



ORIGINAL ARTICLE

A comparison of anthropometric characteristics and somatotypes in a group of elite climbers, recreational climbers and non-climbers



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Abstract Sport climbing has become a very popular and competitive sport. Despite growing interest in the research of climbing, there is still scant evidence regarding the adaptations it produces in the anthropometric characteristics of climbers. The objective of this study was to provide descriptive data about the anthropometric and somatotype characteristics of a group of elite and recreational climbers and compare them with a group of healthy non-climber volunteers. Twelve elite climbers (9 males and 3 females), 10 recreational climbers (7 males and 3 females), and 10 healthy non-climbers (6 males and 4 females) were assessed. Body mass, height, body mass index (BMI) and anthropometric measurements were used to obtain body fat percentage (BF%) and somatotype according to the Heath-Carter protocol. We found that females and males elite climbers (EC) have a significantly lower BF% and endomorphic component ($p < 0.05$) than non-climbers (NC). EC males also showed a significantly lower ($p < 0.05$) BMI than NC males. No differences were found between the anthropometric characteristics of EC and recreational climbers (RC); however, the EC had significantly higher mean results ($p < 0.05$) in climbing ability level and years of experience. The mesomorphic component was dominant in both groups of climbers. We concluded that EC, both males and females, are thin individuals with a predominance of musculoskeletal development, significantly less endomorphic characteristics, more ectomorphic characteristics and a lower BF% than the general population. © 2017 Universidad Autónoma de Nuevo León. Published by Masson Doyma México S.A. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

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Introduction

Sport climbing has developed into a mainstream competitive sport and the number of participants has increased significantly since the 1970s.^{1,2} In August 2016, the International Olympic Committee approved its inclusion in the Olympic Games in Tokyo 2020. It is a sport that is evolving at an accelerated rate and with the development of safety measures there has been an enormous increase in the difficulty of the routes,³ making it more challenging for climbers to attain a high level of performance.

It is well known that athletes' body composition tends to differ from the general population and from other athletes who practice a different sport.⁴ Gualdi-Russo and Zaccagni⁵ stated that body shape and size are important variables, among others, that can influence an athlete's success. The identification of the body composition and somatotype of elite athletes may serve as a guide for planning and monitoring athletic training and talent selection in a certain sport.^{6–8} Since the sport of climbing has become more popular, there has been an increase in research in this area. However, there is still scant scientific evidence on the somatotype of these athletes, and no consensus has been reached as to which physiological and anthropometric factors are important in determining climbing performance.¹

Several studies have examined specific physical characteristics associated with high standard performance in the sport,^{1,9–11} since there is evidence that body characteristics play an important role in determining high sporting performance.^{4,12} Watts et al.¹⁰ reported that body fat percentage (BF%) and strength to body mass ratio best predicted climbing performance. They concluded that elite climbers were extremely lean athletes with extremely low estimated BF% (4.7% and 10.7% for males and females, respectively), with a small stature and a high strength to body mass ratio. Grant et al.⁹ found that elite climbers differed from recreational climbers and active non-climbers on shoulder girdle endurance, finger strength and hip flexibility. However, they found no differences in body mass, height, height:body mass ratio, BF%, arm length, and leg length. Elite male climbers in the study by Grant et al. had a greater BF% (14%) than those in the study by Watts et al., Mermier et al.,¹ reported an average BF% of 9.8% and 20.7% in male and female sport climbers. Viviani and Calderan⁴ analyzed a group of top free climbers and reported a low BF% (8.3%) and an average mesomorph–ectomorph somatotype.

Since there is still little scientific information regarding the adaptation that this activity produces in the anthropometric characteristics and somatotypes of climbers, our aim was to provide descriptive data of elite and recreational climbers and compare them with an age-matched healthy non-climbing group.

Material and methods

Twenty-three experienced climbers from two local climbing organizations volunteered for this study (17 males and 6 females). They were separated into two groups based on their self-reported climbing ability.

