CHAPTER II

Physique of the World's Best Climbers: Accurate Measurement of Adipose Tissue, and Body Shape Correction of the BMI

(Original Scientific Article)

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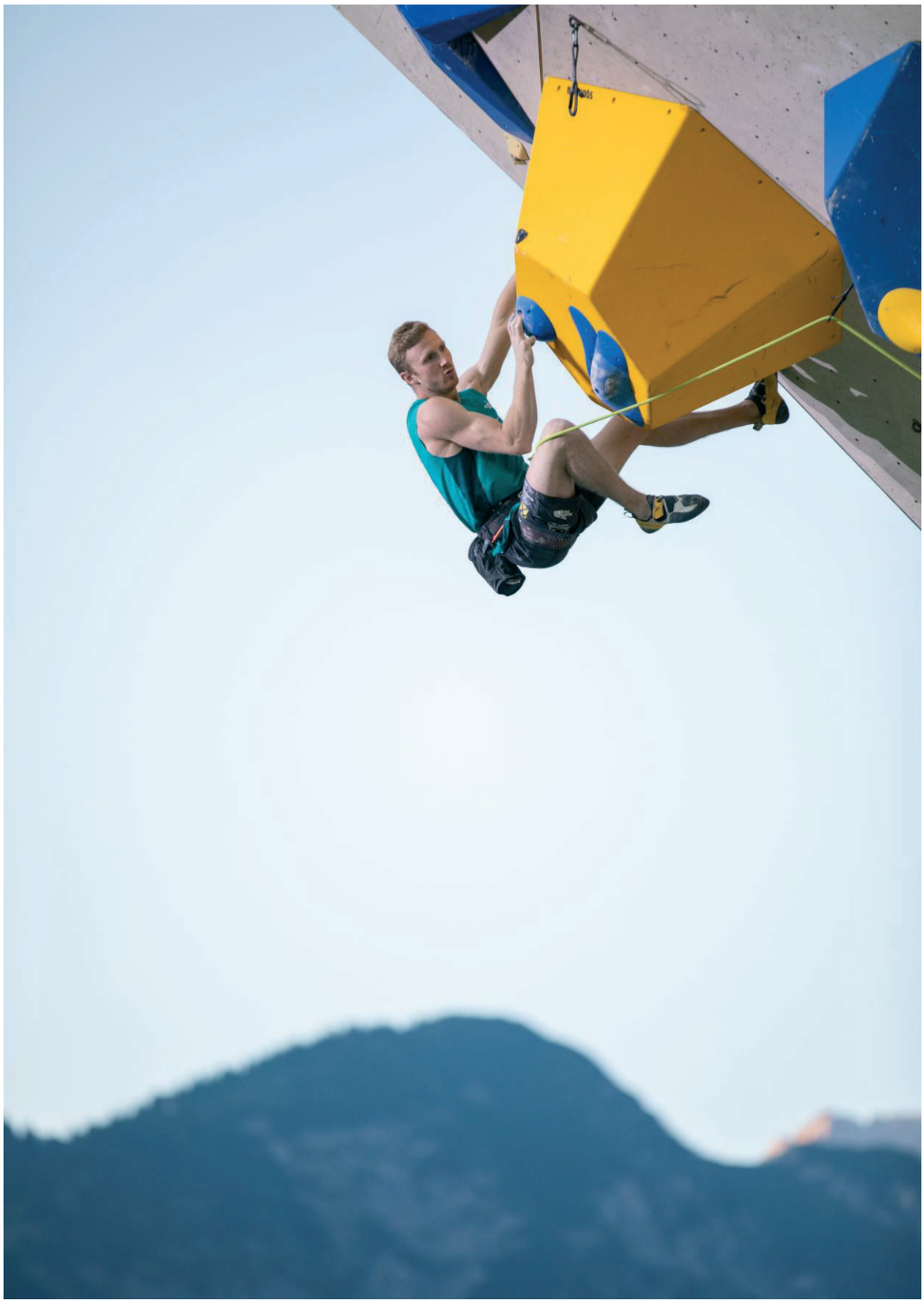

Image 1: Sport Climbing (Lead): Jakob Schubert, four-times World Champion and double Olympic bronze medallist.

