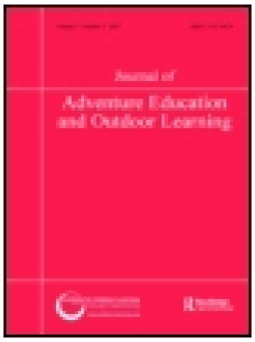

Journal of Adventure Education and Outdoor Learning

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/raol20

# Energy balance during outdoor education winter training: a pilot study

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JOURNAL OF ADVENTURE EDUCATION AND OUTDOOR LEARNING
https://doi.org/10.1080/14729679.2023.2196639



# Energy balance during outdoor education winter training: a pilot study

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**ABSTRACT**

Learning in the mountains during winter prepares upcoming guides for tough environments by placing demands on their energy intake and enabling them to cope with a complex environment. However, few studies have explored energy intake and expenditure in outdoor education. Thus, energy intake during a 24-hour winter mountain course was investigated in a Norwegian educational context, where students must absorb large volumes of information in a challenging environment. Twenty university students (11 men, 9 women) underwent body composition, weighed energy intake, and accelerometry-based energy expenditure measurements. Overall, the students had an energy deficit of>2,300 kilocalories/day, corresponding to an energy balance of 62% for men and 54% for women ($p > 0.05$), despite having received lectures on energy requirements in advance. This sustained stress context combined with challenging environmental conditions and insufficient energy intake can predispose students to early exhaustion, injury risk, and potentially reduced information processing that may limit learning.

**ARTICLE HISTORY**
Received 25 July 2022
Accepted 7 March 2023

**KEYWORDS**
Energy expenditure; energy intake; outdoor activities; winter mountains

## Introduction

*Friluftsliv* (meaning ‘free air life’/”open air life”/”nature life”) is a Scandinavian term with historical traditions dating to the 1800s (Breivik, 2021). *Friluftsliv* is commonly described as staying in, or being physically active in nature, and is characterized by a sense of exuberance (Breivik, 2021). In Norway, *friluftsliv* was introduced into the school-based educational setting in 1939 (Haslestad, 2002) and is strongly present in descriptions of physical education, which were renewed in 2020 (The Directorate for Education and Training, 2021). As such, *friluftsliv* is performed at every Norwegian school in some form during the school year. A key *friluftsliv* learning goal in the 7$^{th}$ and 10$^{th}$ grades of junior high school is to travel to and dwell in diverse types of natural environments in different seasons. After the 10$^{th}$ grade, the students must be able to perform risk assessments and travel safely in the outdoors (The Directorate for Education and Training, 2021). In high school, *friluftsliv* is practiced throughout the school year. Furthermore, most universities in Norway offer *friluftsliv* as a one-year, bachelors or masters degree (Studentum, 2021). Historically, dating to the history of explorers Fridtjof Nansen and Roald Amundsen, wintertime *friluftsliv* in Norway’s high mountains has had a strong position in outdoor education, especially at high schools and universities. However, traveling in mountainous areas during wintertime is not without risks because the environment is both challenging and complex, and can include rough, steep terrain, cold climates, and changing weather conditions (Beals et al., 2019). Students must learn to master such scenarios quickly and be able to cover their basic needs.

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However, spending time in these environments requires extra knowledge among both teachers and students. Traditionally, outdoor education students learn through a mix of experiential learning and information assimilation (Priest & Gass, 2018). Topics like nutrition requirements are often taught in advance, through theoretical teaching, before spending time in nature. Food and fluid requirements are especially important topics, as they are basic needs, and not meeting them can have both physiological and psychological impacts (Mountjoy et al., 2014, 2018). Furthermore, energy requirements increase during the winter (Beals et al., 2019). In both sports and military settings, it is well-known that insufficient energy intake negatively impacts physiology and can lead to early fatigue, poor recovery, and increased risk of illness and injury. It can also impact cognition, including reducing decision-making, cognitive restraints, and exuberance (Beals et al., 2019; Friedl et al., 2000; Jensen et al., 2019; Jurov et al., 2021; Kyrolainen et al., 2008; Mountjoy et al., 2014; Nindl et al., 2007). However, current research has investigated populations that differ vastly from outdoor educational students; thus, it is unknown whether their methods or results generalize to these student populations.

