Sport Sci Health (2017) 13:295–301
DOI 10.1007/s11332-017-0356-7

ORIGINAL ARTICLE

# The impact of adventure racing practice on anthropometry and energy balance of athletes

**Thaiz M. Sureira**[1,2] · **Luiz A. Lopes**[1] · **Olga M. S. Amancio**[1]

Received: 23 August 2016 / Accepted: 25 February 2017 / Published online: 10 March 2017


**Abstract**

*Purpose* The objective was to assess energy expenditure and intake, anthropometric changes and handgrip strength as well as the subjective perception of effort of Adventure Racing athletes before, during and after a national competition circuit.

*Methods* Twenty-one athletes aged 24–48 years were included in the study. Assessments were conducted at five time intervals: interval 1 (30 days before the race), interval 2 (7 days before race), interval 3 (during briefing), interval 4 (at the end of the race), and interval 5 (7 days after the race). The athletes were submitted to anthropometric, handgrip strength, and energy intake and expenditure assessments.

*Results* Between time intervals 3 and 4, we observed a mean weight loss of 1.92 kg, ($p < 0.001$), a decrease in the percentage of fat (mean 0.74%) as well as other anthropometric variables: amount of lean body mass, body mass index and arm muscle area, reflecting a negative energetic balance. Assessment of energy and macronutrient intake presented variation between the time intervals before, during and after the race, in both total consumption and relative consumption.

*Conclusions* The results suggest that adventure racing athletes compete with a negative energy balance and that the race structure directly affects this deficit, as well as food choices during the race.

**Keywords** Running · Energy intake · Energy expenditure · Body weight · Anthropometry

✉ Thaiz M. Sureira
sureira78@gmail.com

1 Departament of Pediatrics, Escola Paulista de Medicina, Universidade Federal de São Paulo, São Paulo, Brazil

2 Núcleo de Ensino Superior do Trairi, Universidade Federal do Rio Grande do Norte, Rua Trairi S/N, Centro, Santa Cruz, Rio Grande do Norte 59200-000, Brazil

## Introduction

Adventure racing (AR) is a sport that is gaining adherents in the world and in Brazil. Starting in the 1980s, in New Zealand, AR may be described as a planned competitive expedition in places that offer the greatest possible diversity of land to enable the practice of activities, such as mountain biking, trekking, paddling, climbing, abseiling, among others [1–4]. AR also includes other skills such as map reading and navigation [5]. Physical fitness, teamwork, emotional control and overcoming limits are required in this competition [1–5]. This modality began in Brazil, in the 1990s, with the organization of the first adventure race, called the Atlantic Forest Expedition (AFE) [6].

The length of the race can vary from a few hours (minimum of 3 h) to more than 10 days [7]. The first team to complete the race course as directed, visiting all the race checkpoints (CPs) and transition areas (TAs) is considered the winning team [8]. The exact course is not released until the day before the event when the athletes receive a topographic map of the region and the race course book with geographic coordinates [9]. ARs may be classified as 'Expedition Races' (1–10 days) or 'Sprint Races' (3–24 h) [1, 10, 11].

The physiological demands on the participants are extreme, forcing a large number to abandon the competition [5, 12]; throughout the race, athletes are subject to a variety of situations ranging from environmental alterations (heat, cold), sleep deprivation, tiredness and fatigue, even a reduction in dietetic and water intake [9]. According to Zimberg et al. [7], ultra-endurance events result in a significant loss of body mass after the competition although there are no specific data on adventure athletes. This is related to the fact that in most ultra-endurance activities, energy intake is lower than expenditure, which results in an energy deficit. However, there is a lack of information on energy balance in AR [4].

Currently, available literature does not incorporate the physiological alterations/adaptations that occur in races. This is probably due to the relatively recent development of the sport and the remote locations of events, and also limitations associated with data collection in the field [8].