We defined climbing ability as the most difficult self-reported ascent rated on the Yosemite decimal system (YDS)

performed by lead climbing in the two years previous to the study. In order to calculate means we used the modified YDS scale, which assigns a numerical value to replace the letter grades. Letter subdivisions of the YDS were assigned values of $a=0.00$, $b=0.25$, $c=0.50$, and $d=0.75$.¹¹ Climbers who had lead climbed a route that was rated at least 13a by the YDS scale were categorized as elite climbers (EC) and the rest were categorized as recreational climbers (RC).

Based on these criteria, 12 climbers were EC (9 males and 3 females) and 10 were RC (7 males and 3 females). The climbers were compared to a control group made up of 10 healthy non-climber (NC) volunteers (6 males and 4 females) who did not perform any sport that demanded upper limb efforts on a regular basis.

Ethical approval was obtained from the Research Ethics Committee of the School of Medicine of the Universidad Autonoma de Nuevo Leon. Prior to the study, each volunteer provided written informed consent after receiving an oral and written description of the procedures that would be performed.

Participants were scheduled for testing on an individual basis. All participants were evaluated in a resting state and were previously instructed not to perform strenuous exercise at least one day before the study. All measurements were performed by a single investigator. Standing height was recorded using a SECA wall-mounted measuring tape (SECA m.206, Seca GmbH & Co. KG, Hamburg, Germany) with the participant barefoot and with their back against a vertical wall, registering to the nearest 0.1 cm. Body mass was measured with a body composition analyzer (InBody 3.0 SN, InBody Co., Seoul, Korea). Body mass index (BMI) was calculated by dividing the mass by the height squared.

All participants underwent anthropometry using the restrained profile established by the International Society for the Advancement of Kinanthropometry (ISAK). Skin fold thickness was measured to the nearest 0.5 mm at eight sites (biceps, triceps, subscapular, iliac crest, supraspinal, abdominal, anterior thigh and medial calf) with a calibrated Slim Guide Skinfold Caliper (Creative Health Products, Inc., Ann Arbor, MI) (constant pressure 10 g/mm²) on the participant's right side; circumferences (relaxed arm, flexed arm, waist, hips and calves) were measured using a Lufkin metallic tape (model W696PM, Apex Tool Group, Sparks, MD), and two bone breadths (bicipondylarhumerus and femur) were measured with a CESCORF sliding bone caliper (INNOVARE 16 cm). In order to calculate the percentage of body fat, we used the Durnin and Womersley formula¹³: $\text{Density} = c - m \times \log(\text{folds})$; where c and m are constants determined by gender and age and which were previously calculated by the authors. The logarithm is calculated from the sum of the thickness of four skin folds (biceps, triceps, subscapularis, and supra-iliac).

Once the anthropometry measurements were collected, somatotype components were calculated according to the Heath and Carter anthropometric somatotype method.¹⁴ The following mathematical equations were made in order to obtain the three components of the somatotype:

Endomorphy: $-0.7182 + 0.1451(x) - 0.00068(x^2) + 0.0000014(x^3)$ in which x is the sum of the triceps, subscapular, and supraspinale folds, multiplied by (70.18/height in cm).

Table 1 Anthropometric and demographic characteristics of the population (mean $\pm$ SD).

Characteristic	EC (n = 12)		RC (n = 10)		NC (n = 10)	
	♀	♂	♀	♂	♀	♂
Age (years)	26.33 $\pm$.08	27.44 $\pm$ 5.88	25.67 $\pm$ 2.52	31.14 $\pm$ 6.77	24.25 $\pm$ 2.22	26.83 $\pm$ 4.62
Body mass (kg)	52.1 $\pm$ 9.26	63.81 $\pm$ 7.9*	48.93 $\pm$ 2.78	70.90 $\pm$ 5.3	66.28 $\pm$ 10.9	74.67 $\pm$ 4.4
Height (m)	1.61 $\pm$ 0.06	1.75 $\pm$ 6.07	1.53 $\pm$ 0.02	1.76 $\pm$ 6.06	1.61 $\pm$ 0.04	1.74 $\pm$ 0.07
BMI (kg/m ²)	20.13 $\pm$ 2.2	20.86 $\pm$ 2.0*	21.32 $\pm$ 0.7	22.98 $\pm$ 1.5	25.4 $\pm$ 3.2	24.84 $\pm$ 2.7
BF%	13.60 $\pm$ 8.0*	9.16 $\pm$ 3.0*	21.77 $\pm$ 0.9	10.7 $\pm$ 4.0*	30.7 $\pm$ 6.6	20.9 $\pm$ 6.4

EC, elite climbers; RC, recreational climbers; NC, non-climbers; ♀, female; ♂, male; BMI, body mass index; BF%, body fat percentage.

