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Anthropometric Parameters and Body Composition in Elite Lead Climbers and Boulderers—A Retrospective Study

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Abstract: Based on previous research studies and systematic reviews, success in sport climbing seems to be determined by variables such as strength, power, or endurance. However, besides strength-endurance parameters, several other factors may influence the performance of sports climbing. Moreover, there is a lack of research assessing differences in body composition and anthropometric parameters between lead climbing and bouldering—the two most common sport climbing subdisciplines. The presented research analyzed the connection between body mass, body height, body mass index, and the best result in sport climbing among male lead climbers and boulderers. Additionally, we investigated differences in starting climbing age and climbing experience in both climbing subdisciplines. We analyzed 422 male sport climbers' profiles in two categories: "Route Ranking: Top-10 climbs last 12 months" for lead climbers and "Boulder Ranking: Top-10 climbs last 12 months" for boulderers based on the 8a.nu world ranking website. The results showed that the "Elite" and "Higher Elite" lead climbers had lower body mass and lower body height. These differences were also observed between "Elite" and "Higher Elite" lead climbers. The "Higher Elite" group started climbing at a younger age and had a more extended period to achieve the most challenging route than "Elite" climbers in both subdisciplines. Our results suggest that lower body mass and lower body height can be key factors in lead climbing performance.

Keywords: sport climbing; lead climbing; bouldering; body composition; anthropometry

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1. Introduction

Over the last few decades, a significant increase in interest in sports climbing has been observed [1]. It is a relatively young sport discipline included in the Tokyo 2020 Olympic Games program [2]. The subdisciplines of sports climbing presented in Tokyo were lead climbing, bouldering, and speed climbing. The first two subdisciplines are the most frequently trained sport climbing styles [2–4]. There are many differences between bouldering and lead climbing regarding the length of the climbing route, belaying methods, and the nature of physical effort. In bouldering, the climber ascends short technical boulder routes up to 4–5 m on low walls using crash mats instead of ropes [4,5]. The climbing routes in lead climbing are much longer (10 to 40 m) and, thus, contain more movements than in bouldering. In lead climbing, the climber is attached to a rope clipped into permanent bolts using "quickdraws", spaced intermittently from the bottom up [3–5]. Different forms of sport climbing require different sets of skills and physiological conditions [2]. Nevertheless, only a few previous research studies have compared the physical characteristics of sport

climbers between lead climbing and bouldering subdisciplines. Lead climbing is characterized by more static, slow, and controlled movements than bouldering [6]. Moreover, lead climbers are more capable of longer routes than boulderers, with a shorter climbing duration (30 s for bouldering vs. 2–7 min for lead climbing). On the other hand, bouldering routes are shorter, but the movements are performed with maximum effort [4,5]. This suggests that bouldering can be classified as a strength subdiscipline, while lead climbing is characterized by endurance effort [5]. Several studies showed that boulderers are characterized by higher explosive strength of the forearm muscles compared to lead climbers [6–8]. The differences between lead climbers and boulderers were also observed at the genetic level and concern the functional polymorphism of the ACTN3 gene, which, depending on the genotype, is associated with the strength or endurance of skeletal muscles [9].

According to the systematic review by Saul et al. [10], the anthropometric data connected with success in sports climbing are large bone-to-tip pulp associated with generating a higher lifting force, and great forearm volume is an indirect parameter of muscle mass. Moreover, in several research studies, body mass values differ significantly between sport climbers and controls [11,12]. However, differences in body mass and height can vary within the groups because the researchers tried to recruit subjects of similar age and body size to compare physiological parameters like strength and endurance. Therefore, this generates difficulty in interpreting this data type in studies analyzing other main motor and physiological parameters. Several studies showed differences in anthropometrical, physiological, and strength-endurance parameters between elite sport climbers, less advanced athletes, and controls [13]. However, so far, there are no studies comparing body composition, anthropometric parameters, or the age of peak performance between lead climbers and boulderers.

Thus, the present study investigated the relationship between age, climbing experience, and anthropometric data (body mass, body height) and the best result achieved by male sport climbers in bouldering and lead climbing in natural rock formations.

2. Materials and Methods

2.1. Participants

The analysis was carried out with the consent of the Bioethics Committee of the Medical University of Lublin (KE-0254/93/2020). For the study, the competitors' profiles from "www.8a.nu (accessed on 30 August 2020)" were analyzed in two categories: "Route Ranking: Top-10 climbs last 12 months" and "Boulder Ranking: Top-10 climbs last 12 months". The www.8a.nu website consists of volitional self-reporting data that serve as experimental variables. The first 500 profiles were analyzed in each category. The data are made public voluntarily and free of charge. The values of the ascent difficulty level have been adopted according to the recommendation of the International Rock Climbing Research Association (IRCRA) [14]. The rock-climbing ascent difficulty level values have been converted from the French scale for lead climbing and from the Font scale for bouldering to the IRCRA level [14].