Abstract

Background

In climbing, the gravitational force has to be overcome by ground reaction forces that act via very small and disadvantageously formed grips and surfaces. To succeed, high forces need to be produced by the small finger and toe muscles. The lower the body mass, the lower are the forces needed to hold these grips and to stand on the toes or to hook with the heels, and to hold the body in advantageous positions for solving climbing tasks. Therefore, the relation of finger and toe strength to body weight is crucial for performance; consequently, the athletes strive for low body weight, despite the need for substantial muscle mass. The Medical Commission of the International Federation of Sport Climbing (IFSC) was concerned about the extremely low body and adipose tissue (AT) masses in some of the elite female climbers and the extremely low AT values in some of the male climbers. Therefore, the IFSC initiated a project to determine the physique of leading World-Cup climbers based on state-of-the-art measurement methods. All widely used indirect or doubly indirect methods for quantifying AT (tissue/organ level) or fat mass (FM; molecular level: nonpolar lipids) including dual energy X-ray absorptiometry (DXA), skinfolds, bio-impedance analysis (BIA), hydro-densitometry, air displacement plethysmography, and anthropometric surrogates fail to distinguish between the AT amounts or FM values of athletes in weight sensitive sports because the error ranges of these methods exceed the values to be measured.

Methods

Therefore, the standardised ultrasound method (SUM) using brightness- (B-) mode images for robust measurement of subcutaneous adipose tissue (SAT) has been applied to determine athletes' SAT: SUM enables thickness measurements with an accuracy of 0.1 mm – i.e. the size of a single fat cell. According to a multi-centre study, reliability of SUM for the mean SAT thickness of eight standardised sites is 0.15 mm, corresponding to an SAT-monitoring precision better than 0.2 kg. An SAT classification scheme for athletes derived from percentiles of comprehensive data sets of elite athletes (354 males, 180 females) from various sports was used; it distinguishes between eight classes of AT levels, including three classes of leanness (Low-I, Low-II, and Low-III). SUM can also quantify the fibrous structures (fasciae) embedded in the SAT. Furthermore, body mass with respect to body dimensions was determined in terms of the mass index (MI). The MI takes into account the body shape of men and women in terms of sitting height, which the body mass index (BMI) ignores, although shape has a large impact on BMI. For persons with long legs, MI>BMI, and vice versa. For analyses of possible correlations between performance and SAT, MI (and BMI), the Continuously Updated World Ranking (CUWR) was used. In this study, we evaluated the physique of 77 elite climbers (37 males and 40 females; participation rate: 97%), all of them were World Cup semi-finalists.

Results

The median SAT mass was 2.0 kg (range: 0.6 to 3.0 kg) in the male, and 4.0 kg (range: 1.0 to 6.9 kg) in the female lead climbers when fasciae embedded in the SAT were included. SAT-masses with embedded fasciae excluded were 1.4 kg (range: 0.5 to 2.8 kg) and 3.5 kg (0.8 to 6.2 kg), respectively. Among the male climbers, 35% were in the leanness class Low-III (mean

uncompressed SAT thickness of the eight sites below $d_{I,mean=}$1 mm, embedded fasciae included), and 43% of the female climbers (class Low-III for females: $d_{I,mean}$<4 mm). All climbers were in the leanness categories Low-III, Low-II, or Low-I, except for two males and three females who were in the Medium-I class, and one female who was at the border between Medium-II and High-I. Several female climbers had extremely low mean SAT thicknesses (the lowest one was 0.8 mm), and the lowest mean SAT thickness in the male group was 0.25 mm. Women had substantially higher adipose tissue values than men. No low weight problem among male climbers was detected, except for one athlete with an MI of only 17.4 kgm^{-2} (BMI of 18.0 kg m^{-2}), whereas eight women had MI-values below 17.5 kgm^{-2}. Pronounced sex differences were found in terms of SAT-masses, SAT-patterning, MI and also in BMI. No correlation was found between SAT and ranking (CUWR) in the whole male group; among the top 10 male climbers, even a highly significant negative correlation resulted. Furthermore, there was no significant correlation between MI (or BMI) and ranking in the male group. Among the best 10 female climbers, there was no correlation between ranking and SAT or MI (or BMI), whereas, correlations were significant when taking the entire female group into account.

Discussion and Perspectives

The results demonstrate that there is a high demand for accuracy and reliability in distinguishing between the body compositions of athletes in weight-sensitive sports, such as the group of the world's top sport climbers. The AT classification scheme, derived from percentiles of large groups of elite athletes from various sports, provides a framework that allows the assignment of medical findings to these classes that are based on accurately measured SAT values. We recommend to include only accurate measurements of AT to avoid misleading results and feedbacks, and to use the MI for classifying body mass with respect to body dimensions because BMI ignores the important impact of body shape.