These reasons explain the rationale for conducting this study, which aims to assess energy expenditure, energy intake, anthropometric changes and handgrip strength (HGS) of AR athletes before, during and after a national competition circuit held in the interior of Rio Grande do Norte/Brazil.

## Methods

This is a prospective, analytical before-and-after study conducted with 21 athletes (17 men and four women) aged 24–48 years, AR participants in two- or four-person teams with more than three years of practice. This study was approved by the Research Ethics Committee of the Universidade Federal de São Paulo/Escola Paulista de Medicina (#1833/11), with prior written approval from all participants.

The competition chosen was the 13th Expedição Carcará, valid for the Potiguar Adventure Racing Circuit/PARC—2013 and the Brazilian Ranking of Adventure Racing/BRAR, held 21–22 June 2013 (21/06—briefing 10 p.m.; 22/06—start 8 a.m.) in the city of Acarí/RN (local temperature of 35 °C and relative humidity of 32% at the start line). The total course was 77.2 km, consisting of: trekking—34 km, mountain biking—40.7 km, orienteering—1.5 km, swimming—1.0 km. The course had 14 CPs and 9 TAs.

The sample was determined based on two pilot studies conducted in 2012, during the Expedição Carcará and the Desafio Carbono Zero. From the athletes mean weight loss before and after the races (4.0 ± 6.92 kg), the following was established $\alpha = 95\%$ and $\beta = 80\%$ for one-tailed hypothesis, with a result of 16 athletes, selected by convenience.

The athletes were assessed at five time intervals: interval 1 (30 days before the race), interval 2 (7 days before race), interval 3 (during pre-race briefing), interval 4 (at the end of the race), and interval 5 (7 days after the race). At time intervals 1, 2 and 5 the athletes were submitted to anthropometric, handgrip strength, and energy intake assessments; at time interval 3, the athletes were submitted to anthropometric and handgrip strength assessments; at time interval 4, the athletes were submitted to anthropometric, handgrip strength, and energy intake and energy expenditure assessments (both during the race).

For anthropometric measurements, data were collected on weight with electronic scales (Inbody R20, Seoul, Korea) with the athletes wearing race clothing at all the time intervals, on height with stadiometer (Sanny, Sao Paulo, Brazil), on cutaneous folds with scientific adipometer (Cambridge Scientific Industries Inc., Maryland, USA), and arm circumference according to technical standards developed [13]. The body mass index (BMI) was calculated from the data obtained; the Jackson and Pollock (1985) [14] skinfold and Siri (1961) equations were used to estimate body fat percentage and lean body mass, as well as estimating arm muscle area (AMA) [14].

HGS was measured using a Jamar manual dynamometer (Lafayette Instrument Company, Indiana, USA) adopting the standard testing position as recommended by the American Society of Hand Therapists; measurements were taken as recommended by manufacturer and according to protocol by Hornby et al. [15].

Athletes were instructed to fill out food record on three non-consecutive days at time intervals 1, 2 and 5. At the end of the race, athletes responded a food recall questionnaire on consumption during the race. In addition, they were told to keep the packaging of supplements/foods consumed during the competition. Analysis of food consumption was conducted using the software Virtual Nutri 1.0 (University of Sao Paulo, Brazil, 1996). Intake of macronutrients was compared with the recommendations proposed by the American Dietetic Association (ADA) [16].

The basal metabolic rate (BMR) was estimated based on the dietary reference intake (DRI) [17] prediction equations for normal weight men and women, from the data collected on weight, height and age. Energy expenditure during the competition was estimated using the Metabolic Equivalent of Task (MET). The weight of the backpack was added to the weight of each athlete (kg). Subsequently, the MET values of the corresponding activities were determined: trekking, 17,080–6.0 METs; mountain biking, 01009–8.8 METs; orienteering, 17,190–3.5 METs; swimming, 18,300–6.0 METs [18–20]. The duration thereof was determined according to the time sheets for each team.