In this pilot study, we aimed to investigate how well university Outdoor Education students can prepare for and execute a harsh winter course by examining their energy balance during a multiday winter mountain field trip to the Norwegian high mountains. The study was performed to better understand how: 1) students used their theory-based knowledge about energy requirements; and 2) whether previous methods for estimating energy balance are feasible for use with this population.

## Methods

### Study design

We used a cross-sectional study design. Before the field trip, students received a theory-based lecture on campus about how to prepare for a challenging winter skiing field trip in the Norwegian high mountains. This lecture included detailed information on energy requirements and recommended food and fluid intakes. Anthropometrics were measured before departure. Measurements of energy intake through foods and fluids, and energy expenditure via accelerometry, were performed during the first 24 hours of a three-day field trip. The study protocol was approved by the faculty's ethical committee (FEK no. 19/09431) and the Norwegian Center for Research Data (NSD no. 388140). The protocol was performed in accordance with the 2013 Helsinki Declaration.

### Participants

The inclusion criterion was that participants had to be enrolled in a university-level outdoor education program in Norway. Initially, all students from one program (24 students) were invited and received information about the study. Twenty students (9 women, 11 men) volunteered to participate (overall sample mean ± standard deviation [SD]: age, 21.9 ± 2.3 years; height, 176.6 ± 8.5 cm; body weight, 77.5 ± 11.5 kg). Prior to inclusion, students received verbal and written information about the study and test procedures and gave their informed consent.

### Theory-based lecture

Two weeks before the field trip, students received a 90-minute theoretical lecture on campus about how to prepare for a challenging winter skiing field trip in the Norwegian high mountains. The lecture was held in a classroom with PowerPoint slides (Microsoft Corp, Redmond, WA, USA) for visual aids. The lecture provided detailed descriptions of expected energy requirements and relevant information on appropriate energy-rich foods for outdoor winter travel and dwelling.

### *Body composition*

Three days before departure, students' heights were measured without shoes to the nearest 0.1 cm using a wall-mounted centimeter scale (Seca Optima, Seca, Birmingham, UK). Body weight was measured in underwear to the nearest 0.01 kg using an electronic scale (Seca 1, Model 861; Seca). Body mass index (BMI) was calculated as body weight divided by height squared ($kg/m^2$). Body composition, including fat-free mass (FFM) and percentage of body fat, was measured via bioimpedance using Inbody 720 (Inbody Co., Ltd., Biospace, Seoul, Korea). All measurements were performed between 8 a.m. and 10 a.m. according to current standards (Kyle et al., 2004).

### *Field trip procedures and measurements*

Upon arrival, students were given a plastic bag with instructions to store all their used food packaging within it and to seal it after 24 hours. They also had an accelerometer attached to their arm before departure. All materials were collected after 24 hours. Elevation profiles were found using a Foretrex 601 global positioning system (Garmin International Inc., Olathe, KS, USA).

### *Energy intake through foods*

The students registered their food intake for 24 hours. Verbal instructions were given well in advance of departure and the students were instructed to use the nutrition knowledge they had been taught at the 90-minute lecture two weeks before departure (described above) by reviewing and preparing their meals based on a demanding winter educational course. The students were encouraged to bring the original food packaging, which made registration and logging easier. If students brought home-cooked food, they were asked to weigh and record the amount and type of food that each portion contained. After the food had been consumed, the students were asked to put the empty packaging in the plastic bag they had been given at departure, and to log the amount and type of food and drink on paper. The used packaging and logs were collected after 24 hours. The food log was then checked for missing information in relation to the discarded food packaging, and the students were contacted for follow-up questions if discrepancies were found. All dietary data were analyzed using Dietist Net software (Dietist Net, Diet and Nutrition Data, Bromma, Sweden) with access to the Norwegian nutrition table, as well as an open Norwegian nutrition information database.