The following exclusion criteria were applied: profile incompleteness (lack of at least one record in the athlete's profile), sports classification below the "Elite" level, and female sex due to the small number of female athletes in the "Elite" and "Higher Elite" categories included in the www.8a.nu ranking.

Based on the above criteria, 422 male profiles were qualified for the study. The "Route Ranking: Top-10 lead climbs last 12 months" category included 164 lead climbers (average age = 28 $\pm$ 8 years), 86 lead climbers in the "Elite" group (IRCRA = 26 $\pm$ 1), and 78 lead climbers in the "Higher Elite" group (IRCRA = 29 $\pm$ 1). In comparison, 258 boulderers (average age 27 $\pm$ 6) were qualified for the "Boulder Ranking: Top-10 climbs last 12 months" category, including 114 boulderers in the "Elite" group (IRCRA = 26 $\pm$ 1) and 144 boulderers in the "Higher Elite" group (IRCRA = 29 $\pm$ 1).

2.2. Procedure and Data Preparation

Four independent researchers conducted the data collection from the www.8a.nu ranking website. Two of them assessed athletes' profiles in lead climbing. The others assessed sport climbers' profiles in bouldering. After analysis of the athletes' profiles and initial qualification for the present research, the authors analyzed the qualified profiles among themselves. After double-checking the examination, the qualified athletes' profiles did not differ between the two independent studies. The extracted and examined parameters from the www.8a.nu ranking website included the hardest lead climbing route or boulder ascent in Red Point (RP) style, age when climbing the hardest route or boulder, years of climbing experience, body mass, and body height. After obtaining and checking the above-mentioned data, additional parameters were calculated. Body mass index (BMI) was calculated based on body height and body mass. The time to achieve the best climbing ascent was calculated based on the year of climbing the hardest route or boulder and the year of starting climbing based on the formula:

$$\text{The time to achieve} = \text{the year of the hardest climb} - \text{the year of starting climbing} \quad (1)$$

Based on the hardest route or hardest boulder ascent, the sport climbers were qualified for the "Elite" and "Higher Elite" groups according to IRCRA standards. The qualification of the athletes to one of the groups was carried out using the IRCRA scale, which is used to classify climbing routes for statistical calculations [14]. The "Elite" level for lead climbers was determined between 24 and 27 IRCRA points (between 8a+ and 8c on the French scale). The "Higher Elite" level for lead climbers was determined between 28 and 32 IRCRA points (between 8c+ and 9b+ on the French scale). The "Elite" level for boulderers was marked between 24 and 27 IRCRA points (between 7C and 8A+ on the Font scale). The "Higher Elite" level for boulderers was determined between 28 and 32 IRCRA points (between 8B and 8C+ on the Font scale).

2.3. Statistical Analyses

The analysis of the obtained results was performed as described below:

1. Comparison of the age of starting climbing, age when climbing the hardest route, time to achieve the hardest route, body mass, body height, and BMI between the "Elite" and "Higher Elite" groups in the lead climbing.
2. Comparison of the age of starting climbing, age when climbing the hardest route, time to achieve the hardest route, body mass, body height, and BMI between the "Elite" and "Higher Elite" groups in bouldering.
3. Comparison of the age of starting climbing, age when climbing the hardest route, time to achieve the hardest route, body mass, body height, and BMI between the "Elite" and "Higher Elite" groups between lead climbers and boulderers.
4. Comparison of the age of starting climbing, age when climbing the hardest route, time to achieve the hardest route, body mass, body height, and BMI collectively in the "Elite" and "Higher Elite" groups between lead climbers and boulderers.

Statistical analyses were performed using the IBM SPSS STATISTICS 21 program (IBM Corp., Armonk, NY, USA). The Shapiro–Wilk test and the Kolmogorov–Smirnov test (with the Lilliefors correction) were applied first to verify the normality of the distribution. When the distribution was close to normal, the ANOVA parametric test was used, and when it was non-normal, the non-parametric Kruskal–Wallis test was used. The level of significance was determined at $p < 0.05$.

3. Results

The results of the Shapiro–Wilk normality test in "the age of starting climbing" and "age when climbing the hardest route" in "Elite" and "Higher Elite" lead climbers were close to normal. Thus, the ANOVA parametric test was used. In other cases, the distribution deviated from normality. Therefore, the non-parametric Kruskal–Wallis test (×2) was used.