Initially, data were submitted to the Shapiro–Wilk normality test and subsequently analyzed descriptively. To assess the variation between the periods before, during and after the competition for the variables studied, the

Generalized Estimating Equation (GEE) via an unstructured correlation matrix and a log-linear model was used. In this technique, the hypothesis test used was the Wald Chi-square and Bonferroni post hoc with Cohen's d effect size being used, when applicable, to determine practical and clinical significance which is categorized as trivial ($d \leq 0.10$), small ($d > 0.10$ to <0.3), medium ($d \leq 0.30$ to $\leq 0.5$) and large ($d > 0.5$). Pearson's correlation coefficient was used to estimate the correlation between weight loss and loss of AMA. A significance level of <5% was adopted for all inferential analyses. Data were analyzed using the Statistical Package for the Social Sciences (IBM SPSS Statistics—version 20.0, Illinois, USA).

## Results

After the race, there was a mean weight loss of 1.92 kg ($p < 0.001$), and nine male athletes presented loss above 2.0 kg. Mean weight recovery was 1.48 kg ($p < 0.001$) and six male athletes exhibited above average weight recovery; it is worth noting that these same athletes were part of the group with above average weight loss (Table 1).

In relation to lean body mass, during the race, four male athletes had an above average loss (2.76 kg), yet between intervals 4 and 5 all the athletes assessed had almost recovered to the values presented before the race.

AMA presented significant reduction (end of the race) and improvement (1 week after race), $p < 0.001$ (Table 1). With regards to HGS there were no significant findings, with large increases and decreases in HGS values at the different time intervals (Table 1).

The comparison between energy intake and expenditure showed that the athletes maintained a negative energy balance during the competition, with a mean energy deficit of 19,625.56 ± 7405.71 kJ; mean energy expenditure was 26,056.16 ± 6052.39 kJ, and intake was 5793.27 ± 2953.17 kJ. However, analysis of energy intake at the different time intervals showed that the highest intake occurred at interval 5 (Table 2).

There was a significant increase in carbohydrate intake after the race (Table 2). Different from relativized intake, where greater consumption occurred before the race ($p < 0.001$) (Table 3).

With regards to protein intake, it was greater before and after the race ($p = 0.01$ and $p < 0.01$, respectively)

**Table 1** Comparative analysis of temporal variability before (time interval 3), during (time interval 4) and after (time interval 5) the adventure race of some anthropometric variables in athletes

| Variable | Time intervals | Difference between means | *df* | *p* value[a] | 95% CI | Cohen's *d* |
|---|---|---|---|---|---|---|
| Weight (kg) | 3 vs 4 | 1.92 | 1 | <0.001 | 1.48, 2.36 | 0.75 |
| | 3 vs 5 | 0.44 | 1 | 0.05 | 0.001, 0.88 | 0.19 |
| | 4 vs 5 | −1.48 | 1 | <0.001 | −1.88, −1.08 | 0.66 |
| BMI (kg/m$^2$) | 3 vs 4 | 0.58 | 1 | 0.03 | 0.02, 1.14 | 0.90 |
| | 3 vs 5 | 0.14 | 1 | 0.79 | −0.16, 0,45 | 0.22 |
| | 4 vs 5 | −0.44 | 1 | 0.001 | −0,73, 0.15 | 0.70 |
| Body fat % | 3 vs 4 | 0.74 | 1 | <0.001 | 0.34, 1.15 | 0.81 |
| | 3 vs 5 | 0.20 | 1 | 0.28 | −0.09, 0.50 | 0.21 |
| | 4 vs 5 | −0.53 | 1 | <0.001 | −0.78, −0.29 | 0.60 |
| AMA (mm$^2$) | 3 vs 4 | 826.47 | 1 | <0.001 | 343.39, 1309.55 | 2.58 |
| | 3 vs 5 | −1037.88 | 1 | <0.001 | −1674.95, −400.80 | 3.44 |
| | 4 vs 5 | −1864.36 | 1 | <0.001 | −2779.44, −949.27 | 5.84 |
| Lean body mass (kg) | 3 vs 4 | 1.21 | 1 | <0.001 | 0.81, 1.61 | 0.78 |
| | 3 vs 5 | 0.19 | 1 | 0.97 | −0.27, 0.65 | 0.11 |
| | 4 vs 5 | −1.01 | 1 | <0.001 | −1.46, −0.05 | 0.65 |
| Handgrip strength (kgf) | 3 vs 4 | 2.76 | 1 | 0.12 | −0.46, 6.00 | 1.44 |
| | 3 vs 5 | 2.60 | 1 | 0.26 | −1.04, 6.25 | 1.34 |
| | 4 vs 5 | −0.16 | 1 | 0.99 | −3.82, 3.49 | 0.08 |

