marathoners [13]. In

longer probes as the 24 h ultra run race [14] and mountain ultramarathon [15], the personal best time in marathon was the most important feature related with the time probe.

Mountain races differ to other races conducted by ultraendurance runners, since specific technical characteristic of the mountain as the field and the elevation profile or the altitude, require different running race and nutrition intake strategies, as energetic and physiological demands are different to normal line ultraendurance races. Specifically, the physiological response of runners in mountain marathon is different than line marathon runners, due to the different nature of ground and environment, and the cumulative altitude involved in these races [16].

The association between anthropometric, training characteristics and performance has been previously investigated in different sport disciplines, but to the best of our knowledge no research has investigated the relation of these parameters with performance in a mountain marathon event. Thus, the aim of the present study was to investigate the association between anthropometric, training experience and race time in a mountain marathon and predict the race time in a mountain marathon with the most important anthropometric and training features of athletes.

Method

Participants

Fifty-two male athletes were volunteered for this study (Mean ± S.D.) age 38.3 ± 10.1 years, height 173.9 ± 6.5 cm, body mass 72.7 ± 9.9 kg, 12.9 ± 12.9 years practising sports, 7.8 ± 4.7 years of athletic training, 5.2 ± 2.8 days of training per week, 10.5 ± 8.7 weekly training hours and 87.2 ± 41.9 min of daily training. The experimental procedures were explained to all participants prior to the race, while all of them provided a written informed consent prior to the investigation in accordance with the Declaration of Helsinki.

The Race

Measurements were held on the first, and second "Pueblo de los Artesanos" mountain marathon held in Torrejoncillo (Spain). The event took place over a distance of 42.195 km with a 2147 m cumulative altitude change, of which 1070 m were downhill and 1077 m uphill. The race consisted of 23 km between 300 and 500 m altitude, 12 km between 500 and 700 m altitude and 7.2 km between 700 and 900 m altitude. The race started at 09:00 AM and, during the race, the temperature varied between 5 °C and 15 °C. Athletes took an average of 236.3 ± 41.6 min to cover the mountain marathon.

Body Composition Measurement

Four models were used to study body composition: (a) Level V – whole study: body mass (BM), height, body mass index and circumferences; (b) Level IV - tissues: fat mass (FM), fat-free mass (FFM) and BF; (c) Level III – cellular: intracellular and extracellular water; (d) Level II – molecular: water and protein. A bioimpedance analyser (InBody 720, Biospace Co. Ltd., Seoul, South Korea) was used for body mass measurement (to the nearest .1 kg). A portable stadiometer (SECA, Leicester, UK) and a caliper (Harpenden, West Sussex, UK) were used for the measurement of body height (to the nearest 1 cm). BMI was calculated as the quotient of body mass (kg) to height squared (m^2). FM and BF were assessed by bioimpedance analysis and FFM was calculated as FFM = BM - FM.

Bioimpedance Analysis

Body composition and body mass was assessed with a segmental multifrequency bioimpedance analyser (InBody 720, Biospace Co. Ltd., Seoul, South Korea) with measurements obtained as described by the manufacturer. InBody 720 is a multifrequency impedance body composition analyser, which uses an eight-point tactile electrode method to take readings from the body. It measures resistance at five specific frequencies (1 kHz, 50 kHz, 250 kHz, 500 kHz, and 1 MHz) and reactance at three specific frequencies (5 kHz, 50 kHz, and 250 kHz) on each of five segments (right arm, left arm, trunk, right leg and left leg). Bioelectrical-impedance analysis (BIA) is one of the methods available for measuring body composition in sporting populations and InBody provides a precise analysis for body development status and balance; analysis of items by segment and various body indexes are used as essential data for exercise prescription. Its simplicity, portability, cost, and subject acceptance make it a very desirable technique [17]. The reliability of BIA compared to other body composition measurement methods, like DEXA, has been successfully demonstrated [18].

In order to carry out the tests, the athletes stood upright on foot electrodes on the instrument platform, with legs and thighs apart and arms not touching the torso. They were barefooted and without excess clothing. Four foot electrodes were used, two of which were oval-shaped and two heel-shaped, and prior to testing both the skin and the electrodes were cleaned and dried. Athletes were asked to grip the palm and thumb electrodes (two of each electrode per athlete). The system was calibrated prior to the testing session. Body height was measured using a commercial scale. Data were electronically imported to Excel using Lookin'Body 3.0 software.