The results of this study indicate that education and medical surveillance do not appear to be sufficiently successful in preventing cases of alarmingly low body weight in female elite climbers (with some individuals even below 17 kgm^{-2}) and extremely low AT values (Low-III) in both sexes. A requirement that athletes be above a minimum MI-value would induce a self-regulating process: athletes with extremely low MI could adapt their body mass accordingly in time, or otherwise would have to carry additional weight to fulfil the MI-criterion. Additionally, medical surveillance is an important tool to protect athletes' health. Currently, the Medical Commission of the International Sport Climbing Federation (IFSC) attempts to address the issue of relative energy deficiency in sport (REDs) in accordance with recent suggestions, but accurate determination of grades of leanness and underweight (considering body shape) are missing in this protocol. The validity of medical screenings and scientific studies will be enhanced when the state-of-the-art methods available now are integrated into future study designs. Longitudinal studies will be of particular importance, as severe health effects may manifest with a delay.

Key Points

- This study represents almost all of the world's best climbers: participation rate was 97%. All 37 male and 40 female participants were World-Cup semi-finalists.
- The brightness-mode standardised ultrasound method (SUM) of subcutaneous adipose tissue (SAT) thickness measurements revealed that 35% of the male, and 43% of the female climbers were in leanness class Low-III, i.e. mean SAT thickness (of the eight sites) below 1 mm in the male and below 4 mm in the female climbers.
- Only two male and three female climbers were in class Medium-I and one female was at the border between Medium-II and High-I, all the others were in the leanness classes Low-I to Low-III.
- The male lead climbers' mean SAT-thicknesses (with embedded fasciae included) ranged from only 0.25 to 2.0 mm, corresponding to only 0.6 kg (0.8%) to 3.0 kg (4.5%) SAT-mass (median was 2.0 kg). Such low values cannot be detected with sufficient accuracy with any other method.
- The female lead climbers' mean SAT-thicknesses ranged from only 0.8 mm to 7.8 mm (corresponding to 1.0 kg to 6.9 kg SAT mass; 2.8% to 12.3%, respectively).
- Male climbers had approximately twice the percentage of fasciae (fibrous structures) embedded in their SAT compared to the female group.
- The SAT patterns showed highly significant differences between the male and female climbers, with the highest female thicknesses typically at lateral thigh, and the highest male values typically at lower abdomen.
- In the female group, several extremely low SAT values were accompanied by alarmingly low mass index MI values: lowest MI was 16.0 kgm^{-2} (BMI 15.4 kgm^{-2}), whereas in the male group, only one athlete had a concerningly low MI value of 17.4 kgm^{-2} (BMI: 18.0 kgm^{-2}).
- The median MI was higher by 2.25 kgm^{-2} (BMI by 2.42 kgm^{-2}) in the male lead group compared to the female lead group ($p<0.01$), but only by 0.62 kgm^{-2} (BMI: 0.84 kgm^{-2}) in the boulder groups (not significant).
- In the whole male group, no correlation between mean SAT thicknesses and ranking (CUWR) was found, and among the top 10 male climbers, even a highly significant negative correlation resulted. Furthermore, there was no correlation between MI and ranking. In the entire female group, significant correlations between ranking and both mean SAT thicknesses and MI were observed, but, interestingly, in the group of the top 10 female climbers, no significant correlation could be detected.
- None of the indirect methods that are in use for determining AT (or body fat at the molecular level) can distinguish with sufficient accuracy between the individual values of athletes in weight-sensitive sports like climbing.
- We recommend to use the MI instead of (or in addition to) the BMI because body shape needs to be taken into account for determining levels of underweight. Additionally, we recommend to consider that women's group medians in MI (and also in BMI) are substantially lower than men's values. This has been shown previously in a variety of populations with high or low physical activity.

Keywords

B-mode ultrasound, standardised ultrasound method, SUM, adipose tissue, body fat, anthropometry, body shape, Cormic index, body mass index, BMI, mass index, MI, anthropometry, sex differences, sexual dimorphism, weight-sensitive sports, relative energy deficiency in sports, REDs.

Image 2: Climbing position on a natural boulder
Boulder and lead climbing are experiencing huge growth worldwide, including elite and hobby athletes, and can be practised both in indoor facilities and outdoors on natural rock – as shown here.