### *Energy expenditure through activity*

Energy expenditure was examined using the SenseWear Pro accelerometer with associated software (SWA, software version 8.1; BodyMedia, Pittsburgh, PA, USA). Energy expenditure was calculated using the built-in proprietary algorithm which includes height, weight, age, and gender, in combination with accelerometry, galvanic skin response, heat exchange, and skin temperature. Energy expenditure per hour was downloaded from the device and expressed in kilocalories (kcal). The SWA was placed around the triceps of the nondominant arm, and students were asked to use the SWA over a 24-hour period, including during sleep.

### *Statistics*

Data were analyzed using RStudio (RStudio, version 1.3.1093; PBC, Boston, MA, USA). The dataset was checked for missing data and signs of abnormal distribution using histograms as a reference, as well as the Shapiro—Wilk normal distribution test. All data were considered normally distributed and are presented as mean ± SD, unless otherwise stated. Between-group differences on continuous data were assessed using the Welch *t*-test for unequal variance. Statistical significance was defined as $p <$

**Table 1.** Sample characteristics.

| | Overall sample ($n = 20$) | Men ($n = 11$) | Women ($n = 9$) | Effect size |
|---|---|---|---|---|
| Age (years) | 21.9 ± 2.3 | 21.9 ± 1.9 | 21.8 ± 2.7 | 0.05 |
| Height (cm) | 176.5 ± 8.5 | 181.9 ± 4.8 | 169.9 ± 7.4*** | 1.96 |
| Body weight (kg) | 77.5 ± 11.5 | 83.6 ± 12.2 | 70.1 ± 4.1** | 1.43 |
| BMI (kg/m$^2$) | 24.9 ± 3.3 | 25.3 ± 4.1 | 24.3 ± 2.0 | 0.28 |
| FFM (kg) | 59.6 ± 11.2 | 68.1 ± 6.3 | 49.2 ± 5.2*** | 3.24 |
| Body fat (%) | 23.1 ± 9.3 | 17.8 ± 8.1 | 29.6 ± 6.3** | 1.61 |

BMI, body mass index; FFM, fat-free mass. Effect size expressed as Cohen's d. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

0.05 and data are presented as mean ± SD, with Cohen's *d* to indicate effect size (Cohen, 1988) as trivial (<0.2), small (0.2–0.5), moderate (0.5–0.8), or large (>0.8).

## Results

Descriptive data are presented in Table 1. Figure 1 shows the elevation profile of the route to the site of the snow cave digging, with an inclination of 220 meters over approximately 2.3 kilometers.

### *Energy intake and expenditure*

Discrepancies between energy intake and expenditure differed significantly between women and men (differences of 43% and 31%, respectively). No significant gender difference in energy balance was found. At the macro level, significant gender differences were found on carbohydrates (26%) and fat (62%), but not protein (Table 2).

Energy expenditure was highest in the period from departure to completion of the snow cave (day one, from 1 p.m. to 10 p.m.). The lowest activity was at rest between 12 a.m. and 6 a.m. on day two (Figure 2).