* Significantly different from the non-climbers group ($p < 0.05$).

Mesomorphy: $(0.858 \times H) + (0.601 \times F) + (0.188 \times B) + (0.161 \times P) - (0.131 \times E) + 4.5$, where H is the biepicondilar breadth of the humerus, F is the bicondilar breadth of the femur, B is the flexed arm circumference, P is the perimeter of the calf, and E is height.

Ectomorphy: for this parameter, there are three formulas based on the weight index, which were the result of the formula $WI = \text{Height} \sqrt{\text{Weight}}$

If $WI \geq 40.75$, the formula was $0.732 \times WI - 28.58$;

If $WI < 40.75$ but > 38.25 , the formula was $0.463 \times WI - 17.63$;

and if $WI \leq 38.25$, the given value was 0.1.

Statistical analysis

Descriptive statistics for all variables was performed. Inferential statistics to confirm the normality of the data was performed using the Kolmogorov–Smirnov test. Depending on the results, comparisons were performed using the two-tailed Student's t -test and ANOVA for parametric data, and the Mann–Whitney and Kruskal–Wallis tests for nonparametric data. The sequential Bonferroni correction with a significance level of .05 was used for multiple comparisons. A p value of ≤ 0.05 was considered statistically significant. SPSS version 20 (IBM, Armonk, NY) for Windows 7 was used.

Results

We observed that there were no significant differences in gender distribution or age when the three groups were divided by gender and compared. When comparing the other variables, we found that EC females had a significantly lower BF% than NC females ($p < 0.05$). EC males had a significantly lower BF%, lower BMI, and lower body mass

than NC males ($p < 0.05$). RC males had a significantly lower BF% than NC males ($p < 0.05$). There were no significant differences when comparing the EC and the RC group for both males and females. The participants' anthropometric and demographic characteristics are shown in Table 1.

We observed that both male and female EC had a significantly higher mean ability and years of climbing experience than their male and female counterparts in the RC group ($p < 0.05$). Mean days of training per week were significantly higher for the male EC than for the RC group over the previous 2 years ($p < 0.05$). The mean and SD of the self-reported training variables for both climbing groups are shown in Table 2.

The EC female group revealed an average ectomorphic-mesomorph somatotype; the RC and the NC female groups showed a mesomorph-endomorph category and a mesomorphic-endomorph category, respectively. The EC male group revealed an average ectomorphic-mesomorph category; the RC male group showed a balanced mesomorph category, and the NC male group showed a mesomorph-endomorph category. Somatotype means among the three climbing groups are specified in Table 3.

Endomorph and ectomorph somatotype components were significantly different between the female study groups. We found that the endomorphic component was significantly lower ($p < 0.05$) and the ectomorphic component significantly higher ($p < 0.05$) in the EC group vs the NC group. Regarding the male groups, we observed that the endomorphic component was significantly lower ($p < 0.05$) in the EC and RC groups compared to the NC group and the ectomorphic component was significantly higher ($p < 0.05$) in the EC compared to the NC group. We did not find any differences between the three groups in the mesomorphic component.

Mesomorphy was the dominant somatotype component for the EC and RC in both male and female groups. For the

Table 2 Self-reported training variables (mean $\pm$ SD).

