Original article

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Behavioural determinants of daily energy intake during a 28 day outdoor expedition in Arctic Norway

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Abstract

Background: Energy requirements during expeditions are often inadequately matched by concurrent energy intake, to the potential detriment of human health.
Objective: This study investigated the behavioural determinants of daily energy intake (DEI) on expedition. The study was conducted primarily with a view to enhancing DEI in the expedition situation.
Design: Twelve adolescents recorded energy intake, energy expenditure and various behavioural factors associated with energy intake concurrently for 28 days using adapted food diaries, while on expedition in Arctic Norway.
Results: Data tested for reliability and validity ($n = 217$) were analysed using correlation and regression analyses. Greater DEI was significantly independently associated with a greater number of eating occasions, greater time spent consuming, greater happiness before consuming and greater pleasantness of the food consumed.
Conclusions: These findings suggest that energy intake on expedition can be enhanced by allowing plenty of opportunity and time for consuming, ensuring that morale remains high, and providing foods that are perceived as pleasant by those consuming. These practical suggestions could benefit human health and well-being in the expedition situation.

Keywords: *adolescents*; *eating situation*; *energy expenditure*; *energy intake*; *expedition*; *food consumed*; *food diaries*

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Introduction

The expedition, "an organised journey . . ., often requiring strenuous and sustained physical activity, in a hostile environment" (1, p. 542), has long posed an issue for human health. The physical demands of an expedition often necessitate high levels of energy expenditure, yet this energy expenditure is rarely adequately matched by concurrent energy intake (2), and insufficient energy intake can be detrimental to human health and well-being (3–5).

The mismatch between energy intake and energy expenditure on expedition arises predominantly from a combination of unusually high levels of energy expenditure and the often compromised nature of expedition food and the conditions in which it is consumed (2–6). High levels of energy expenditure are often unavoidable. Energy intake, however, may be more easily manipulated.

Considerable research is currently available demonstrating the importance of a variety of behavioural factors in food consumption, in non-expedition or expedition-type environments (e.g. 7). These include internal factors, such as hunger (8, 9), external factors, such as location of consumption (10), and various food-related factors, such as food pleasantness and variety (3, 4, 11). The importance of these factors, when acting concurrently in an expedition situation, however, remains unknown.

This study investigated the importance of a number of internal, external and food-related factors for daily energy intake (DEI) on expedition. The work was conducted primarily with a view to enhancing DEI on expedition, so it focused specifically on variables that can be manipulated in the expedition environment.

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Methods

Energy intake, energy expenditure, and various internal, external and food-related factors were measured concurrently during a 28 day outdoor expedition, and the importance of all factors for DEI was subsequently determined using statistical analyses.

Participants

Twelve adolescents took part in the study: nine males and three females, aged 17–19 years. Adolescents were involved in the study as this age group is increasingly participating in expeditions [D. Martin, British Schools Exploring Society (BSES), London, personal communication, 2002]. All participants were non-smokers, lean (as measured at the start and end of the study in minimal clothing and identical conditions), of average fitness [as assessed using the 20 stage shuttle run test (12)], and had no known medical, appetite or taste disorders. All participants gave informed consent before their involvement. The study was given ethical approval by the ethics committee of the Department of Psychology, University of Surrey, UK.

Energy intake, energy expenditure, internal, external and food-related factors

All variables of interest were measured using adapted self-report food diaries, to be completed for every occasion on which foods or fluids were consumed. These diaries have previously been validated as reliable tools for measuring food intake and physical activity in the natural environment (10, 13–15).

Energy intake. To measure energy intake, participants recorded all foods and fluids consumed. The majority of foods were prepackaged, individual-sized portions of dried or dehydrated foods, provided as part of five different daily ration packs (BeWell Nutritional Products, Peterborough, UK), each providing a daily energy availability of approximately 3500 kcal. Participants were free to consume as much or as little of each ration pack as they wished, all foods were available at all times, and participants were free to store items for consumption on subsequent days or exchange items with peers. Additional foods, such as condiments, sauces and treats, were also consumed occasionally dependent on availability, and recorded in as much detail as possible using standard portion sizes.

