LOW ENERGY AVAILABILITY AND CARBOHYDRATE INTAKE IN COMPETITIVE ADOLESCENT CLIMBERS

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Abstract:

Competitive adolescent sport climbers are reported to keep very low energy intake in order to achieve the highest possible strength-to-mass ratio required for their sport. Long term low energy availability (< 30 kcal/kg fat free mass/day) is known to have a detrimental effect on health and performance. Due to the potential severity of consequences and the lack of the data on specific population, our aim was to assess energy availability and dietary intake of 27 members of the Slovenian Youth Climbing Team (13-18 years of age). Three-day food and activity records, questionnaires and anthropometric measurements were used to determine participants' energy availability, nutritional intake, avoidance of food groups and selected health history. Average energy availability in climbers was 27.5 ± 9.8 kcal/kg fat free mass/day and 63% of participants failed to meet the recommended 30 kcal/kg fat free mass/day. Their average carbohydrate (4.3 ± 1.3 g/kg body mass/day), calcium (780 ± 300 mg/day) and vitamin D (2.6 ± 2.3 μg/day) intake were also too low. Average protein intake was in recommended range, but 56% of participants did not meet the minimum recommended limit. Iron intake was too low in females (10 ± 5 mg/day; target 15 mg/day). Only 15% of participants reported not avoiding any food groups. The menstrual dysfunction was detected in five female climbers (36%); all had energy availability < 30 kcal/kg fat free mass/day. We recommend nutritional education of climbers, their coaches, and parents as well as regular individual nutritional assessment of competitive adolescent sport climbers.

Key words: *energy intake, food avoidance, dietary intake, body composition, relative energy deficiency in sport*

Introduction

Sport climbing is a rapidly growing and popular sport that has been part of the Olympic games since Tokyo 2020 (IOC, 2016). It is composed of three disciplines: bouldering, speed climbing, and lead climbing which differ in terms of their physiological requirements. Anaerobic and aerobic systems participate in the production of adenosine triphosphate. Data suggest that climbing requires the use of a significant portion of whole body aerobic capacity, with anaerobic power being more important in more difficult routes with steeper angles (Bertuzzi, Franchini, Kokubun, & Kiss, 2007; Sheel, 2004). Climbing is considered a gravitational sport and thus for achieving success in it requires a high strength-to-mass ratio (Watts, Martin, & Durtschi, 1993). Adolescent climbers, as well as adults, tend to have a smaller stature, lower body mass (BM), lower body fat (BF) and a greater handgrip-to-BM ratio compared to their peers (Watts, Joubert, Lish, Mast, & Wilkins, 2003). Their body mass index (BMI) is similar to the control group of non-climbers, while lower sums of skinfolds indicate a greater share of fat free mass (FFM) (Watts, et al., 2003). Research has shown that the variance in climbing performance could be explained by the trainable variables such as knee and shoulder strength, grip strength, upper and lower body power, hang time and %BF rather than by the anthropometric characteristics like BM, body height, leg length, arm span, and ape index (Mermier, Janot, Parker, & Swan, 2000). Despite that, anecdotal evidence suggests that low BM is desirable among climbers which is why they resort to different restrictive diets, most often characterized by very low carbohydrate (CHO) intake irrespective of training volume or intensity (Gibson-Smith, Storey, & Ranchordas, 2017). Importance of adequate CHO intake for athletes is well recognized for its role in performance and adaptation to training (Thomas, Erdman, & Burke, 2016).

There is limited information available about the nutritional needs and nutritional intake of young climbers. Energy requirements in adolescent climbers were assessed only in a single study (Watts & Ostrowski, 2014), and recently a pilot study that monitored macronutrient intake and eating attitudes in recreational and competitive adolescent rock climbers was published (Michael, Witard, & Joubert, 2019). Both studies and others, performed with adult climbers (Gibson-Smith, Storey, & Ranchordas, 2020; Kemmler, et al., 2006; Merrells, Friel, Knaus, & Suh, 2008; Sas-Nowosielski & Wycislik, 2019; Zapf, Fichtl, Wielgoss, & Schmidt, 2001), report suboptimal energy intake (EI). The aforementioned studies, except for the study by Gibson-Smith et al. (2020), used energy balance (EB) as the traditional metric for determining the adequacy of EI. However, the body adapts to chronic low EI by resourcing energy needed for training from other physiological functions, which results in a lower resting metabolic rate (RMR) and makes the athletes only appear in EB, while their physiological systems are not working properly in an effort to adapt to a chronic lack of energy (Loucks, Kiens, & Wright, 2011). Therefore, energy availability (EA), which represents the amount of energy that is available for bodily functions, growth and development, taking into consideration energy expenditure during the planned physical activity (Loucks, et al., 2011), is encouraged to be used in research. Low EA (LEA), defined as EA <30 kcal/kg FFM/day, has severe negative impact on athlete's health, training consistency and competitive performance (Mountjoy, et al., 2014, 2018). Optimal and therefore recommended EA has been identified to be at least 45 kcal/kg FFM /day in female adults (Loucks, 2013) and 40 kcal/kg FFM/day in adult exercising men (Koehler, et al., 2016), but may be even higher in adolescents who are still growing and developing (Weiss Kelly, Hecht, & Council on Sports Medicine and Fitness, 2016). This is why we used a cut-off value of 45 kcal/kg FFM/day in this study to identify optimal EA in adolescent climbers for both sexes. EA of 30-45 kcal/kg FFM/day was considered a reduced EA. Athletes should only stay within this range for a short period of time, e.g. when aiming to reduce BM (Melin, Heikura, Tenforde, & Mountjoy, 2019).

LEA is perceived to be the main reason for relative energy deficiency in sport (RED-S) which refers to disturbed physiological functions caused by the relative energy deficiency, which, among other things, includes the metabolic rate and also reproduction, bone health, immunity, protein synthesis, and cardiovascular health (Mountjoy, et al., 2014). Long-lasting LEA in adolescent athletes may result in numerous health issues, such as the late onset of puberty, menstrual cycle abnormalities, poor bone health, stunted growth, the development of disordered eating, and higher risk of injury (Desbrow, et al., 2014).