3.1. Lead Climbing vs. Boulderers

The comparison of the climbers in the "Elite" groups between the lead climbers and boulderers showed that the lead climbers started to climb at a younger age (14.3 ± 4.7 years vs. 16.3 ± 5.3 years; $p = 0.001$) and had a longer time to achieve the hardest route than boulderers (11.1 ± 4.8 years vs. 8.6 ± 5.1 years; $p = 0.001$) (Tables 1 and 2). The remaining parameters were not statistically significantly different ($p > 0.05$).

Table 1. Characteristics of sport climbers (mean values ± standard deviation).

Group	N	Age (Years)	Age of Starting Climbing (Years)	Body Mass (kg)	Body Height (cm)	BMI (kg/m^2)	IRCRA Scale Result	Time to Achieve the Hardest Route (Years)	Age When Climbing the Hardest Route (Years)
ELC	86	27.5 ± 7.2	14.3 ± 4.7	65.7 ± 9.1	175.5 ± 8.6	21.3 ± 2.3	26.6 ± 0.6	11.1 ± 4.8	25.4 ± 6.4
HELC	78	28.8 ± 8.2	12.5 ± 5.1	63.3 ± 8.4	173.3 ± 6.3	21.0 ± 1.9	29.1 ± 1.0	13.3 ± 5.3	25.8 ± 6.8
EB	114	26.4 ± 6.7	16.3 ± 5.3	66.5 ± 7.5	176.3 ± 7.3	21.3 ± 1.5	26.6 ± 0.6	8.6 ± 5.1	24.9 ± 6.3
HEB	144	27.0 ± 6.2	13.0 ± 4.7	66.8 ± 8.8	176.1 ± 7.6	21.5 ± 2.2	29.4 ± 1.0	12.2 ± 5.4	25.3 ± 5.8
AEC	200	26.9 ± 6.9	15.5 ± 5.1	66.1 ± 8.2	175.9 ± 7.9	21.3 ± 1.9	26.6 ± 0.6	9.7 ± 5.1	25 ± 6
AHEC	222	27.7 ± 7.0	12.8 ± 4.9	65.6 ± 8.8	175.1 ± 7.3	21.3 ± 2.1	29.3 ± 1.0	12.6 ± 5.4	25.4 ± 6.2
ALC	164	28.1 ± 7.7	13.5 ± 5.0	64.5 ± 8.8	174.4 ± 7.6	21.2 ± 2.1	27.8 ± 1.4	12.1 ± 5.2	25.6 ± 6.6
AB	258	26.8 ± 6.4	14.5 ± 5.3	66.7 ± 8.2	176.2 ± 7.5	21.4 ± 1.9	28.1 ± 1.6	10.6 ± 5.5	25.1 ± 6.0

ELC—elite lead climbers; HELC—higher elite lead climbers; EB—elite boulderers; HEB—higher elite boulderers; AEC—all elite climbers; AHEC—all higher elite climbers; ALC—all lead climbers; AB—all boulderers.

Table 2. Comparison between sport climbers' groups.

Subdiscipline	Sport Level	Age of Starting Climbing (p)	Body Mass (p)	Body Height (p)	BMI (p)	Time to Achieve the Hardest Route (p)	Age When Climbing the Hardest Route (p)
LC	E	0.016 * $x^2 = 5.911$	0.013 * $x^2 = 6.127$	0.008 * $x^2 = 7.111$	0.334 $x^2 = 0.934$	0.008 * $x^2 = 7.051$	0.735 $x^2 = 0.115$
	HE						
B	E	0.001 * $x^2 = 22.752$	0.929 $x^2 = 0.008$	0.722 $x^2 = 0.126$	0.821 $x^2 = 0.051$	0.001 * $x^2 = 33.550$	0.495 $x^2 = 0.466$
	HE						
LC	E	0.001 * $x^2 = 23.074$	0.797 $x^2 = 0.453$	0.877 $x^2 = 0.262$	0.581 $x^2 = 1.082$	0.001 * $x^2 = 35.503$	0.648 $x^2 = 0.869$
B							
LC	HE	0.081 $x^2 = 5.026$	0.008 * $x^2 = 7.065$	0.019 * $x^2 = 5.512$	0.170 $x^2 = 3.547$	0.002 * $x^2 = 9.597$	0.532 $x^2 = 0.532$
B							
LC	All	0.024 * $x^2 = 5.130$	0.008 * $x^2 = 7.065$	0.019 * $x^2 = 5.512$	0.054 $x^2 = 3.709$	0.002 * $x^2 = 9.597$	0.532 $x^2 = 0.532$
B							

LC—lead climbers; B—boulderers; E—elite climbers; HE—higher elite climbers; *—statistically significant difference.