Variable	EC (n = 12)		RC (n = 10)	
	♀	♂	♀	♂
Climbing ability in the modified YDS scale	13.5 $\pm$ 0.5*	13.72 $\pm$ 0.3*	11.6 $\pm$ 0.7	12.42 $\pm$ 0.8
Climbing experience (years)	13.3 $\pm$ 3.2*	6.8 $\pm$ 4.5*	3 $\pm$ 1	3.1 $\pm$ 1.2
Climbing sessions (days/week)	4 $\pm$ 1	4.8 $\pm$ 0.9*	3.6 $\pm$ 0.5	4.0 $\pm$ 0.5
Climbing duration (hours/session)	2.6 $\pm$ 0.5	2.7 $\pm$ 0.4	2.6 $\pm$ 0.5	2.6 $\pm$ 0.3

EC, elite climbers; RC, recreational climbers; ♀, female; ♂, male; YDS, Yosemite decimal system.

* Significantly different from recreational climbing group ($p < 0.05$).

Table 3 Somatotype components (mean $\pm$ SD).

	EC (n=12)		RC (n=10)		NC (n=10)	
	♀	♂	♀	♂	♀	♂
Endomorphy	2.0 $\pm$ 1.1*	1.5 $\pm$ 0.4*	3.9 $\pm$ 0.6	2.3 $\pm$ 0.9*	5.8 $\pm$ 1.8	5.0 $\pm$ 1.7
Mesomorphy	3.6 $\pm$ 0.3	4.3 $\pm$ 0.9	4.1 $\pm$ 0.1	5.0 $\pm$ 0.8	4.5 $\pm$ 0.8	5.1 $\pm$ 1.1
Ectomorphy	3.0 $\pm$ 0.8*	3.5 $\pm$ 1.1*	1.8 $\pm$ 0.2	2.5 $\pm$ 0.9	1.0 $\pm$ 0.6	1.8 $\pm$ 1.4

EC, elite climbers; RC, recreational climbers; NC, non-climbers; ♀, female; ♂, male.

* Significantly different from the non-climbers group ($p < 0.05$).

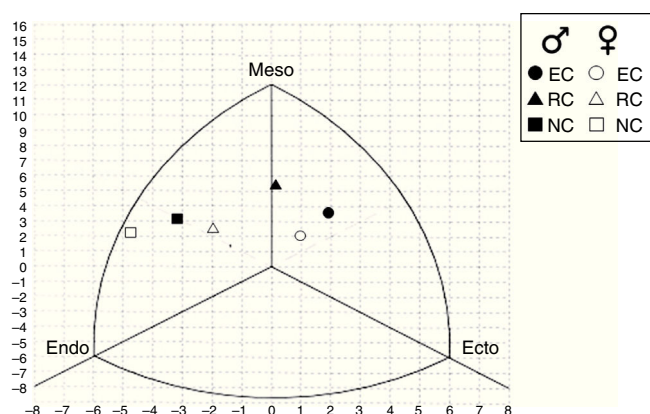


Figure 1 Somatotype chart with the mean somatotype values of the elite and recreational climbing groups and the non-climbing group. EC, elite climbers; RC, recreational climbers; NC, non-climbers; ♀, female; ♂, male.

NC female group, the dominant somatotype component was endomorphy, while in the NC male group it was mesomorphy. The dominance of each component can be seen in the somatotype chart (Fig. 1), where the mean somatotype values for each group are plotted. We can see that NC groups are the most distant of the three males and female groups; they are closer to the endomorphic component, while the EC groups are closer to the ectomorphic component.

Discussion

Despite the growing interest in climbing research, there is still scant evidence about the anatomic adaptations that the sport induces in climbers, and little is known about the anthropometric factors that determine climbing performance.¹ The objective of this study was to provide descriptive data on the anthropometric characteristics and the somatotype among elite climbers, and to compare the results with a group of recreational climbers and non-climbers. In our study, we found differences among these variables between the three study groups.