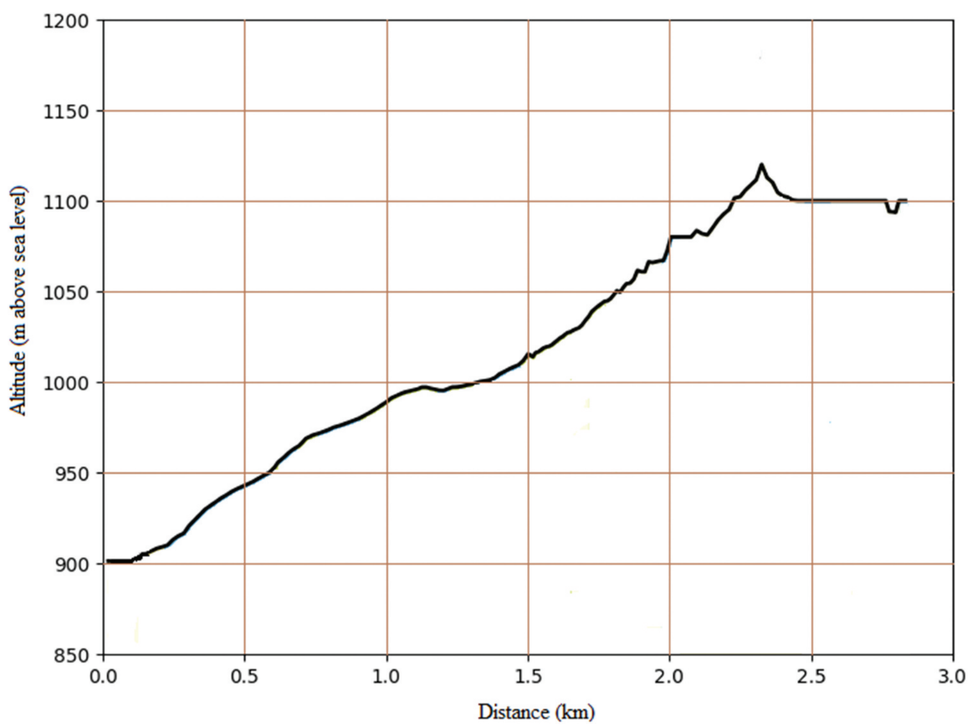


**Figure 1.** Elevation profile from the start of the route to the snow cave digging site.

**Table 2.** Energy intake and expenditure, and macronutrients.

| | Overall sample ($n = 20$) | Men ($n = 11$) | Women ($n = 9$) | Effect size |
|---|---|---|---|---|
| Energy intake (kcal) | 3,145 ± 1,528 | 3,746 ± 1,749 | 2,410 ± 788* | 0.95 |
| Energy expenditure (kcal) | 5,460 ± 1,083 | 6,219 ± 843 | 4,533 ± 371*** | 1.49 |
| Energy balance (kcal) | −2,315 ± 1,608 | −2,472 ± 2,044 | −2,123 ± 916 | 0.21 |
| Energy balance (%) | 57.9 ± 24.4 | 61.5 ± 29.0 | 53.6 ± 17.9 | 0.32 |
| Carbohydrates (g) | 348 ± 107 | 389 ± 114 | 298 ± 77.2* | 0.91 |
| Relative carbohydrates (g/kg) | 4.5 ± 1.4 | 4.8 ± 1.6 | 4.2 ± 0.9 | 0.38 |
| Protein (g) | 108 ± 73 | 126 ± 84 | 86.3 ± 54.1 | 0.55 |
| Relative Protein (g/kg) | 1.4 ± 0.9 | 1.6 ± 1.1 | 1.2 ± 0.7 | 0.35 |
| Fat (g) | 138 ± 100 | 177 ± 119 | 91.2 ± 38.3* | 0.92 |
| Relative fat (g/kg) | 1.8 ± 1.3 | 2.2 ± 1.6 | 1.3 ± 0.5 | 0.71 |

Effect size expressed as Cohen's *d*. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