Due to the increase in popularity of sport climbing and the lack of data on EA and dietary intake for elite and advanced climbers in the period of adolescence, our aim was to determine them exactly since LEA can be subclinical. The long-term effects of LEA can be debilitating and potentially irreversible; however, they can be prevented if diagnosed in time.

Methods

Participants

All the members of the Slovenia Youth Climbing team (38) were invited to participate in the measurements performed during the national team selection camp in February 2020. Final cohort consisted of 27 subjects. The study was approved by the Republic of Slovenia National Medical Ethics Committee (No.: 0120-690/2017/8). All the participants and their parents provided written informed consent.

Anthropometric measurements

Body height (BH) was measured to the nearest 0.5 cm and BM to the nearest 0.01 kg on a scale with integrated stadiometer (M304641-01, AED, Germany). The whole body bioelectrical impedance analysis in supine position was performed using an alternating sinusoidal electric current of 400 μA at an operating frequency of 50 kHz (BIA 101 Anniversary AKERN, Florence, Italy, medically approved: EN ISO 13485 − ISO 9001 and approved for pediatric use) according to recommendations (Kyle, et al., 2004) with emptied urine bladder and with no physical activity, alcohol or food intake in the last eight hours. FFM, percentage of fat mass (%FM), and predicted basal metabolic rate (BMR) were calculated by an integrated software (BODYGRAM® PLUS, AKERN, Florence, Italy). Due to the age interval (13-18 years of age), BH, BM and BMI were expressed in percentiles for individual age and sex using growth charts from Centers for Disease Control and Prevention (CDC, 2019) for better comparison with standards.

Dietary assessment, energy consumption evaluation and EA calculation

Climbers were asked to continue their normal diet and physical activity but to keep weighted food and activity records for three consecutive days, including one training free day. They were fully briefed (written and oral instructions by a dietitian) on how to complete the diary. They were asked to include food labels, photos, and recipes for mixed dishes in their record and to be accurate and sincere. All records were reviewed and if any abnormalities were observed, climbers were contacted to clarify the issue. Dietary intake was assessed with a dietary assessment and planning tool Open Platform for Clinical Nutrition (OPEN; http://www.opkp.si/en_GB/cms/vstopna-stran, accessed in July 2021). Physical activity was recorded by type, duration, and intensity. Energy expenditure for planned exercise (EEE) was calculated based on the activity logs using metabolic equivalent of task (MET), in accordance with the literature (Ainsworth et al., 2000).

EA was calculated with the following equation (Loucks, et al., 2011):

$$EA = \frac{EI - EEE}{FFM}$$

Evaluation of the dietary intake of macro- and micronutrients was based on valid sports nutrition guidelines for young athletes (Desbrow, et al., 2014). Where reference values were not defined for adolescent athletes specifically, we used Slovene Reference values for energy and nutrient intake (NIJZ, 2020). Given the type, intensity and duration of the exercise, we set the minimum threshold for CHO intake at 5 g/kg, the minimum required intake for protein 1.3 g/kg (Desbrow, et al., 2014), whereas the dietary fat intake minimum was set at 30% of EI, calcium intake at 1200 mg, vitamin D at 20 µg and iron intake at 12 mg per day for male and 15 mg per day for females based on general recommendations for this age group (NIJZ, 2020).

Questionnaires

Information on climbing ability, dietary habits, frequency of infections and menstrual history was obtained by a questionnaire. Climbing ability was determined with the International Rock Climbing Research Association (IRCRA) scale (Draper et al., 2015). Primary amenorrhea was determined as the failure of menses to occur by the age of 16 years, secondary amenorrhea as the loss of menses for three or more months and/or oligomenorrhea as 35 or more days between menses (Nattiv, et al., 2007).

Statistical analysis

SPSS 20.0 for Windows (IBM Corp., New York) and Microsoft Excel were used to analyse the data. Data are presented as mean ± standard deviation. Normality of distributions was determined with Shapiro-Wilk's test of normality. Differences between the means of two groups were tested with independent-samples *t*-tests for normally distributed data. Nonparametric Mann-Whitney test was used when distribution normality was violated. To test differences between actual and target dietary intake, paired sample *t*-tests were used. Wilcoxon Signed Rank tests were used when normality was violated. To test differences between two categorical variables, Pearson chi square test was used. Significance was considered when $p<.05$.

Results

Participants

Twenty-seven adolescent climbers (15.7 ± 1.5 years of age; 14 females) participated in the study. Their average climbing experience was 9.50 ± 1.25 years. Based on the IRCRA scale (Draper, et al., 2015), the group was comprised of eight elite, 15 advanced and one intermediate climber; three climbers did not report their climbing standard. Other characteristics of the climbers are presented in Table 1

Table 1. Characteristics of adolescent climbers divided by sex

	All (N= 27)	Male (n= 13)	Female (n=14)	p
Age (years)	15.7 ± 1.5	15.5 ± 1.6	15.9 ± 1.5	.477
Body height (cm)	166.0 ± 8.0	170.5 ± 8.0	161.5 ± 5.0	.002
Body mass (kg)	54.0 ± 8.5	56.4 ± 11.0	51.7 ± 4.3	.177[a]
BMI (kg/m²)	19.5 ± 1.8	19.2 ± 2.2	19.8 ± 1.5	.383
BM percentile (CDC)	48 ± 19	49 ± 23	46 ± 14	.665
BH percentile (CDC)	58 ± 25	64 ± 23	52 ± 25	.191
BMI percentile (CDC)	40 ± 21	36 ± 24	44 ± 18	.355
EI (kcal/day)	1790 ± 470	1880 ± 470	1710 ± 460	.366
BMR (kcal/	1560 ± 160	1630 ± 210	1500 ± 70	.051
FFM (kg)	47.5 ± 8.2	51.4 ± 10.2	44.0 ± 3.1	.026[a]
Fat mass (%)	12.0 ± 4.4	8.9 ± 3.3	14.9 ± 3.2	<.001[a]
Phase angle (°)	7.0 ± 0.60	7.0 ± 0.73	7.0 ± 0.48	0.961
Training load (h/week)[c]	15.6 ± 3.5	15.3 ± 3.9	15.9 ± 3.1	.659
Climbing ability (IRCRA)	20.4 ± 2.3[d]	21.1 ± 2.2[e]	19.9 ± 2.3[f]	.198

Note. BH – body height; BM – body mass; BMI – body mass index; CDC – Centers for Disease Control and Prevention; BMR – basal metabolic rate; EI – energy intake; FFM – fat free mass; IRCRA – International Rock Climbing Research Association; PA – phase angle; [a]equal variances not assumed; [b]predicted; [c]self reported; [d]N = 24; [e]N = 10; [f]N = 14.