Mean BMI results revealed that our group of NC females were slightly overweight according to WHO cutoff values.¹⁵ Considering that they were mostly sedentary volunteers, this finding is consistent with the results of the most recent National Health and Nutrition Survey in Mexico, which states that 69.4% of Mexican males and 73% of Mexican females are overweight or obese.¹⁶ Mean BMI for both climbing groups was similar, and both groups showed a normal nutritional status.¹⁵

Several authors have focused on which anthropometric characteristics influence climbing performance. When comparing our results with those in the literature, we observed that the BF% of our EC sample was similar to what has been reported. The EC in the study by Watts et al. had, on average, a lower BF% and a lower ability level in the YDS scale than the climbers in this study.¹⁰ It is important to mention that in the study by Watts et al. the sample of climbers was recruited at an international-level climbing competition. As expected, the athletes had prepared themselves rigorously for the event, so at the time of the study they were at their top level. On the other hand, our sample, despite being recruited in the winter season which is considered the most appropriate season for climbing in the local area, was not preparing for any particular event, so their dietary regimen might not have been so strict.

The climbers in the study by Mermier, et al. had very similar results to our study; their male climbers group had a slightly lower BF% than the EC of our study and the female climbers had a greater BF% than that found in our EC. It should be noted that the average level of climbing ability of their sample was well below the level of our EC; considering this variable and that of the BF% we realized that even though our EC had a very high skill level, their BF% was not as low as what might be expected by their performance level.¹

Watts et al.¹⁰ observed that their elite climbers shared common anthropometric characteristics such as a small stature and low BF%. However, they concluded that these factors were not necessarily required to attain a high level of climbing performance. Although Mermier et al.¹ found BF% as a predictor of climbing ability, they also concluded that it was not the anthropometric characteristics that significantly explained climbing ability. This was explained by the training component. Our findings support their conclusions, since the training variables of our two climbing groups were significantly different, and the anthropometric characteristics were not.

Grant's⁹ study of elite and recreational climbers did not find any significant differences in age, body mass, height and BF% between EC and RC groups. This is consistent with our results, however, our group of EC did show a tendency to be taller, lighter, and with a lower BMI and BF% than RC.

Viviani and Calderan's⁴ top-level European free climbers and Barbieri's¹⁷ Italian climbers had a dominant mesomorphic component. According to Viviani and Calderan, the fact that climbers show a greater relative muscle mass is an advantage that helps them initiate and sustain movements on the wall. Both of our climbing groups reflected a predominant musculoskeletal development in their somatotype evaluation.

As we expected, the EC in our study, both males and females, showed greater leanness than adiposity and a low endomorphic component. It is well-known that fat adds unnecessary weight for climbers during ascent. This causes them to use additional energy and speeds the onset of fatigue.⁴

Unlike the EC, the males' RC's adiposity and linearity components were similar. The RC females demonstrated a mesomorph–endomorph somatotype category, which implies that endomorphy and mesomorphy are equal, and ectomorphy is smaller.¹⁴

Although it was not significantly different, ECs had a tendency to show the lowest endomorphic and the highest ectomorphic component. This result may have been influenced by training-related anthropometric components such as muscle hypertrophy and body fat.¹ The greater experience and training time that EC reported compared to RC could explain these differences.

This study focused on male and female climbers who were recruited at local gymnasiums, although all of our athletes regularly practiced sport climbing, some of them were more specialized in boulder competition. The results among the two specialties within this sport might be different, but to assess such diversity was beyond our objectives. Further investigation is warranted to better define the somatotype and anthropometric characteristics particular to each climbing specialty.

We concluded that, according to their somatotype classification, ECs, both males and females, are lean participants with a predominant musculoskeletal development. They are significantly less endomorphic, more ectomorphic and with a lower BF% than the general population, and are more experienced than RC. However, they do not necessarily differ from RC in anthropometric characteristics such as body mass, height, BMI, and BF% or in somatotype components.

This study agrees with the anthropometric profile of elite climbers described by other authors. This information may be useful to design training programs and evaluate an athlete's progress.

Ethical disclosures

Protection of human and animal subjects. The authors declare that the procedures followed were in accordance with the regulations of the relevant clinical research ethics committee and with those of the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Confidentiality of data. The authors declare that they have followed the protocols of their work center on the publication of patient data.

Right to privacy and informed consent. The authors have obtained the written informed consent of the patients or subjects mentioned in the article. The corresponding author is in possession of this document.

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Conflict of interest

The authors have no conflicts of interest to declare.

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