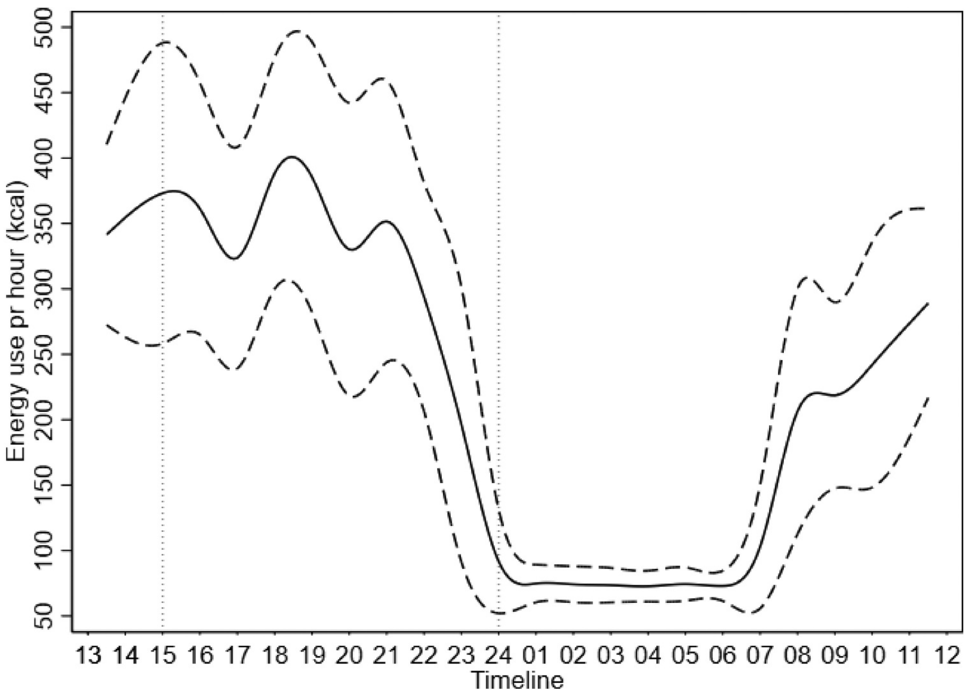


**Figure 2.** Hourly energy expenditure over 24 hours using the ISO8604 24-hour clock. Solid line shows average energy expenditure for the entire sample (n = 20) as kcal/hour ± SD (dashed lines). Vertical dotted line at 1500 hours (3 p.M.) shows time of arrival at the snow cave digging site; line at 2400 (midnight) hours shows the difference between days one and two.

## Discussion

Dwelling for multiple days in mountainous regions during the winter presents unique physiological and psychological challenges, and places great demand on covering basic needs like nutrition. This is essential to maintain optimal concentration, performance, and learning (Beals et al., 2019; Friedl et al., 2000; Jensen et al., 2019; Kyrolainen et al., 2008; Nindl et al., 2007). These challenges are important to recognize in an educational setting, as teachers or guides should seek to maximize their students' or clients' learning. The purpose of this pilot study was to examine energy intake and expenditure during the first 24 hours of a four-day winter education course for Norwegian outdoor students to investigate how they use theory-based knowledge delivered in advance.

During the first 24 hours of the course, these students experienced large energy deficits, initiated by a sharp increase in energy expenditure during skiing and snow cave preparations. This large negative energy balance illustrated that students did not use the theory-based knowledge they had been taught in advance. Such imbalances may lead to increased physiological stress and predispose students to premature fatigue, risk of injury, diminished cognition, and reduced enthusiasm (Beals et al., 2019; Friedl et al., 2000; Jensen et al., 2019; Kyrolainen et al., 2008; Nindl et al., 2007). These are all unwelcome consequences in an educational setting within a challenging environment.

### *Energy intake and expenditure during high intensity winter activities*

There is a limited literature describing winter energy intake requirements in outdoor educational settings. Horgen (2009) refers to an assumption that energy expended during winter activities is 3,500–4,000 kcal/day. The basis for these values is out dated and not readily available for interpretation. Among military personnel who perform demanding training and operations ranging from days to weeks, several studies have shown an average energy consumption of 4,565–4,920 kcal/day, primarily due to traveling across demanding terrains, weather conditions, carrying heavy backpacks and equipment, over long distances (Beals et al., 2019; Hoyt et al., 2001; Margolis et al., 2014; Mullie et al., 2019). Despite assessing varying populations, there are commonalities among these studies. They included similar methods of transportation during demanding conditions, the establishment of living quarters in a challenging natural environment, the need to carry a heavy backpack, and similar energy consumption assessments.