All numbers are absolute

*AMA* arm muscle area, *BMI* body mass index, *CI* confidence interval, *df* degrees of freedom

[a] Based on Bonferroni test

**Table 2** Comparative analysis of temporal variability before (time intervals 1 and 2), during (time interval 4) and after (time interval 5) the adventure race of carbohydrate, protein, lipid and energy intake in athletes

| Variable | Time intervals | Difference between means | *df* | *p* value[a] | 95% CI | Cohen's *d* |
|---|---|---|---|---|---|---|
| Carbohydrate (g) | 1 and 2 vs 4 | 36.94 | 1 | 0.99 | −93.45, 167.35 | 0.97 |
| | 1 and 2 vs 5 | −149.10 | 1 | 0.21 | −346.29, 48.08 | 3.51 |
| | 4 vs 5 | −186.05 | 1 | <0.001 | −267.67, −104.43 | 6.15 |
| Protein (g) | 1 and 2 vs 4 | 72.57 | 1 | 0.01 | 10.72, 134.4 | 4.73 |
| | 1 and 2 vs 5 | −10.76 | 1 | 0.99 | −133.50, 111.97 | 0.41 |
| | 4 vs 5 | −83.34 | 1 | <0.01 | −147.41, −19.27 | 5.12 |
| Lipid (g) | 1 and 2 vs 4 | 16.15 | 1 | 0.99 | −27.28, 59.58 | 1.44 |
| | 1 and 2 vs 5 | −14.40 | 1 | 0.99 | −57.29, 28,48 | 1.01 |
| | 4 vs 5 | −30.55 | 1 | 0.72 | −93.02, 31.91 | 2.05 |
| Energy intake (kJ) | 1 and 2 vs 4 | 1148.58 | 1 | 0.90 | −1505.01, 3802.21 | 1.33 |
| | 1 and 2 vs 5 | −4755.63 | 1 | 0.02 | −8968.48, −542.81 | 1.72 |
| | 4 vs 5 | −5904.25 | 1 | <0.01 | −10,022.26, −1786.24 | 4.61 |

All numbers are absolute

*CI* confidence interval, *df* degrees of freedom

[a] Based on Bonferroni test

**Table 3** Difference in macronutrient intake in grams per kilogram of body weight in athletes before (time intervals 1 and 2), during (time interval 4) and after (time interval 5) the adventure race

| Variable | Time Intervals | Difference between means | Standard error | Wald ×2 | *df* | Sig. |
|---|---|---|---|---|---|---|
| Carbohydrate (g/kg of weight) | 4 vs 1 and 2 | −1.54 | 1.05 | 2.16 | 1 | 0.14 |
| | 5 vs 1 and 2 | −2.184 | 0.34 | 66.23 | 1 | <0.001 |
| | 4 vs 5 | 1.29 | 0.97 | 1.74 | 1 | 0.18 |
| Protein (g/kg of weight) | 4 vs 1 and 2 | −1.33 | 0.22 | 36.72 | 1 | <0.001 |
| | 5 vs 1 and 2 | −1.33 | 0.02 | 3221.97 | 1 | <0.001 |
| | 4 vs 5 | −0.01 | 0.21 | 0.001 | 1 | 0.94 |
| Lipid (g/kg of weight) | 4 vs 1 and 2 | 3.73 | 1.71 | 4.74 | 1 | 0.02 |
| | 5 vs 1 and 2 | 18.67 | 0.35 | 2697.12 | 1 | <0.001 |
| | 4 vs 5 | −14.93 | 1.71 | 75.63 | 1 | <0.001 |

All numbers are absolute

*df* degrees of freedom

(Table 2). The intake of relativized protein was also higher before the race ($p < 0.001$) (Table 3).