Energy expenditure. To estimate energy expenditure, participants recorded average type of activity, intensity of activity (nine-point Likert scale: 0 = nothing at all to 8 = extremely high), weight carried (kg), height gain (number of map contour lines) and terrain difficulty (five-point Likert scale: 0 = not at all difficult to 4 = very difficult) since the previous eating occasion. Weight carried, height gain and terrain difficulty were measured to classify activity as walking, hiking or trekking (13). Attempts were also made to measure energy expenditure using accelerometry (16), but accelerometers were found to be inconvenient to wear while carrying rucksacks and highly susceptible to weather-related water damage. All data collected by accelerometry were subsequently discarded.

Internal factors. Before each eating occasion, each participant recorded subjective hunger, thirst, happiness, alertness, lethargy and perceived body temperature (seven-point Likert scales: 0 = not at all to 6 = extremely).

External factors. After each eating occasion, each participant recorded the type of meal consumed (snack, breakfast, lunch, evening meal, supper), location of the meal [camp, break (from activities), moving], number of others present and number of others consuming. At the end of each day, each participant also recorded the total number of eating occasions for the day and total time spent consuming.

Food-related factors. After each eating occasion, each participant also recorded pleasantness, tastiness, sweetness, savouriness, heat, coldness, familiarity and satisfaction of the food consumed (seven-point Likert scales: 0 = not at all to 6 = extremely).

Diaries were completed for 28 consecutive days, allowing a high variety in all variables of interest, but limiting the period for which individuals were required to record their intake (17). All participants were trained in the completion of the adapted food diaries and completed one practice diary day before participation in the study. The importance of honesty and accuracy was repeatedly stressed (17).

Expedition

The study was conducted from 23 July to 19 August 2002, during BSES Expedition Arctic Norway 2002, based around Oksfjordjokelen, Finnmark, Norway. Throughout this period, all participants of the study acted as a single, 12-person unit accompanied by two leaders, and completed a variety of expedition activities: training (tuition in outdoor practices), walking (load approximately 0 kg), hiking (load approximately 5 kg), trekking (load approximately 20 kg) and relaxing. Details of expedition activities are shown in Table 1. All activities were undertaken on rough mountainous terrain and ice-cap surfaces. All daily living was undertaken outdoors in basic conditions (temperature: mean $12.1 \pm 2.8^{\circ}C$; precipitation: mean 3.1 ± 4.3 mm day^{-1}; cloud cover: mean 6.4 ± 2.3 octas; sunshine: mean 4.4 ± 4.6 h day^{-1}; wind speed: mean 2.3 ± 1.6 m s^{-1}; Norwegian Meteorological Office, http://www.met.no, personal communication, 2003). Energy intake, internal factors and food-related factors remained natural throughout the 28 day period, while energy expenditure and external factors were highly varied. Both leaders were aware of the nature of the research study and made adequate provision at all times for the spontaneous consumption of foods and the completion of food diaries. Neither of the leaders, however, was aware of the likely outcomes of the study, and they were unlikely to have inadvertently influenced the study's findings.

Analysis

Following data collection, all diaries were checked against an independent diary of eating situations and activities, and suspected missing entries from any individual diary resulted in a recording of missing data for that entire day. All foods were converted into energy intake (kcal) based on manufacturers' information and compositional data (18), and summed to provide a value for DEI

Table 1. Details of the expedition for the 28 day data collection period (23 July–19 August 2002)