Dietary intake vs recommended values

Average EA (27.5 ± 9.8 kcal/kg FFM/day) was below the recommended level (p<.001), with no participant meeting the target of 45 kcal/kg FFM/day and 63% being in the range of LEA (Figure 1A). Average daily CHO intake (4.3 ± 1.3 g/kg BM) was below the target of 5.0 g/kg BM (p=.007), 75% of participants were below the target (Figure 1B), whereas 44% of participants were above the target for protein intake (Figure 1C). Average protein intake was 1.3 ± 0.4 g/kg BM/day. Average daily fat intake was 31.8 ± 4.7% EI, but 37% of participants did not meet the target of 30% EI (Figure 1D). Only 15% of participants met the target of 1200 mg of calcium per day (Figure 1E). Average calcium intake was 780 ± 300 mg/day which was significantly lower than the target (p<.001). As regarded iron intake, 70% of males met the target, 12 mg/day (Figure 1F) with an average intake of 14 ± 5 mg/day, while the average iron intake of females was 10 ± 5 mg/day, which was significantly lower than the target, 15 mg (p=.007). Only 21% of females met the target (Figure 1F). None of the participants met the target vitamin D intake of 20 μg. The average intake was significantly lower, 2.6 ± 2.3 μg/day (p<.001).

Summary of characteristics by the energy availability classification status

Taking into consideration the LEA cut-off point, we divided participants in two groups: the group EA<30 (EA < 30 kcal/kg FFM/day; 17 climbers; 47% males and 53% females) and the group EA30-45 (EA between 30 and 45 kcal/kg FFM/day; 10 climbers; 50% males and 50% females) and compared their characteristics (Table 2). No significant difference between the two groups was found

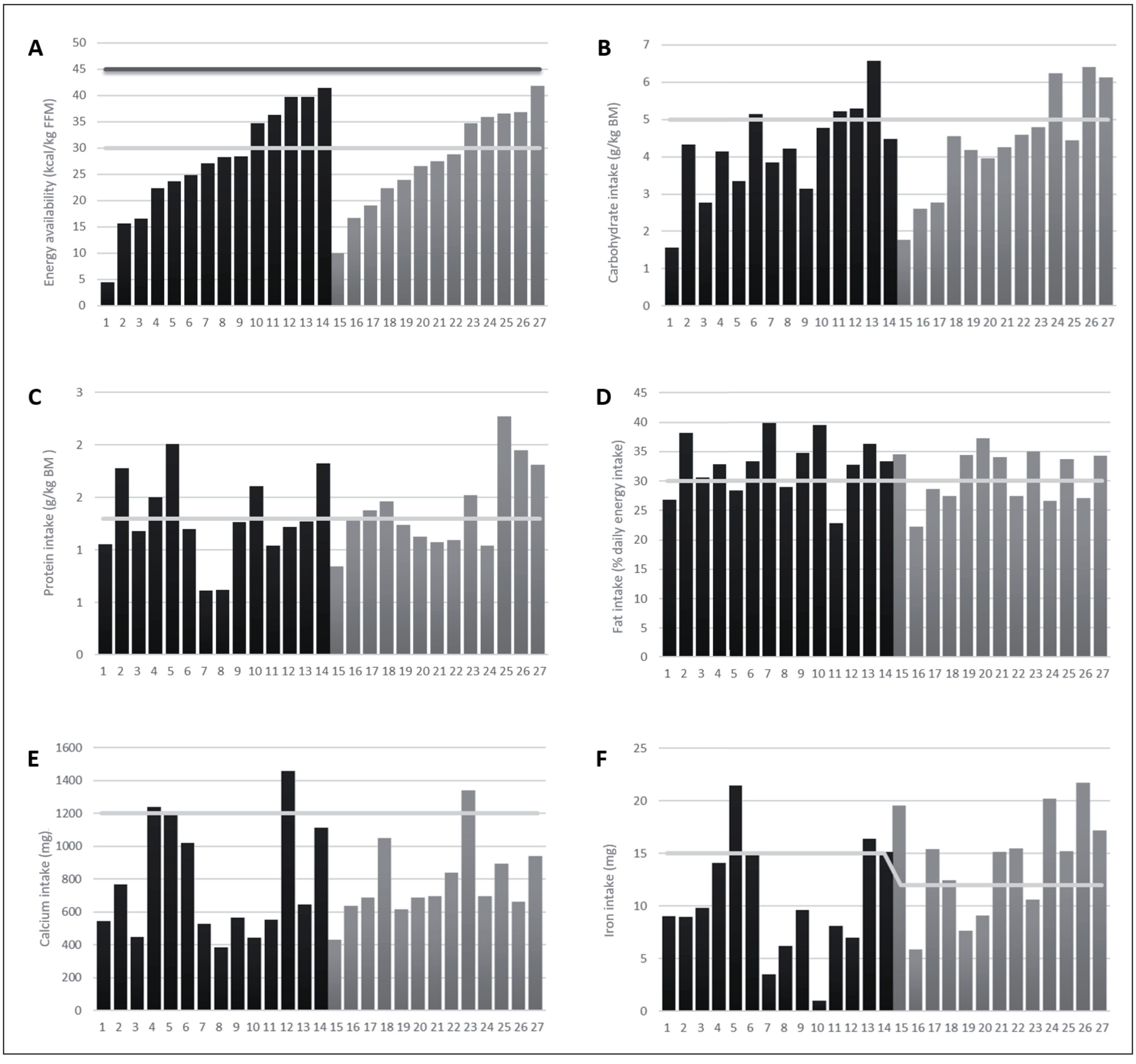

Figure 1. Dietary intake of competitive adolescent sport climbers. A – Energy availability, B – Carbohydrate intake, C – Protein intake, D – Fat intake, E – Calcium intake, F – Iron intake. Black bars – female climbers; grey bars – male climbers; full line – recommendation: where applicable: light line – lower limit; dark line – upper limit.