Herein, the students' average energy consumption was 5,460 ± 1,083 kcal (6,219 ± 843 kcal for men, 4,533 ± 371 kcal for women). As Figure 2 shows, energy expenditure was relatively constant from the start of the field trip to the site where sleeping quarters were established (snow caves) several hours later. Energy expenditure during this physical activity was~350 ± 70 kcal/hour, regardless of activity type. Our results are thus consistent with previous research on soldiers, showing that these students were unable to compensate for their energy expenditure, regardless of physical activity type, which alternated between moderate and vigorous (Haskell et al., 2007). Among military personnel, negative energy balance (from −740 – −1,433 kcal/day) is often observed during very demanding qualification tests in Belgium, New Zealand, and the USA, and during military exercises in Finland (Beals et al., 2019; Friedl et al., 2000; Kyrolainen et al., 2008; Mullie et al., 2019). Furthermore, several studies examining the physiological consequences of an excessive energy deficit (i.e.~1,000 kcal/day or more) have shown decreases in body composition, performance, and hormone concentrations over time (Friedl et al., 2000; Jensen et al., 2019; Kyrolainen et al., 2008; Nindl et al., 2007). In comparison, the students herein had an average energy deficit of–2,315 ± 1,608 kcal (men: −2,472 ± 2,044, women: −2,123 ± 916 kcal). Although military studies have often assessed a longer period compared with ours, even a large short-term negative energy balance can impact both physiology and psychology, and requires greater recovery (Logue et al., 2018; Mountjoy et al., 2014, 2018). Participating students were unable to compensate for their increased energy expenditure, and thus ended up with an energy deficit after the first 24 hours of an educational course of over 2,000 kcal, corresponding to~50–60% of their total energy requirements.

### *Learning outcomes*

As described earlier, the aim of the university outdoor education program, including the winter field trip, is to train future guides to lead school outdoor education programs. The learning outcomes of such field trips are twofold. First, the students must learn to properly prepare for challenging field trips. Second, they must learn to overcome multiple hazards in mountainous terrain.

Herein, it is interesting to observe that although the students received a 90-minute theory-based lecture two weeks before the field trip and were more than eight months into an education program that included multiple field trips, they seriously underestimated the energy requirements of traveling across complex terrain. In fact, specific details about energy requirements were described and foods were recommended in advance. While the current study cannot definitively explain the students' choices, we can speculate. Outdoor education in Norway is strongly inclusive of experiential learning (Hofmann et al., 2018). In contrast, university lectures often use information assimilation (Priest & Gass, 2018). Despite being more time efficient, it has been argued that information assimilation is less effective for achieving learning outcomes compared with experiential learning (Coleman, 1982; Priest & Gass, 2018). Whether this was case herein is unknowable, but these data certainly demonstrate that the lecture did not translate into proper field trip planning as intended. Despite data showing that information assimilation is less effective for learning, it is nevertheless a common approach to safety and preparation throughout Norway's outdoor education programs. This study thus reveals several new questions for future investigations, such as ensuring that students are well-prepared and to investigate the impact on students when in an energy deficit state.

### Practical implications

Overall, it is concerning that students attending a one-year study program in outdoor education showed a large energy deficit during a demanding winter field trip, as this can affect both their physiological and cognitive functioning (Mountjoy et al., 2014, 2018). The environment in which these students are trained can be both challenging and stressful, with potentially unfamiliar activities like skiing with a heavy pack or digging snow caves. Furthermore, students are asked to engage in moderate-to-vigorous physical activity (Haskell et al., 2007) for 8–10 consecutive hours, and may underestimate the energy required to participate in such a demanding winter educational course, despite receiving advance information.