The comparison of the "Higher Elite" climbers between lead climbers and boulderers showed that the lead climbers had lower body mass (63.3 ± 8.4 kg vs. 66.8 ± 8.8 kg; $p = 0.008$), lower body height (173.3 ± 6.3 cm vs. 176.1 ± 7.6 cm; $p = 0.019$), and a longer time to achieve the hardest route (13.3 ± 5.3 years vs. 12.2 ± 5.4 years; $p = 0.002$) in comparison with boulderers (Tables 1 and 2). The remaining parameters were not significantly different ($p > 0.05$).

The comparison of the collective groups "All Lead Climbers" and "All Boulderers" showed that the lead climbers started climbing at a younger age (13.5 ± 5.0 years vs. 14.5 ± 5.3; $p = 0.024$), had a lower mass (64.5 ± 8.8 kg vs. 66.7 ± 8.2; $p = 0.008$), lower height (174.4 ± 7.6 cm vs. 176.2 ± 7.5 cm; $p = 0.019$), and a longer time to achieve the hardest route (12.1 ± 5.2 years vs. 10.6 ± 5.5 years; $p = 0.002$) in comparison with the boulderers (Tables 1 and 2). BMIs and age at the time of climbing the most difficult route were not significantly different within all groups ($p > 0.05$) (Table 2).

3.2. Elite vs. Higher Elite Sport Climbers

When comparing the "Higher Elite" and "Elite" groups in lead climbing, the "Higher Elite" group started climbing at a younger age (12.5 ± 5.1 years vs. 14.3 ± 4.7 years; $p = 0.016$), had lower mass (63.3 ± 8.4 kg vs. 65.7 ± 9.1 kg; $p = 0.013$), lower height (173.3 ± 6.3 cm vs. 175.5 ± 8.6 cm; $p = 0.008$), and a longer climbing time to achieve the hardest route (13.3 ± 5.3 years vs. 11.1 ± 4.8 years; $p = 0.008$) (Tables 1 and 2).

When comparing the "Higher Elite" and "Elite" groups in bouldering, the "Higher Elite" group started climbing at a younger age (13.0 ± 4.7 years vs. 16.3 ± 5.3 years; $p = 0.001$) and had a longer climbing time to achieve the hardest route (12.2 ± 5.4 years vs. 8.6 ± 5.1 years; $p = 0.001$) (Tables 1 and 2). BMI and age at the time of climbing the most difficult route were not significantly different within all groups ($p > 0.05$) (Table 2).

4. Discussion

Due to the great interest in sports climbing, an increasing number of investigations are trying to prove which physiological and psychological parameters or training factors influence success in sports climbing subdisciplines. Training-modified parameters seem to be most important in shaping the climber's physical form [15]. However, anthropometric data can also influence sports climbing performance [10]. Therefore, the presented study aimed to analyze the relationship between age, climbing experience, anthropometric data, and the best result in sport climbing achieved by male sport climbers in bouldering and lead climbing.

In the presented study, a higher level of climbing performance was associated with starting training at an earlier age in lead climbing and bouldering. According to Myer et al. [16], initiating integrative neuromuscular training early in youth may help increase training abilities in the future and set the stage for even more significant gains in physical fitness during their post-pubertal years. However, the current literature lacks reports on the optimal age to initiate sport climbing training. Despite earlier reports suggesting that the level of sport climbing is mainly made up of variables that can be learned [15], the presented study showed that the lead climbers at the "Higher Elite" level had a lower body mass and lower height than the "Elite" lead climbers. Therefore, height and body mass may be important factors concerning the sport level among lead climbers. The possible mechanism of the influence of body mass on the climbing level in lead climbing may be associated with a longer period of effort during sports climbing. Since gravity is an important factor in climbing activity, lower body mass puts less gravitational force on the climber's body and enables them to exert prolonged efforts on the climbing wall. Thus, lower body mass during a longer time on the climbing wall can affect the slower fatigue of the athlete and result in better sports performance. Moreover, shorter climbers can be at a bit of an advantage in dynamic moves because they are forced to adapt to this issue earlier in their climbing progression. On the other hand, lower body mass may be less important than strength capabilities in the bouldering subdiscipline. Boulderers are often associated with greater muscle mass and, thus, with greater overall body mass. Moreover, boulderers are characterized by higher explosive strength than lead climbers, which also involves muscle and body mass [6–8]. Hence, lower body mass seems to be a more important factor in the lead climbing subdiscipline than in the bouldering subdiscipline, which is also confirmed by the results of this study. Moreover, lower body mass can relate to a lower body fat percentage, which has also been demonstrated in several research studies [13]. Body fat reduction may contribute to muscular and cardio-respiratory endurance as well as to the development of speed and agility, which can be essential for climbing performance [17].