Table 2. Characteristics of participants divided by energy availability

	EA<30 (N=17)	EA30-45 (N= 10)	p
Energy availability (kcal/kg FFM)	21.5 ± 6.9	37.7 ± 2.7	<.001[a]
Body height (cm)	167.30 ± 8.77	163.60 ± 6.00	.251
Body mass (kg)	56.0 ± 10.0	51.0 ± 5.0	.168
BMI (kg/m²)	19.8 ± 1.8	19.1 ± 1.9	.347
BM percentile CDC	53 ± 18	38 ± 18	.048
BH percentile CDC	65 ± 25	46 ± 19	.052
BMI percentile CDC	44 ± 18	33 ± 24	.194
Fat free mass (kg)	49.0 ± 9.6	45.0 ± 4.5	.443[a]
Fat mass (%)	12.1 ± 4,5	11.8 ± 4.4	.835
Energy intake (kcal/day)	1590 ± 430	2140 ± 300	.001
Basal metabolic rate (kcal/day)	1590 ± 190	1500 ± 100	.152
EEE (kcal/dan)	530 ± 220	450 ± 140	.223[a]
Training load (h/week)	15.3 ± 3.5	16.2 ± 3.5	.551
Carbohydrate intake (g/kg BM)	3.6 ± 1.0	5.4 ± 0.8	<.001
Protein intake (g/kg BM)	1.2 ± 0.3	1.6 ± 0.4	.005
Fat intake (g/kg BM)	1.0 ± 0.3	1.5 ± 0.2	<.001
Fat intake (%EI)	31.3 ± 5.1	32.6 ± 4.2	.505

Note. BMI – body mass index; CDC – Centers for Disease Control and Prevention; EEE – energy expenditure for planned exercise; FFM – fat free mass; BM – body mass; BH – body height; EI – energy intake; [a]equal variances not assumed.

for climbing ability, although in group EA<30, three climbers did not report their climbing ability.

Eating habits and health condition

The majority of participants were omnivores, except for two males and two females who reported being vegetarian or vegan. One female reported intermittent fasting, without specific description of her eating pattern.

As regards energy intake restriction, 41% (two females and nine males) of the participants never consciously restricted EI; 37% of them (nine females and one male) reported that they rarely did it, while 22% of participants (three females and three males) reported that they sometimes did it.

Further, 15% (one female, three males) of participants reported that they did not avoid any food. Most of the others avoided high-fat meat (67%, 11 females, seven males) and sugar and sweet foods (44%, seven females, five males), while 26% (five females, two males) avoided medium-fat meat and 19% (two females, three males) avoided fats and fatty foods. No significant differences in food avoidance were found between the two EA groups ($p>.05$).

Also, 63% (nine females, eight males) of participantss reported that they had never visited a doctor due to a respiratory infection, while others had visited a doctor once or twice in the last 12 months.

Regarding menstrual cycle regularity, 43% of female climbers reported having regular menstrual cycles, while 29% had not yet got their first period. Among the latter group, we identified primary amenorrhea in one climber (7%). We also identified one climber with secondary amenorrhea (7%) and in three climbers (21%) we identified oligomenorrhea. All the girls with menstrual dysfunction had EA under 30 kcal/kg FFM/day, while three of them also had too low calcium and vitamin D intake. Assumptions for testing significant differences in menstrual cycles between the two EA groups were not met (more than 25% cells had expected count less than five).

Discussion and conclusions

EA and dietary intake were assessed in competitive adolescent sport climbers. We observed low EA and low carbohydrate and other key nutrients intake in our participants, advanced and elite adolescent climbers, aged 13 to 18 years. This is the first study on adolescent climbers, which, in addition to the dietary intake of macronutrients, also determined micronutrients key for sports performance and EA.

Average EA was significantly lower than 45 kcal/kg FFM/day without any major differences between the sexes. This is of concern, as 45 kcal/kg FFM/day is reported to support all physiological functions needed to maintain optimal health (Loucks, et al., 2011). Further, adolescents are still growing, which requires additional energy for growing tissues (Torun, 2005). Yet, 37% of the investigated climbers achieved the value of EA between 30 and 45 kcal/kg FFM/day, which is conditionally acceptable for a shorter time period (Mountjoy, et al., 2018), while others had EA under the minimum recommended limit of 30 kcal/kg FFM/day, which is concerning. It is known that longer-lasting energy shortage and LEA lead to RED-S which may lead to a dysfunction of numerous physiological systems and may endanger health and performance (Desbrow, et al., 2014; Smith, Holmes, & McAllister, 2015), and in adolescents, also growth and maturation status (Desbrow, et al., 2014). All the studies with climbers known to us concluded that EI, when compared to predicted energy expenditure (calculated as a product of basal metabolic rate and physical activity factor), was too low in both adolescent (Michael, Joubert, & Witard, 2019) and adult climbers (Kemmler, et al., 2006; Merrells, et al., 2008; Sas-Nowosielski & Wycislik, 2019; Zapf, et al., 2001). The only study that determined EA was conducted with adult climbers and the average EA of the participants was 41.4 ± 9 kcal/kg FFM/day, with significantly higher EA in females than in males (45.6 ± 7 kcal/kg FFM/day vs. 37.2 ± 9 kcal/kg FFM/day, respectively) (Gibson-Smith, et al., 2020). Further, 78% of elite adult climbers failed to meet the predicted energy requirement to support a moderate level of physical activity with an average of 12 hours of training/week, while 18% failed to meet the predicted RMR values (Gibson-Smith, et al., 2020). In our study, EI of as many as 26% of adolescent climbers (four males, three females) failed to meet the predicted BMR, despite the high training load. The only research that determined EI in adolescent climbers found that as many as 82% of the participants did not reach the recommended EI of 2,471 ± 493 kcal/day (Michael, Joubert, et al., 2019). They reported an average EI of 1,963 ± 581 kcal/day, while we observed even lower EI in our study. Despite the observed low EA, our adolescent climbers were distributed within the normal CDC percentile range for their age for all the three observed anthropometric parameters (BM, BH, and BMI). Similar BMI values in adolescent climbers as in control group were reported before (Watts, et al., 2003). The International Federation of Sports Climbing has been monitoring BMI during competitions for the past 10 years, so normal BMI was expected for our participants. If BMI falls below the parameters, the athlete and the National Federation are informed. Medical, psychological and nutritional help should be provided to support the affected athletes (IFSC, 2021). However, LEA and RED-S may be present even if no loss of BM has occurred (Mountjoy, et al., 2018). Interestingly, the group EA<30, which comprised nearly 2/3 of the participants, had statistically higher value of BM expressed in CDC percentiles and lower EI than the group EA30-45. There were no differences between the groups in other EA components (EEE, FFM), other anthropometric characteristics, the climbing ability, nor in training load. We believe that higher BM, according to CDC tables, might be the reason for the observed lower EI in the group EA<30, as higher BM is perceived as not desirable in sport climbing. With our crossectional study, however, we cannot determine whether the recorded low EA was the acute one during the preparation for the national team selection camp or a longer-term effort of the climbers to counteract genetic anthropometric predispositions. The climbers with lower EA were also higher in stature; the difference was close to statistical significance.