For lipid intake, there was no significant difference between time intervals (Table 2), yet in the assessment of relative lipids, we identified significantly increased intake after the race ($p < 0.001$) (Table 3).

## Discussion

Analyzing the results we observed a significant decrease in body weight, BMI, body fat percentage, AMA and lean mass between time intervals 3 and 5, which reflected the negative energy balance brought about by the competition.

Regarding weight loss during ultra-endurance competitions, the duration of the race seems to have an influence; in longer events rest periods are scheduled, which may reduce weight loss. In one of the stages of the study by Enqvist et al. [4], no significant loss of body weight in athletes was observed during a 5-day AR, whereas in the present study, mean weight loss was 1.92 kg in a 10-h race, without rest periods. Another fact to be considered in the comparison with results of simulation studies is that inherent factors already mentioned in this study affect field practice, interfering directly with weight loss, either through insufficient energy intake, insufficient fluid intake or due to high loss of body water. The study by Zimberg et al. [7] based on AR simulation lasting about 67 h showed significant weight loss (0.75 ± 1.0 kg). Compared to the results of this study we acknowledged the likely influence of the 'outdoor factor' on this variable [4].

We observed variations in weight loss among the athletes, which can be explained through the roles that each one plays on the team. Still, the same increase in energy intake and decrease in energy expenditure in the week following the race were reported, possibly due to an attempt to establish a positive energy balance for weight recovery.

Evaluating the percentage of body fat and the amount of lean body mass (Table 1), the use of skinfolds may have been influenced by the presence of edema resulting from the very long competition [21], or even through a dehydration process that athletes may have developed during the race. Given that, associated to possible insufficient water intake and weather conditions on the race day contributed to the development of a dehydrated state in athletes; this may influence skinfold thickness, altering the values collected during the race, as well as the comparisons of these results at the time intervals. However, similar to the results obtained in this study on loss of body fat during competition (0.76 kg), Enqvist et al. [4] observed in a 24-h simulation stage, a mean body fat loss of 0.9 kg. The aim of body fat stores, in athletes who practice ultra-endurance sports, is to preserve endogenous glycogen reserves for metabolically demanding stages, among other functions [22].

The measurement of AMA (Table 1) showed that athletes presented significant loss after the race and full recovery of this measure within one week after the event, with significant increase. Thus, this measurement may provide an accurate and precise technique to assess body composition, especially given the difficulties of using more accurate techniques in the field; moreover, AMA is less expensive and shows good accuracy for application in such a situation [23]. Reinforcing this finding, we identified moderate correlation ($r = 0.70$) between the difference of AMA at intervals 3 and 5 with weight loss. A similar result was reported by Witt& Bush [24], where AMA was positively related to BMI in most athletes. So, the monitoring of AMA in athletes could be used as an indicator of weight change and nutritional status.