Inexperience may also play a role. As it is noticed that over time, fewer students in such courses have previously experienced dwelling in harsh conditions, especially during the wintertime. Even though both the course syllabus and lectures include topics on recommended nutrition for winter activities, and several students in this sample had backgrounds in nutrition and/or sports, only three of 20 students (15%) satisfactorily met their energy needs (i.e. energy balance>90%). We speculate that these students underestimated the importance and did not apply the knowledge they were given in the lectures. Thus, future studies should examine this issue specifically. Indeed, the primary goal of outdoor education is to maximize student learning outcomes, which includes ensuring they are well-prepared and increasing their exuberance. As Horgen (2009) wrote '*by exuberance I mean that you have the time, desire and energy to learn from and reflect on the situations that arise*.' In our opinion, energy intake that is too low during such courses will not help student fulfill this.

The findings herein thus reveal several new questions. Do students fail to translate theoretical framework into practice in a context in which concentration, learning ability, and exuberance are important? Do they forget the information they learned and instead focus on the demanding task ahead in a complex winter environment? Are the current teaching methods best suited to the learning outcomes? Answering these important questions will likely improve teaching and optimize learning. Posing these questions is also important because many students later become outdoor educators or work in the outdoor industry as teachers or guides.

### Strengths and limitations

This study had both limitations and strengths. First, as a cross-sectional study, it cannot be used to deduce causal relations. Second, though it did not investigate how or why students did not appear to apply their theoretical knowledge, it does support the need for further investigations. Third, research on energy intake during prolonged stressful activities has mostly been performed in soldiers (Beals et al., 2019; Friedl et al., 2000; Hoyt et al., 2001; Jensen et al., 2019; Kyrolainen et al., 2008; Margolis et al., 2014; Mullie et al., 2019; Nindl et al., 2007) and athlete populations (Logue et al., 2018; Mountjoy et al., 2014, 2018), raising questions as to whether these generalize to outdoor education contexts. However, this study shows that the methods are well suited for this context. Fourth, though energy intake is notoriously difficult to measure, we used the validated gold-standard method of weighing or precisely measuring foods before and during activity (Bingham et al., 1995). Further, the researchers were available to the students during data collection; therefore, any questions about the data could be quickly verified in the field. Overall, this study was a pilot project as far as it only examined the first 24 hours of a four-day education course. Therefore, we cannot say anything about whether the students' energy balance would remain low throughout the field trip, or whether they would recover on subsequent days, but our findings highlight the need for further investigations.

A main study strength was our use of validated energy expenditure assessments. SWA is noninvasive, inexpensive, and widely used to examine activity levels among different populations with good validity (Lopez et al., 2018). SWA was also chosen because digging snow caves is often performed in positions that limit lower body movements. Because most work is performed with the upper body, hip-based activity meters were not an option. However, we cannot exclude the possibility that this led to an overestimate of energy expenditure; the accuracy with which the SWA calculates energy expenditure in this specific context, and how well it can differentiate between full-body versus upper body energy expenditure, are unknown.

We recommend that future studies include measurements over a longer period, preferably multiple days or weeks. Future studies should also investigate how energy deficits may affect students' recovery time, ability to concentrate, and learning outcomes. They should also specifically evaluate why students underestimate their energy needs during outdoor educational courses, despite receiving information in advance.

## Conclusion

The students who participated in this study did not appear to properly apply the theory-based information they were taught before the field trip. They were thus unable to compensate for the heavy energy expenditures required by traveling across demanding terrains with a heavy pack, including establishing a living site in the snow. This resulted in an energy deficit corresponding to an energy balance of only 58% of that needed. No gender difference was observed, indicating that energy balance deficit is a general problem among all students.

## Disclosure statement

No potential conflicts of interest were reported by the authors, and no funding was received to support this study.

## Notes on contributors

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***Geir Øvrevik*** is an Assistant Professor of Sport Science and Physical Education at the University of Agder, Norway. He is a highly experienced physical education and *friluftsliv* teacher, and has taught students across a wide age range during his career. He has published a range of books on outdoor education and physical education.

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