Of the macronutrients, low CHO intake contributed the most to the observed low EA in our climbers. Three quarters of the participants did not reach the target of at least 5-g of CHO/kg BM/day and average intake of CHO, 4.3 ± 1.3g CHO/kg BM/day, was below the target. Michael et al. (2019) came to a similar conclusion, namely, 86 % of their adolescent climbers did not reach the same target, 5-g CHO/kg BM/day, their average daily CHO intake was 4.3 ± 1.6 g CHO/kg BM. Studies with adult climbers show even lower intakes of CHO, below 4.0 g CHO/kg BM/day (Gibson-Smith, et al., 2020; Sas-Nowosielski & Wycislik, 2019). Considering the lack of studies, the minimum daily recommended intake is unclear, so Michael et al. (2019) recommend 3-7 g CHO/kg BM, while setting 5-g CHO/kg BM is the value which would prevent the depletion of glycogen in activities with similar physiological requirements as sport climbing. The group with lower EA had lower CHO intake than the group with higher EA.

It has been known that young athletes who have an adequate EA reach or exceed protein intake recommendations (Gibson, Stuart-Hill, Martin, & Gaul, 2011; Heaney, O’Connor, Gifford, & Naughton, 2010; Petrie, Stover, & Horswill, 2004). Considering the fact that none of our climbers reached the optimal EA of 45 kcal/kg FFM/day, we wanted to determine whether the climbers managed to satisfy their protein requirements. We estimated increased protein requirements in adolescent climbers to be 1.3-1.8 g/kg BM/day. The determined average value for male and female climbers was not significantly different from the minimum recommended value, 1.3 g/kg BM/day; however, 56% of the participants did not achieve that minimum recommended limit, which was a much higher number than it was determined in a similar study (Michael, Joubert, et al., 2019) where the minimum required daily intake was assessed to be 1.6 g/kg BM and only 23% of the participants did not reach it. Group EA<30 had lower protein intake, with most participants from the group not reaching the minimum recommended limit. Sufficient protein intake is very important in the case of low EA, especially in combination with low CHO intakes, because part of the protein is used in gluconeogenesis to form glucose as an energy substrate, potentially lowering the amino acid availability for basic physiological functions (Desbrow, et al., 2014). It is proven that only five days of EA below 30 kcal/kg FFM/day reduce muscle protein synthesis by 27% (Areta, et al., 2014) and is therefore highly undesirable.

According to sports nutrition guidelines, young athletes should consume a moderate amount of fats, which in accordance with national recommendations represent 30% of EI (NIJZ, 2020). On average, our subjects were within the recommended range, 63% reached the recommended values. Considering this was a relative share of total EI, which on average was too low, the results are not relevant and the guidelines for young athletes should express fat intake recommendations in grams relative to BM, as they do for CHO and proteins. The majority of our climbers reported avoiding foods containing fat. Group EA<30 had significantly lower fat intake than group EA30-35.

Low EI and food avoidance is reflected in micronutrient intake of our group of adolescent climbers. In young athletes, special attention is suggested to be paid to iron, calcium and vitamin D intake due to the elevated risk of deficiency of these nutrients (Desbrow, et al., 2014). The average daily calcium intake was significantly lower than the recommended intake of 1200 mg per day and close to the fact stated in the literature that young athletes achieve only half of the recommended calcium intake (Gibson, et al., 2011; Juzwiak, Amancio, Vitalle, Pinheiro, & Szejnfeld, 2008). There were no differences between the sexes or EA groups, although there was a trend of lower calcium intake in group EA<30. Inadequate calcium intake and increased calcium loss may increase risk of osteopenia and osteoporosis, which is especially emphasized in athletes with low EA (Sale, & Elliott-Sale, 2019), as were our subjects. National recommendations for daily contribution to vitamin D pool are 20 μg of vitamin D, which is to be achieved by way of internal synthesis in the skin or with food (NIJZ, 2020). Since the study was conducted in wintertime, when the incident angle of the sun at our latitude (above 35th parallel north) is too small for the biosynthesis of vitamin D in the skin (Owens, Fraser, & Close, 2015), all daily contribution to vitamin D pool was by dietary intake. The daily vitamin D intake was poor. For an adequate assessment of the vitamin D status, we should determine 25-(OH) D serum values (Halliday, et al., 2011). We do not have data for adolescents, but among Slovenian adults, there is high prevalence of insufficient serum 25(OH)D and vitamin D deficiency during extended wintertime (November-April) (Hribar, et al., 2020). In case of insufficiency, vitamin D intake should be appropriately replaced with vitamin D supplements (Desbrow, et al., 2014). We observed too low daily iron intake in females for which recommended intake is higher than for males (15 mg vs. 12 mg). This was in contrast with other reports, where dietary intake of iron in young male athletes exceeded recommendations, while the females were within the recommended limits (Gibson, et al., 2011; Heaney, et al., 2010; Juzwiak, et al., 2008). A recent study of adult climbers showed that approximately 17% of male climbers and 45% of female climbers had suboptimal iron status, with a significant medium-strength correlation between iron intake and daily EI (Gibson-Smith, et al., 2020). A too low iron intake may lead to iron deficiency, with or without anemia, which negatively affects endurance performance capacity and aerobic adaptation (Rodenberg & Gustafson, 2007). LEA may contribute to iron deficiency and, at the same time, iron deficiency, through its effect on the thyroid function, causes a decrease in appetite and average energy consumption which leads to further deterioration of EA (Petkus, Murray-Kolb, & De Souza, 2017). Indeed, the group with lower EA had lower iron intakes.