Day	Major activity[a]	Approx. time spent in activity (h)	Terrain	Weather
1	Trekking	8	Mountainous	Cloud/rain
2	Training	6	Mountainous	Cloud/rain
3	Training	6	Mountainous	Cloud/rain
4	Hiking	10	Mountainous	Cloud/rain
5	Trekking	4	Mountainous	Cloud/rain
6	Relaxing		Mountainous	Cloud/rain
7	Hiking	4	Ice/snow	Rain
8	Training	6	Ice/snow	Rain
9	Training	6	Ice/snow	Rain
10	Hiking	5	Ice/snow	Rain
11	Trekking	5	Mountainous	Cloud
12	Trekking	9	Mountainous	Cloud
13	Trekking	10	Mountainous	Cloud
14	Hiking	2	Mountainous	Cloud
15	Trekking	8	Mountainous	Cloud
16	Trekking	10	Mountainous	Cloud
17	Trekking	4	Mountainous	Cloud
18	Hiking	7	Ice/snow	Sun
19	Trekking	4	Ice/snow	Sun
20	Relaxing		Ice/snow	Sun
21	Trekking	7	Ice/snow	Sun
22	Relaxing		Mountainous	Cloud/sun
23	Trekking	2	Mountainous	Cloud/sun
24	Hiking	4	Mountainous	Cloud/sun
25	Trekking	2	Mountainous	Cloud/sun
26	Relaxing		Mountainous	Cloud/sun
27	Trekking	6	Mountainous	Cloud/sun
28	Hiking	5	Mountainous	Cloud/sun

[a] Most strenuous activity for the day. Hours not given here were spent in quiet relaxing activities or sleep.

per participant per day. Measures of activity were converted into energy expenditure (kcal) using the 'Compendium on physical activities: classification of energy costs of human physical activities' (13), and summed to provide a value for daily energy expenditure (DEE) per participant per day. Estimated energy balance (EB) was calculated using DEI – DEE. Values for DEI were checked against equations for estimating energy requirements for basal metabolic activity (19), and values for EB were checked against calculations of expected EB based on changes in body weight over the whole expedition (20). Data on internal, external and food-related factors were summed or meaned, to provide one value per measure per participant per day.

The importance of all factors for DEI was investigated using Pearson product moment correlations and nested multiple linear regressions. Nested linear regressions (nested variable–participant ID) were used because all individuals provided multiple data points. All internal, external and food-related factors were used as predictor variables. Personal details [gender, age, body weight, body mass index (BMI)], details of energy intake (food types, macronutrient types) and details of energy expenditure (activity undertaken, activity intensity) were not used as predictor variables. These variables are important determinants of DEI (13, 19, 20, 21), but often cannot be manipulated within the expedition environment, so were of minimal interest to this study. It should be noted that this work does not intend to investigate all determinants of DEI on expedition, only those that may be of practical value to those in the expedition situation.

Results

Food diaries from eight participants (six males, two females) were used for analysis: one male withdrew from the expedition as a result of injury, and data from two males and one female were removed from all analyses owing to suspected inaccuracies in reporting. Allowing for days of suspected missing data, data for 217 individual days were used for analysis.

Personal characteristics of all eight participants are given in Table 2. Descriptive statistics for DEI, DEE, EB and all internal, external and food-related factors are provided in Table 3. In particular, DEI and DEE were comparable to or slightly higher than in other studies of adolescents in the natural environment, as would be expected in an expedition situation (14, 15). EB was also negative, as may also be expected during an expedition (2), and is comparable with calculations of expected EB based on body weight losses ($t_7 = 1.28$, $p = 0.24$; $r = 0.99$, $p < 0.01$). As further checks of the validity of the data, EB was also negatively associated with initial body weight ($r = -0.70$, $p = 0.05$), as may be expected (20), and associations between EB and mean DEI and mean DEE were as expected, although these did not reach significance ($r = 0.59$, $p = 0.13$ and $r = -0.70$, $p = 0.06$, respectively). Relationships between EB and initial body weight, mean DEI and DEE are shown in Figs. 1–3.

Table 2. Personal characteristics of participants included in the analysis ($n = 8$)

Participant	Age (years)	Body weight at day 1 (kg)	BMI at day 1 (kg m^{-2})	Max. shuttle level at day 1 (0–20)	Change in body weight over expedition (kg)	Calculated EB over expedition based on change in body weight (kcal)	Estimated EB over expedition based on DEI and DEE reports (kcal)
1	17	56	21.8	7.6	0.5	3 500	3 388
2	18	73	22.5	7.6	−2.7	−18 900	−20 104
6	18	57	18.6	7.9	0	0	1 260
7	19	65	21.2	7.0	−1.9	−13 300	−14 392
8	17	66	20.4	13.0	−2.9	−20 300	−18 928
9	17	59	20.4	4.5	−4.0	−28 000	−31 192
10	17	63	21.8	7.9	−3.9	−27 300	−29 372
11	19	77	23.8	7.8	−5.8	−40 600	−41 188
Mean	17.8	64.5	21.3	7.9	−2.6	−18 113	−18 816
SD	0.9	7.5	1.6	2.8	2.1	14 695	15 503

BMI: body mass index; EB: energy balance; DEI: daily energy intake; DEE: daily energy expenditure.