Circumference Measurements [19]

Arm, thigh and leg circumference was measured with a cloth tape fitted with a Gullick handle before the race. Upper leg

length was measured from the *trochanter major* to the *meniscus lateralis*, and lower leg length from the *meniscus lateralis* to the *malleolus lateralis*. The largest circumferences of the upper arm and calf were measured to the nearest .1 cm. Arm circumference was measured at the point midway between the acromial and olecranon processes, with the arm relaxed and hanging down at the side. To measure thigh circumference the tape was placed horizontally immediately distal to the gluteal furrow. It is recommended that body mass is shifted to the right leg and the thigh is tensed during this measurement. Chest circumference was measured on a horizontal plane at the end of expiration; the tape can be placed around the chest at the level of the fourth costosternal joint. The circumference of the abdomen was measured horizontally at the level of its greatest anterior extension. Measurement of the neck circumference was taken at a point just below the larynx (Adam's Apple) and perpendicular to the long axis of the neck. Hip circumference was measured by positioning the tape around the hips so that it passed over the greatest protrusion of the gluteal muscles (buttocks) as viewed from the side.

Training Diary

Upon inscription to the study, until the start of the race, the athletes were asked to maintain a comprehensive training diary recording training sessions showing distance and duration in the preparation for the race. The training record consisted of the years practicing sport, years practicing athletic, minutes of daily training, days of training per week and hours of training per week.

Statistical Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 17 (SPSS Inc., Chicago, Ill., USA). Bivariate correlation analysis between training and anthropometric parameters and probe time was performed using a Pearson product-moment correlation coefficient r. The following criteria were adopted to interpret the magnitude of correlations: $r \leq .1$, trivial; $.1 < r \leq .3$, small; $.3 < r \leq .5$, moderate; $.5 < r \leq .7$, large; $.7 < r \leq .9$, very large; and $r > .9$, almost perfect. Stepwise multiple regression analysis was then used to determine the variables correlated with the race time. Finally, participants were divided in two groups, higher performance and lower performance groups, depending on the probe time. A t test was performed between these two groups to analyze differences in the study parameters. The level of significance was set at $p < .05$.

Results

Data are presented as mean ± standard deviation. Anthropometric and training features of athletes are showed in Tables 1, 2 and 3. In the bivariate analysis (Tables 4 and 5), age,

Table 1 Athlete's anthropometrics characteristics

Parameter	Value
Age (years)	38.31 ± 10.01
Height (m)	1.73 ± .60
Body mass (kg)	72.70 ± 9.87
BMI (kg/m^2)	23.99 ± 2.66
Fat mass (kg)	12.09 ± 4.71
BF (%)	16.42 ± 5.13
Level of abdominal obesity	.86 ± .04
Intracellular water (l)	27.81 ± 3.50
Extracellular water (l)	16.53 ± 2.23
Proteins mass (kg)	12.01 ± 1.50
Mineral mass (kg)	4.24 ± .53
Total body water (l)	44.33 ± 5.71
Skeletal muscle mass (kg)	57.09 ± 7.32
Free fat mass (kg)	60.61 ± 7.75
Right arm muscle mass (kg)	3.31 ± .60
Left arm muscle mass (kg)	3.28 ± .60
Trunk muscle mass (kg)	26.03 ± 3.47
Right leg muscle mass (kg)	9.21 ± 1.28
Left leg muscle mass (kg)	9.20 ± 1.25

BMI body mass index, *BF* body fat percentage

FM, BF and level of abdominal obesity were significantly related to race time and training features of years practicing sports and minutes of daily training were also related to race time (Table 6).

Multivariate analysis is showed in Table 7. When all significant variables after bivariate analysis were entered into a regression model, race time of 'Maraton de los Artesanos' might be predicted by the following equation ($R^2 = .948$):

Race time (min) = 979.79–.227 (daily training, min) - .629 (sports practicing experience, years) - 2.716 (age, years) + 5.010 (FM, kg) + 7.292 (BF, %) – 1156.903 (level of abdominal obesity).