The literature reports a higher susceptibility for infection in association with a low EI (Mackinnon, 2000); however, our subjects did not report any frequent infections. Menstrual dysfunction was detected in five female climbers (36%), all appertaining to group EA<30. A lack of research on adolescent female climbers prevents us from comparing our results. Menstrual dysfunction prevalence may vary and has been reported to be between 26% and 43% in young athletes (Austin, Reinking, & Hayes, 2009; Barrack, Rauh, & Nichols, 2008; Tenforde, Fredericson, Sayres, Cutti, & Sainani, 2015), with the highest rate among the athletes of sports that emphasize leanness and low BM (Ackerman & Misra, 2018; Torstveit & Sundgot-Borgen, 2005). Primary amenorrhea prevalence was reported to be 7% among the general population and 22% among cheerleaders, divers, and gymnasts (Beals & Manore, 2002). Menstrual dysfunction is often not given enough attention and remains overlooked despite the fact that it increases the risk of the early onset of osteoporosis (Mountjoy, et al., 2014). Too low calcium levels and vitamin D intake represent an additional risk factor and were discovered in three female climbers in addition to their menstrual dysfunction and low EA.

The absence of protocol for determining EA outside of a laboratory and methodological issues in measuring each individual EA component (Burke, Lundy, Fahrenholtz, & Melin, 2018) might contribute to the observed low EA. To minimize these issues, we tried to limit the majority of possible errors with detailed instructions by a dietitian for filling out the 3-day food records, including training-free days, revision and explanation of ambiguities in the record, strictly following the protocol when carrying out bioimpedance measurements and selecting a device clinically approved for pediatric use. Measurement of EEE was the biggest obstacle and we assessed it from activity logs using the MET (Ainsworth, et al., 2000), which was described as less precise (Burke, et al., 2018). To determine whether the observed low EA was acute or chronic, the athletes should be subjected to regular screening for risk factors and symptoms included in RED-S over a longer period and in different periods of annual training periodisation.

This study suggests that two thirds of the investigated advanced and elite adolescent sport climbers were at risk of LEA, which can, if persistent for a longer time, lead to a decline in performance and compromise their health.

Low energy and dietary intake, regardless of whether intentional or unintentional, combined with high training load in competitive adolescent sport climbers, led to macronutrient (most markedly CHO) and/or micronutrient (most markedly Ca^{2+} and vitamin D) intake insufficiency as well, which can have further negative consequences.

Based on the acquired information and considering the findings by other authors, we conclude that adolescent climbers, both female and male, should be subjected to regular screening for risk factors and symptoms included in RED-S, implying that their regular professional nutrition management should also be considered.

References

Ackerman, K.E., & Misra, M. (2018). Amenorrhoea in adolescent female athletes. *The Lancet. Child & Adolescent Health*, *2*(9), 677-688. https://doi.org/10.1016/S2352-4642(18)30145-7

Ainsworth, B.E., Haskell, W.L., Whitt, M.C., Irwin, M.L., Swartz, A.M., Strath, S.J., …, & Leon, A.S. (2000). Compendium of physical activities: An update of activity codes and MET intensities. *Medicine and Science in Sports and Exercise*, *32*(9 Suppl), S498-S504. https://doi.org/10.1097/00005768-200009001-00009

Areta, J.L., Burke, L.M., Camera, D.M., West, D.W.D., Crawshay, S., Moore, D.R., …, & Coffey, V.G. (2014). Reduced resting skeletal muscle protein synthesis is rescued by resistance exercise and protein ingestion following short-term energy deficit. *American Journal of Physiology. Endocrinology and Metabolism*, *306*(8), E989-E997. https://doi.org/10.1152/ajpendo.00590.2013

Austin, T.M., Reinking, M.F., & Hayes, A.M. (2009). Menstrual function in female high school cross-country athletes. *International Journal of Adolescent Medicine and Health*, *21*(4), 555-565. https://doi.org/10.1515/ijamh.2009.21.4.555

Barrack, M.T., Rauh, M.J., & Nichols, J.F. (2008). Prevalence of and traits associated with low BMD among female adolescent runners. *Medicine and Science in Sports and Exercise*, *40*(12), 2015-2021. https://doi.org/10.1249/MSS.0b013e3181822ea0

Beals, K.A., & Manore, M.M. (2002). Disorders of the female athlete triad among collegiate athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, *12*(3), 281-293. https://doi.org/10.1123/ijsnem.12.3.281

Bertuzzi, R.C. de M., Franchini, E., Kokubun, E., & Kiss, M.A.P.D.M. (2007). Energy system contributions in indoor rock climbing. *European Journal of Applied Physiology*, *101*(3), 293-300. https://doi.org/10.1007/s00421-007-0501-0

Burke, L.M., Lundy, B., Fahrenholtz, I.L., & Melin, A.K. (2018). Pitfalls of conducting and interpreting estimates of energy availability in free-living athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, *28*(4), 350-363. https://doi.org/10.1123/ijsnem.2018-0142

CDC – Centers for Disease Control and Prevention. (2019). *Growth Charts—Clinical Growth Charts*. Published on, January 11, 2019. Retrieved from https://www.cdc.gov/growthcharts/clinical_charts.htm on December 15, 2021.