The participants' BMI and age in none of the analyzed combinations reached statistical significance. The age at which the most difficult route was climbed was similar in all groups and was about 25 years. Thus, the age of peak performance in sports climbing is similar to that in other sports disciplines. The studies conducted by Ganse et al. note that the peak performance age is between 25 and 27 years in athletic disciplines [18]. Similar conclusions were reached by Haugen et al. on world-class track-and-field athletes [19]. However, the

age of elite competition climbers is lower since they enter world-level competitions at the age of 16. It can be because young elite sport climbers tend to climb in natural rock formations less nowadays and leave that type of climbing for a later age, after a competitive career. In addition, frequent training camps and a large number of climbing competitions, both national and international, do not allow for frequent rock climbing.

Moreover, the average BMI of sport climbers in the presented study was 21.00. This is consistent with the literature review carried out by Saul et al., in which the average BMI was 21.66 (n = 1610). Although Saul et al. indicate that low fat and large forearm volume were important features in successful sports climbing, there was no association between BMI and sports climbing achievements during lead climbing and bouldering [10]. On the other hand, a lower BMI may be a prophylactic factor for climbing injuries. According to Lion et al., a BMI above 21 will predispose to injuries of the flexor tendon pulleys in the fingers [20].

The presented results confirm the assumptions of the studies by Laffaye et al., postulating that success in sport climbing is influenced by both training factors and anthropometric variables [21]. However, the authors emphasize that the training component explained 46% of the total variance, while anthropometric variables explained only 4%. Moreover, the previously indicated studies do not answer the question of which anthropometric features differentiate sport climbers at different levels of advancement. Thus, it suggests the need for long-term observation of sports climbers from an early age to their senior career.

The lead climbers had a longer time to achieve the most challenging route than the boulderers in both "Elite" and "Higher Elite" groups. This may be because lead climbing is a less force-dependent subdiscipline than bouldering. Moreover, the effort in lead climbing is based more on the endurance parameters of the sport climber. Peak endurance performance is maintained until 35 years of age, followed by modest decreases until 50–60 years of age [22]. On the other hand, skeletal muscle power starts declining after the age of 30, which can affect bouldering performance in older athletes [23].

The presented research has several practical applications. Our results provide an innovative insight into the performance analysis of world-class sport-climbing athletes. Previously, no study had analyzed anthropometric and body composition parameters on such a large group of the best sports climbers in the world. It may be helpful for athletes, coaches, and sports clubs to set realistic goals and evaluate their success strategies in sports climbing subdisciplines, especially within lead climbing and bouldering. The comparison between the lead climbers and boulderers showed that the lead climbers started to climb at a younger age and had a longer time to achieve the most challenging route than the boulderers. This may indicate the need for the early specialization of sport climbers in the lead climbing subdiscipline. The observations also provide a starting point for future research to explore the mechanisms underlying maximum climbing performance development, considering anthropometric parameters in sport climbers. Hence, future research observing the development of young sport climbers in terms of specialization in particular subdisciplines should be conducted, considering anthropometric, physiological, and psychological data.

The presented study has several limitations. Firstly, the results obtained are based on data from the www.8a.nu rank website, which consists of self-reported data. The research parameters are limited to the athletes' age, body mass, body height, and sports experience due to the lack of other parameters in the 8a.nu database. More parameters, such as somatotype, total skeletal muscle mass, subcutaneous fat mass, bone mass, cardiopulmonary capacity, and limb size, should also be included in future research. Moreover, the age of starting to climb and the age when climbing the hardest route parameters are difficult to correlate with the actual sports duration of the climbers over the years. Therefore, other methods should be adopted in future studies to measure the actual sports activity duration of athletes. Secondly, the study sample consists only of male athletes. Thus, future research should include the female population. Thirdly, generalizing the findings is limited by a need for more information about performance at sport climbing competitions among the

included sport climbers. Therefore, future research should consider rock climbing ascents and competition performance.

5. Conclusions

The lead climbers had a lower body mass, a lower body height, and la onger time to achieve the most challenging route than the boulderers. Body height and body mass are essential to the sports level of "Elite" and "Higher Elite" lead climbers. Therefore, our study suggests that lower body mass and height are more crucial for lead climbing performance than for bouldering. A younger starting age and more extended sporting experience are the critical points in the "Higher Elite" level in both subdisciplines.

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