Mean carbohydrate intake during the race was much lower (0.46 g/kg/h) than that found by Zimberg et al. [7] (0.48 g/kg/h), and the recommended intake for prolonged exercise (ADA) [16], 0.7 g/kg/h, approximately 30–60 g/h, such a situation may have influenced the performance of athletes. Furthermore, Burke et al. [25] consider that adequate intake of carbohydrate for ultra-endurance is 0.5–1.0 g/min., in our study the mean was 0.57 g/min., close to the lower limit of the recommendation which may have affected the performance of participants [7]. Similarly, prior to the competition mean consumption was 4.03 ± 2.06 g of carbohydrate/kg, well below ADA recommendations (7–8 g/kg/day) [16]; and that suggested by Burke, Hawley, Wong, and Jeukendrup [26] for intermittent exercise lasting more than 90 min, for which athletes should consume 10–12 g of carbohydrate/kg/day in the 36–48 h prior to exercise. The reason for this is that in longer activities, carbohydrate improves performance, especially in preventing hypoglycemia [27]. Carbohydrate intake after the race was 4.71 ± 2.27 g of carbohydrate/kg, without special consumption strategy for the 6 h after completion of the race, as recommended by ADA [16] or even reaching intake recommendations. In this case, athletes reported only having a meal, as soon they had rested and showered. However, consumption of a meal or snack near the end of exercise may be important for athletes to reach the daily goals of energy and carbohydrate intake [16].

According Zalcman et al. [12] during intensive training, adequate carbohydrate and protein intake is recommended to maintain body mass, restore muscle glycogen stores and provide an adequate amount of amino acids. Protein intake was lower during the race (Table 2); this was because most of the foodstuffs in the backpacks were a source of carbohydrates (boiled potato, carbohydrate gel, biscuits and bread). Protein intake was restored after the race. However, relative protein intake (Table 3) was significantly higher before the race, compared to other time intervals. Generally, athletes show adequate protein intake before and after the race, according to recommendations by ADA [16] for endurance sports (1.2–1.4 g/kg/day).Nevertheless, consumption during the race does not even meet the Recommended Dietary Allowances (RDA) [17] for non-athlete healthy adults (0.8 g/kg/day). The fact that protein metabolism during and after exercise is affected by gender, age, intensity, duration and type of exercise, energy intake and carbohydrate availability, should be highlighted [18]. In one study, Zimberg et al. [7] reported that mean protein energy intake was 12%, while this study showed a mean intake of 10.32% (±4.15) during the race, meeting the minimum established by the RDA, where protein energy intake for adults is 10–35% of total energy [17]; however, we must remember that this percentage was calculated based on insufficient energy intake relative to expenditure.

Regarding the consumption of lipids, the athletes maintained their intake unchanged even during the competition (Table 2); again this is due to the selection of foods carried during the race. The athletes themselves reported that as this race was short (not allowing stops for food) their foods (nuts) were high energy density (easier to carry). Mean lipid intake was 30.56% of total energy intake during the competition; confirming the result of 29% in the study by Zimberg et al. [7]. During the race this intake was established in a negative energy balance. When lipid intake was analyzed (Table 3), there was a significant increase after the race. Qualitative analysis of the athletes' food choices, showed clear preference for high calorie density/lipid-content foods, to regain weight lost during the competition, according to the athletes' reports. Athletes should follow the general recommendations [16] of 20–35% of total energy intake. Hence, they kept an appropriate mean lipid intake in the time intervals before (36.15%), and after (31.62%) the race.

In the time intervals during the race, there was no difference in energy intake; however, all the athletes remained in negative energy balance during the race due to high energy expenditure (584.07 kcal/h). AR studies report an energy expenditure of 365 kcal/h [7] in simulation, and 525 kcal/h [4] in real situations, contributing to a negative energy balance.

In the experiment by Enqvist et al. [4] (24-h exercise), energy deficit was greater than 50% of total energy expenditure, and Zimberg et al. [7] identified a deficit of 9779 kcal (40%). Energy deficit in this study was 407.27%, much higher than that in the cited studies, which can be explained through the duration of the race, preventing the athletes from scheduling food stops and restriction on the variety of food carried in backpacks [7]. It is important to highlight that energy deficit during ultra-endurance activities may be aggravated by decreased appetite [4], as well as gastrointestinal problems (not reported by the athletes in this study, only by those in the pilot study) [19].