Desbrow, B., McCormack, J., Burke, L.M., Cox, G.R., Fallon, K., Hislop, M., …, & Leveritt, M. (2014). Sports Dietitians Australia position statement: Sports nutrition for the adolescent athlete. *International Journal of Sport Nutrition and Exercise Metabolism*, *24*(5), 570-584. https://doi.org/10.1123/ijsnem.2014-0031

Draper, N., Giles, D., Schöffl, V., Fuss, F.K., Watts, P., Wolf, P., …, & Abreu, E. (2015). Comparative grading scales, statistical analyses, climber descriptors and ability grouping: International Rock Climbing Research Association position statement. *Sports Technology*, *8*(3-4), 88-94. https://doi.org/10.1080/19346182.2015.1107081

Gibson, J.C., Stuart-Hill, L., Martin, S., & Gaul, C. (2011). Nutrition status of junior elite Canadian female soccer athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, *21*(6), 507-514. https://doi.org/10.1123/ijsnem.21.6.507

Gibson-Smith, E., Storey, R., & Ranchordas, M. (2020). Dietary intake, body composition and iron status in experienced and elite climbers. *Frontiers in Nutrition*, *7*, 122. https://doi.org/10.3389/fnut.2020.00122

Gibson-Smith, E., Storey, R., & Ranchordas, M. (2017). Nutritional considerations for bouldering. *International Journal of Sport Nutrition and Exercise Metabolism*, *27*, 1-28. https://doi.org/10.1123/ijsnem.2017-0043

Halliday, T.M., Peterson, N.J., Thomas, J.J., Kleppinger, K., Hollis, B.W., & Larson-Meyer, D.E. (2011). Vitamin D status relative to diet, lifestyle, injury, and illness in college athletes. *Medicine and Science in Sports and Exercise*, *43*(2), 335-343. https://doi.org/10.1249/MSS.0b013e3181eb9d4d

Heaney, S., O'Connor, H., Gifford, J., & Naughton, G. (2010). Comparison of strategies for assessing nutritional adequacy in elite female athletes' dietary intake. *International Journal of Sport Nutrition and Exercise Metabolism*, *20*(3), 245-256. https://doi.org/10.1123/ijsnem.20.3.245

Hribar, M., Hristov, H., Gregorič, M., Blaznik, U., Zaletel, K., Oblak, A., …, & Pravst, I. (2020). Nutrihealth Study: Seasonal variation in vitamin D status among the Slovenian adult and elderly population. *Nutrients*, *12*(6), 1838. https://doi.org/10.3390/nu12061838

IFSC – International Federation of Sport Climbing. (2021). *IFSC Official Statement*. Retrieved from https://cdn.ifsc-climbing.org/images/ifsc/Footer/Commissions/086_IFSC_Medical_Statement.pdf on December 15, 2021.

IOC – International Olympic Committee. (2016). IOC approves five new sports for Olympic Games Tokyo 2020. Published on August 3, 2016. Retrieved from International Olympic Committee website: https://olympics.com/ioc/news/ioc-approves-five-new-sports-for-olympic-games-tokyo-2020 on July 30, 2021.

Juzwiak, C.R., Amancio, O.M.S., Vitalle, M.S.S., Pinheiro, M.M., & Szejnfeld, V.L. (2008). Body composition and nutritional profile of male adolescent tennis players. *Journal of Sports Sciences*, *26*(11), 1209-1217. https://doi.org/10.1080/02640410801930192

Kemmler, W., Roloff, I., Baumann, H., Schöffl, V., Weineck, J., Kalender, W., & Engelke, K. (2006). Effect of exercise, body composition, and nutritional intake on bone parameters in male elite rock climbers. *International Journal of Sports Medicine*, *27*(8), 653-659. https://doi.org/10.1055/s-2005-872828

Koehler, K., Hoerner, N.R., Gibbs, J.C., Zinner, C., Braun, H., De Souza, M.J., & Schaenzer, W. (2016). Low energy availability in exercising men is associated with reduced leptin and insulin but not with changes in other metabolic hormones. *Journal of Sports Sciences*, *34*(20), 1921-1929. https://doi.org/10.1080/02640414.2016.1142109

Kyle, U.G., Bosaeus, I., De Lorenzo, A.D., Deurenberg, P., Elia, M., Manuel Gómez, J., …, & ESPEN. (2004). Bioelectrical impedance analysis—Part II: Utilization in clinical practice. *Clinical Nutrition (Edinburgh, Scotland)*, *23*(6), 1430-1453. https://doi.org/10.1016/j.clnu.2004.09.012

Loucks, A.B. (2013). Energy balance and energy availability. In R.J. Maughan (Ed.) *The Encyclopaedia of Sports Medicine* (pp. 72-87). John Wiley & Sons. https://doi.org/10.1002/9781118692318.ch5

Loucks, A.B., Kiens, B., & Wright, H.H. (2011). Energy availability in athletes. *Journal of Sports Sciences*, *29*(Sup 1), S7-S15. https://doi.org/10.1080/02640414.2011.588958

Mackinnon, L.T. (2000). Chronic exercise training effects on immune function. *Medicine and Science in Sports and Exercise*, *32*(7 Suppl), S369-S376. https://doi.org/10.1097/00005768-200007001-00001

Melin, A.K., Heikura, I.A., Tenforde, A., & Mountjoy, M. (2019). Energy availability in athletics: Health, performance, and physique. *International Journal of Sport Nutrition and Exercise Metabolism*, *29*(2), 152-164. https://doi.org/10.1123/ijsnem.2018-0201

Mermier, C.M., Janot, J.M., Parker, D.L., & Swan, J.G. (2000). Physiological and anthropometric determinants of sport climbing performance. *British Journal of Sports Medicine*, *34*(5), 359-365; discussion 366. https://doi.org/10.1136/bjsm.34.5.359

Merrells, K.J., Friel, J.K., Knaus, M., & Suh, M. (2008). Following 2 diet-restricted male outdoor rock climbers: Impact on oxidative stress and improvements in markers of cardiovascular risk. *Applied Physiology, Nutrition, and Metabolism = Physiologie Appliquee, Nutrition et Metabolisme*, *33*(6), 1250-1256. https://doi.org/10.1139/H08-106

Michael, M.K., Joubert, L., & Witard, O.C. (2019). Assessment of dietary intake and eating attitudes in recreational and competitive adolescent rock climbers: A pilot study. *Frontiers in Nutrition*, *6*, 64. https://doi.org/10.3389/fnut.2019.00064