Table 3. Mean, SD and range for energy intake, internal, external and food-related stimuli, and energy expenditure ($n=217$)

Variable	Mean per day	SD per day	Range per day
Daily energy intake (DEI) (kcal)	2769	832	994 to 6454
Daily energy expenditure (DEE) (kcal)	3437	989	1716 to 6210
Estimated energy balance (EB) (kcal)	−669	1306	−3618 to 3644
Subjective hunger (0 −6)	4.3	0.7	2.0 to 6.0
Subjective thirst (0 −6)	3.8	1.0	1.6 to 6.0
Subjective happiness (0 −6)	3.7	0.9	1.2 to 6.0
Subjective alertness (0 −6)	3.5	0.8	1.2 to 5.8
Subjective lethargy (0 −6)	3.0	0.9	1.0 to 6.0
Subjective body temperature (0 −6)	3.0	0.6	1.4 to 5.0
Mean type of meal consumed (ordered as above)	2.4	0.4	1.3 to 3.5
Mean location of meal consumed (ordered as above)	1.3	0.3	1.0 to 2.3
Mean number of others present (n)	9.8	3.1	1.7 to 16.7
Mean number of others consuming (n)	8.3	3.2	1.3 to 14.0
Mean number of eating occasions (n)	3.9	1.0	2.0 to 7.0
Total time spent consuming (min)	121	52	30 to 309
Pleasantness (0 −6)	4.4	0.7	2.5 to 6.0
Tastiness (0 −6)	4.1	0.8	2.3 to 6.0
Sweetness (0 −6)	3.3	1.1	1.0 to 6.0
Savouriness (0 −6)	2.9	1.1	0.0 to 6.0
Heat (0 −6)	3.0	0.8	0.0 to 5.0
Coldness (0 −6)	2.7	1.5	0.0 to 6.0
Familiarity (0 −6)	4.5	1.1	1.5 to 6.0
Satisfaction (0 −6)	4.4	0.7	2.0 to 6.0

Correlations were found between DEI and many of the variables of interest. In particular, DEI was positively correlated with hunger, happiness, alertness, number of eating occasions, time spent eating, food pleasantness, tastiness, sweetness, coldness and satisfaction (smallest $r=0.13$, $p=0.05$).

Correlations were also found between many of the variables of interest, independent of DEI. Owing to possible effects of multi-collinearity, variables that were highly correlated ($r>0.6$) with any other variable were subsequently excluded from all regression analyses (22). Using all other independent variables, DEI was significantly predicted by a regression equation ($R^2=0.51$, $\sqrt{\text{MSE}}=941.32$). Significant predictors of DEI were number of eating occasions, time spent consuming, happiness before consuming and pleasantness of the food consumed. Coefficients for all variables in the regression models are given in Table 4.

Discussion

This study investigated the behavioural determinants of DEI on expedition, focusing specifically on variables that can be manipulated within the

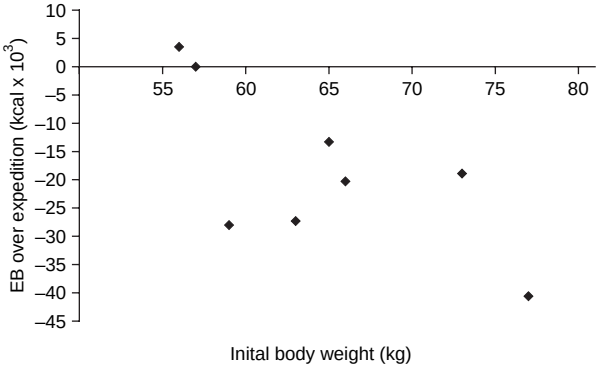

Fig. 1. Relationship between energy balance (EB) and initial body weight.