The results of the comparison between performance groups (Table 8) with regards to body composition and training characteristics agreed with the correlation analysis. The higher performance group was lighter with lower BF, FM and level

Table 2 Athlete's corporal circumferences

Parameter	Value
Neck circumference (cm)	36.13 ± 2.54
Chest circumference (cm)	98.14 ± 7.40
Abdominal circumference (cm)	80.53 ± 6.93
Hip circumference (cm)	95.05 ± 5.94
Right arm circumference (cm)	30.98 ± 2.76
Left arm circumference (cm)	30.87 ± 2.73
Right leg circumference (cm)	51.61 ± 3.08
Left leg circumference (cm)	51.77 ± 3.16

Table 3   Athlete's training characteristics

Parameter	Value
Years practising sports	12.94 ± 12.92
Minutes of daily training	85.44 ± 44.37
Years practising athletic	7.81 ± 4.71
Days of training per week	5.63 ± 2.00
Hours of training per week	10.75 ± 7.78
Mountain marathon time (min)	239.50 ± 46.89

of abdominal obesity, and with more days of training per week than the lower performance group ($p < .05$).

Discussion

The aim of the current research was to study the association among body composition, training experience and sport performance in mountain marathon runners, and predict the race time from the most important body composition and training features of athletes. The main findings of the present study were that (a) the race time in mountain marathon was positively related to BF and negatively related to daily training volume, (b) the race time could be predicted ($R^2 = .948$) by daily training load, sports experience, age, FM, BF and level

Table 4   Athletes's anthropometric variables and their correlation with race time

Parameter	r	p
Age	.502	.002
FM	.632	.000
BF	.754	.000
Level of abdominal obesity	.482	.005
Intracellular water	-.195	.285
Extracellular water	-.121	.511
Proteins mass	-.194	.288
Mineral mass	-.124	.500
Body total water	-.167	.361
Skeletal muscle mass	-.174	.342
Free fat mass	-.170	.351
Right arm muscle mass	-.164	.371
Left arm muscle mass	.063	.731
Trunk muscle mass	-.126	.494
Right leg muscle mass	-.224	.218
Left leg muscle mass	-.126	.492
Height	-.103	.574
Corporal weight	.167	.362
BMI	.283	.117

FM fat mass, *BF* body fat percentage, *BMI* body mass index

Table 5   Athletes's circunferences variables and their correlation with race time

Parameter	r	p
Neck circumference	-.052	.808
Chest circumference	.045	.833
Abdominal circumference	.584	.164
Hip circumference	.287	.175
Right arm circumference	.160	.454
Left arm circumference	.166	.439
Right leg circumference	.129	.550
Left leg circumference	.149	.488

of abdominal obesity and (c) runners with higher performance in the mountain marathon presented lower body mass index, level of abdominal obesity, BF, FM, body mass and a higher number of days of training per week.

As in other ultraendurance events as tripe-ironman and deca-ironman the age of participant was inversely correlated with probe performance [20]. The higher performance in the mountain marathon was obtained with aged between 27 to 36 years. This result was similar to the study of Leyk et al. [21], who found that peak endurance performance was maintained until the age of 30 to 35 years, followed by a moderate decline until the age of 50 to 60 years, and then a progressively steeper decline after the age of 70 to 75 years, independent of the length of the performance and the kind of the discipline.

The highest correlation coefficient in the study variables was observed between race time and BF. A similar trend was recorded for FM and level of abdominal obesity, too. An interpretation for the above-mentioned relationship might be that FM is an extra load that must be carried by runner over a long distance. Previous studies have revealed contradictory findings about the relationship between race time and FM. For instance, the positive correlation between FM and time probe in the mountain marathon was measured in a 161 km ultra-marathon trail [7]. By contrary, this parameter was not related with performance in a 100 km ultra-marathon [14], 24 h ultra-marathon [22] and 100 km skating probe [23]. This fact could be explained due to athletes in these ultraendurance events presented a very low FM due to the demands of training and

Table 6   Athlete's training characteristic and the correlation with race time

Parameter	r	p
Years practising sports	-.467	.007
Minutes of daily training	-.527	.002
Years practising athletic	.067	.717
Days of training per week	-.242	.183
Hours of training per week	-.219	.230