It is worth pointing out that the Compendium of Physical Activities was developed to improve the comparability of the results between studies using self-reported physical activity, being only used to determine energy expenditure and the amount of time athletes spend on exercise, since this instrument estimates energy expenditure according to activity type [19, 20]. However, this instrument was not developed to determine exact energy expenditure of a physical activity within individuals; it is a classification system that standardizes the MET intensities of the physical activities used in this study, since due to the characteristics of the competition and resource limitation it was not possible to carry out another type of procedure. The values in the Compendium do not consider differences in body mass, adiposity, age, gender, geographic and environmental conditions in which the activities are performed [19]. However, in the estimation of athletes' basal metabolism the predictive formula used considers gender, age, weight and height, and when added to energy expenditure of activities performed based on the Compendium, we may consider it an attenuator for such limitation.

Energy intake after the race increased significantly, and according to reports, to regain the weight lost during the event. The study by Zalcman et al. [12] evaluated athletes' energy intake during usual AR training, and found that intake was 44.6 kcal/kg in men and 48.1 kcal/kg in women. Although in this study, intake during training periods was lower than that reported in the study cited above (26.54 kcal/kg before the race, and 36.72 kcal/kg after), it cannot be said that energy intake before and after the race was inadequate; as it was not possible to apply any method to estimate energy expenditure at these time intervals and equalize the athletes' energy balance.

The results showed that AR athletes compete in negative energy balance and that the structure of the race, as well as food choices, directly affects this deficit, impacting negatively on the anthropometric profile which can affect the performance of these athletes. Moreover, food planning before, during and after the race is made without professional supervision, resulting in inadequate macronutrient intake.

**Acknowledgements** First, we would like to thank the organizers of the Adventure Racing events (Expedição Carcará and Desafio Carbono Zero), which served as the setting for the collection of data for the pilot project and this study, and all the athletes who agreed to participate. We would also like to thank the management at the Faculty of Health Sciences, Trairi, Universidade Federal do Rio Grande do Norte (UFRN) for their support in carrying out this study.

**Compliance with ethical standards**

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethical approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

**Informed consent** Informed consent was obtained from all individual participants included in the study.

## References

1. Townes DA (2005) Wilderness medicine: strategies for provision of medical support for adventure racing. Sports Med 35:557–564. doi:10.2165/00007256-200535070-00001
2. Anglem N, Lucas SJ, Rose EA, Cotter JD (2008) Mood, illness and injury responses and recovery with adventure racing. Wilderness Environ Med 19:30–38. doi:10.1580/07-WEME-OR-091.1
3. Kerr JH, Mackenzie SH (2012) Multiple motives for participating in adventure sports. Psychol Sport Exerc 13:649–657. doi:10.1016/j.psychsport.2012.04.002
4. Enqvist JK, Mattsson CM, Johansson PH, Brink-Elfegoun T, Bakkman L, Ekblom BT (2010) Energy turnover during 24 hours and 6 days of adventure racing. J Sports Sci 28:947–955. doi:10.1080/02640411003734069
5. Fordham S, Garbutt G, Lopes P (2004) Epidemiology of injuries in adventure racing athletes. Br J Sports Med 38:300–303. doi:10.1136/bjsm.2002.003350