Michael, M.K., Witard, O.C., & Joubert, L. (2019). Physiological demands and nutritional considerations for Olympic-style competitive rock climbing. *Cogent Medicine*, *6*(1), 1667199. https://doi.org/10.1080/2331205X.2019.1667199

Mountjoy, M., Sundgot-Borgen, J., Burke, L., Carter, S., Constantini, N., Lebrun, C., …, & Ljungqvist, A. (2014). The IOC consensus statement: Beyond the Female Athlete Triad—Relative Energy Deficiency in Sport (RED-S). *British Journal of Sports Medicine*, *48*(7), 491-497. https://doi.org/10.1136/bjsports-2014-093502

Mountjoy, M., Sundgot-Borgen, J.K., Burke, L.M., Ackerman, K.E., Blauwet, C., Constantini, N., …, & Budgett, R. (2018). IOC consensus statement on relative energy deficiency in sport (RED-S): 2018 update. *British Journal of Sports Medicine*, *52*(11), 687-697. https://doi.org/10.1136/bjsports-2018-099193

Nattiv, A., Loucks, A.B., Manore, M.M., Sanborn, C.F., Sundgot-Borgen, J., Warren, M. P., & American College of Sports Medicine. (2007). American College of Sports Medicine position stand. The female athlete triad. *Medicine and Science in Sports and Exercise*, *39*(10), 1867-1882. https://doi.org/10.1249/mss.0b013e318149f111

NIJZ – National Institute of Public Health. (2020). *Referenčne vrednosti za energijski vnos ter vnos hranil, Dopolnjena izdaja 2020.* [Reference values for energy and nutrient intake, updated edition. In Slovenian.] Retrieved from https://www.nijz.si/sites/www.nijz.si/files/uploaded/referencne_vrednosti_2020_3_2.pdf on December 15, 2021.

Owens, D.J., Fraser, W.D., & Close, G.L. (2015). Vitamin D and the athlete: Emerging insights. *European Journal of Sport Science*, *15*(1), 73-84. https://doi.org/10.1080/17461391.2014.944223

Petkus, D.L., Murray-Kolb, L.E., & De Souza, M.J. (2017). The unexplored crossroads of the female athlete triad and iron deficiency: A narrative review. *Sports Medicine (Auckland, N.Z.)*, *47*(9), 1721-1737. https://doi.org/10.1007/s40279-017-0706-2

Petrie, H.J., Stover, E.A., & Horswill, C.A. (2004). Nutritional concerns for the child and adolescent competitor. *Nutrition*, *20*(7), 620-631. https://doi.org/10.1016/j.nut.2004.04.002

Rodenberg, R.E., & Gustafson, S. (2007). Iron as an ergogenic aid: Ironclad evidence. *Current Sports Medicine Reports*, *6*(4), 258-264. https://doi.org/10.1097/01.csmr.0000306481.00283.f6

Sale, C., & Elliott-Sale, K. J. (2019). Nutrition and Athlete Bone Health. *Sports Medicine (Auckland, N.Z.), 49*(Suppl 2), 139–151. https://doi.org/10.1007/s40279-019-01161-2

Sas-Nowosielski, K., & Wycislik, J. (2019). Energy and macronutrient intake of advanced Polish sport climbers. *Journal of Physical Education and Sport*, *19*(Suppl 3), 829-883.

Sheel, A.W. (2004). Physiology of sport rock climbing. *British Journal of Sports Medicine*, *38*(3), 355-359. https://doi.org/10.1136/bjsm.2003.008169

Smith, J.W., Holmes, M.E., & McAllister, M.J. (2015). Nutritional considerations for performance in young athletes. *Journal of Sports Medicine (Hindawi Publishing Corporation)*, *2015*, Art ID 734649. https://doi.org/10.1155/2015/734649

Tenforde, A.S., Fredericson, M., Sayres, L.C., Cutti, P., & Sainani, K.L. (2015). Identifying sex-specific risk factors for low bone mineral density in adolescent runners. *The American Journal of Sports Medicine*, *43*(6), 1494-1504. https://doi.org/10.1177/0363546515572142

Thomas, D.T., Erdman, K.A., & Burke, L.M. (2016). American College of Sports Medicine Joint Position Statement. Nutrition and Athletic Performance. *Medicine and Science in Sports and Exercise*, *48*(3), 543-568. https://doi.org/10.1249/MSS.0000000000000852

Torstveit, M.K., & Sundgot-Borgen, J. (2005). Participation in leanness sports but not training volume is associated with menstrual dysfunction: A national survey of 1276 elite athletes and controls. *British Journal of Sports Medicine*, *39*(3), 141-147. https://doi.org/10.1136/bjsm.2003.011338

Torun, B. (2005). Energy requirements of children and adolescents. *Public Health Nutrition*, *8*(7A), 968-993. https://doi.org/10.1079/phn2005791

Watts, P.B., Joubert, L.M., Lish, A.K., Mast, J.D., & Wilkins, B. (2003). Anthropometry of young competitive sport rock climbers. *British Journal of Sports Medicine*, *37*(5), 420-424. https://doi.org/10.1136/bjsm.37.5.420

Watts, P.B., Martin, D.T., & Durtschi, S. (1993). Anthropometric profiles of elite male and female competitive sport rock climbers. *Journal of Sports Sciences*, *11*(2), 113-117. https://doi.org/10.1080/02640419308729974

Watts, P.B., & Ostrowski, M.L. (2014). Oxygen uptake and energy expenditure for children during rock climbing activity. *Pediatric Exercise Science*, *26*(1), 49-55. https://doi.org/10.1123/pes.2013-0035

Weiss Kelly, A.K., Hecht, S., & Council on Sports Medicine and Fitness. (2016). The Female Athlete Triad. *Pediatrics*, *138*(2), e20160922. https://doi.org/10.1542/peds.2016-0922

Zapf, J., Fichtl, B., Wielgoss, S., & Schmidt, W. (2001). Macronutrient intake and eating habits in elite rock climbers. *Medicine and Science in Sports and Exercise*, *33*, S72. https://doi.org/10.1097/00005768-200105001-00407

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