Table 7 Multivariate analysis with race time as the dependent variable

	Unstandardized coefficients		Standardized coefficients	t	p
	B	SE	ß		
Years practising sports	-.629	.486	-.173	-1.294	.207
Minutes of daily training	-.227	.128	-.215	-1.767	.090
Age	2.716	.823	.580	3.301	.003
FM	5.010	3.693	.503	1.356	.187
BF	7.292	2.977	.797	2.449	.022
Level of abdominal obesity	-1156.903	304.919	-.920	-3.794	.001

$R = .894$, $R^2 = .798$, adjusted $R^2 = .750$, standard error of estimate $= 23.063$, F $= 16.498$, $p = .000$

FM fat mass, *BF* body fat percentage

ultraendurance probe. Also, the influence of FM in performance of shorter ultraendurance probe as mountain marathon, in contrast to longest probes, could be explained since in mountain marathon variables highly influenced by body weight as maximal oxygen uptake, energy cost and energy expenditure of athletes [24] have a higher influence on performance than on longer probes, where other factors as thermoregulation, fat and protein metabolism or hepatic and muscular glycogen stores have higher influence [25].

The volume of training sessions has been one of the training factor that showed a significantly correlation with mountain marathon performance. Runners with longest daily training sessions reached a better time probe. Also, Hewson and Hopkings [26] found a correlation between seasonal mean weekly duration of moderate continuous running in longer distances athletes. As well, the longest volume of training per session was the best predictor of a successful completion of a marathon [12]. The correlation between training volume and performance could be explained because of the high training volume is necessary to obtain physiological adaptations in aerobic and anaerobic threshold [25, 27]. In the same line, Knechtle et al. [12] found a correlation between higher volumes of training and performance in 100 km ultramarathon. In contrast, other studies have showed how training velocity and probe time in shorter ultraendurance event than in the probe analyzed correlated with the probe time [28, 29], also training with lower volume and an incremental distribution of aerobic workload obtain higher

improvements in aerobic performance [30–32]. Other factors as the intensity and periodization of training workloads could also affect the performance in aerobic probes [33–35], therefore, would be interesting to analyze these parameters coupled with the volume of training for future investigations.

The popularity of mountain trails is increasing and few studies have focused on analysing the most important factors related with performance in these ultraendurance events. Specifically, in mountain marathon, both anthropometric and training factors were related with higher performance. Lower level of BF and abdominal obesity and higher volume of daily training were related with mountain marathon performance. Corroborating these data, the comparison between higher and lower performance runners also showed that higher performance runners had lower BF, FM, body mass and trained more days per week, then the combination of low body mass, low BF and high volume of training are the most important parameter related with performance in mountain marathon. These results could help coaches of mountain marathon runners to develop more specific training and obtain a correct body composition of runners to improve their performances in ultraendurance mountain events.

From the current data, it is possible to conclude that in a mountain marathon BF and athlete's age were negatively associated with race performance, by contrary higher volume of daily training were positive associated with mountain marathon performance.

Table 8 Parameters that presented significant differences between the higher and lower performance groups

Parameter	Higher performance group	Lower performance group	t	p
Years practicing sports	9.1 ± 4.0	16.8 ± 16.7	-2.170	.035
Days of training per week	6.4 ± 2.3	4.9 ± 1.2	2.856	.007
FM (kg)	8.5 ± 1.8	15.6 ± 3.7	-8.344	.000
Body mass (kg)	69.0 ± 8.7	76.4 ± 9.3	-2.826	.007
BF (%)	12.5 ± 2.2	20.4 ± 3.7	-9.015	.000
Level of abdominal obesity (a. u.)	.84 ± .02	.88 ± .04	-3.938	.000
BMI (kg.m^{-2})	22.5 ± 1.5	25.3 ± 2.7	-4.164	.000

FM fat mass, *BF* body fat percentage, *BMI* body mass index

Practical Application

Simple instruments as bioimpedianciometer and training diaries could be an important tool for coach to improve athlete's performance. They could focus the nutritional and training periodizations according to the present data to made training more efficient.

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