6. dos Santos G, Pastre CM, do Amaral SL, Monteiro HL (2009) Adventure race's injuries. Science Sports 24:15–20. doi:10.1016/j.scispo.2008.04.005
7. Zimberg IZ, Crispim CA, Juzwiak CR, Antunes HK, Edwards B, Waterhouse J et al (2008) Nutritional intake during a simulated adventure race. Int J Sport Nutr Exerc Metab 18:152–168
8. Lucas SJ, Anglem N, Roberts WS, Anson JG, Palmer CD, Walker RJ et al (2008) Intensity and physiological strain of competitive ultra-endurance exercise in humans. J Sports Sci 26:477–489. doi:10.1080/02640410701552872
9. Clark N, Tobin JJ, Ellis CJ (1992) Feeding the ultraendurance athlete: practical tips and a case study. J Am Diet Assoc 10:1258–1262
10. Peters EM (2003) Nutritional aspects in ultra-endurance exercise. Curr Opin Clin Nutr Metab Care 4:427–434
11. Townes DA, Talbot TS, Wedmore IS, Billingsly R (2004) Event medicine: injury and illness during an expedition-length adventure race. J Emerg Med 27:161–165. doi:10.1016/j.jemermed.2004.02.018
12. Zalcman I, Guarita HV, Juzwiak CR, Crispim CA, Antunes HK, Edwards B et al (2007) Nutritional status of adventure racers. Nutrition 23:404–411. doi:10.1016/j.nut.2007.01.001
13. Lohman TG, Roche AF, Martorell R (1988) Anthropometric standardization reference manual. Human Kinetics, Champaign, IL
14. Jackson AS, Pollock ML (1985) Practical assessment of body composition. Phys Sports med 13:76–90
15. Hornby ST, Nunes QM, Hillman TE, Stanga Z, Neal KR, Rowlands BJ et al (2005) Relationships between structural and functional measures of nutritional status in a normally nourished population. Clin Nutr 24:421–426. doi:10.1016/j.clnu.2005.01.002
16. American Dietetic Association (2000) Position of the American Dietetic Association, Dietitians of Canada, and the American College of Sports Medicine: nutrition and athletic performance. J Am Diet Assoc 100:1543–1556
17. Trumbo P, Schlicker S, Yates AA, Poos M, Food and Nutrition Board of the Institute of Medicine, The National Academies (2002) Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein and amino acids. J Am Diet Assoc 102:1621–1630. doi:10.1016/S0002-8223(02)90346-9
18. Ainsworth BE, Haskell WL, Leon AS, Jacobs DR Jr, Montoye HJ, Sallis JF et al (1993) Compendium of physical activities: classification of energy costs of human physical activities. Med Sci Sports Exerc 25:71–80
19. Ainsworth BE, Haskell WL, Whitt MC, Irwin ML, Swartz AM, Strath SJ et al (2000) Compendium of physical activities: an update of activity codes and MET intensities. Med Sci Sports Exerc 32:S498–S504
20. Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Bassett DR Jr, Tudor-Locke C et al (2011) Compendium of physical activities: a second update of codes and MET values. Med Sci Sports Exerc 43:1575–1581. doi:10.1249/MSS.0b013e31821ece12
21. McLaughlin KA, Townes DA, Wedmore IS, Billingsley RT, Listrom CD, Iverson LD (2006) Pattern of injury and illness during expedition-length adventure races. Wilderness Environ Med 17:158–161. doi:10.1580/PR29-05
22. Jeukendrup AE (2002) Regulation of fat metabolism in skeletal muscle. Ann N Y Acad Sci 967:217–235. doi:10.1111/j.1749-6632.2002.tb04278.x
23. Hogrel JY (2015) Grip strength measured by high precision dynamometry in healthy subjects from 5 to 80 years. BMC Musculoskelet Disord 16:139. doi:10.1186/s12891-015-0612-4
24. Witt KA, Bush EA (2005) College athletes with an elevated body mass index often have a high upper arm muscle area, but not elevated triceps and subscapular skinfolds. J Acad Nutr Diet 105:599–602. doi:10.1016/j.jada.2005.01.008
25. Burke LM, Loucks AB, Broad N (2006) Energy and carbohydrate for training and recovery. J Sports Sci 24:675–685. doi:10.1080/02640410500482602
26. Burke LM, Hawley JA, Wong SH, Jeukendrup AE (2011) Carbohydrates for training and competition. J Sports Sci 29:S17–S27. doi:10.1080/02640414.2011.585473
27. Jeukendrup A (2014) A step towards personalized sports nutrition: carbohydrate intake during exercise. Sports Med 44:S25–S33. doi:10.1007/s40279-014-0148-z