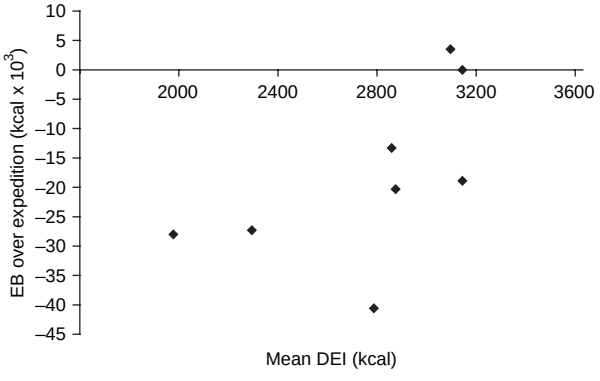

Fig. 2. Relationship between energy balance (EB) and mean daily energy intake (DEI).

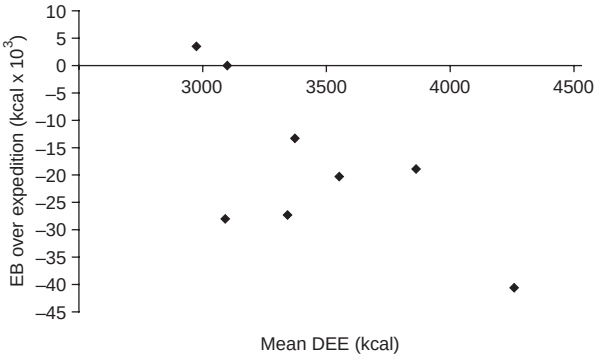

Fig. 3. Relationship between energy balance (EB) and mean daily energy expenditure (DEE).

constraints of the expedition environment. Greater DEI was significantly independently associated with a greater number of eating occasions, greater time spent consuming, greater happiness before consuming and greater pleasantness of the food consumed.

Associations between DEI, number of eating occasions and time spent consuming have previously been found in non-expedition (8, 10) and in expedition-type environments (4, 6). Indeed, Popper et al. (6) found that number of opportunities for eating and time allowed for eating were the most important determinants of energy intake in a military field situation. Correlations between higher elation/lower depression and greater energy intake have also previously been found elsewhere (8). Higher ratings of pleasantness and tastiness have also previously been found to result in increased energy intake, in both non-expedition and expedition-type environments. As examples, Yeomans (11) found significant increases in energy intake for foods rated more pleasant in the laboratory, and Baker-Fulco (3) and Kramer (4) suggest increases in energy intake following increases in the pleasantness of foods in military situations.

These predictors of DEI, therefore, have been found to be independent predictors of energy intake elsewhere. The particular value of this study, however, is that these predictors were found to be significant in a real expedition situation. Based on these findings, suggestions for enhancing energy intake on expeditions should focus on allowing plenty of occasions and plenty of time for consuming, ensuring that individuals remain happy and providing foods that are perceived as pleasant by those consuming.

The absence of associations with various internal and external factors is also worthy of comment. These effects are possibly due to the high requirements for food on expedition and the often limited opportunities for eating. Consumption of foods consequently may occur when possible as opposed to when desirable (2–5). Possibly the greatest difference between expedition and non-expedition situations lies in the constrained nature of the expedition environment and the lack of flexibility surrounding eating (2–6).

Many important determinants of energy intake were not included in this study, owing to its nature. The study intended to investigate only the determinants of energy intake that can be manipulated and

Table 4. Regression coefficients for all variables in the regression model for daily energy intake ($n = 217$)

Variable	Coefficient	95% CI	t	p
No. of eating occasions	264.87	105.29 to 424.58	3.92	0.01*
Time taken	4.52	1.38 to 7.66	3.41	0.01*
Happiness	260.71	84.22 to 437.20	3.49	0.01*
Pleasantness	192.12	36.72 to 347.51	2.92	0.02*
Perceived body temperature	362.08	−6.32 to 730.48	2.32	0.06
Savouriness	−111.60	−261.33 to 38.13	−1.76	0.12
Hunger	197.22	−83.26 to 477.69	1.66	0.14
Thirst	−86.12	−217.85 to 45.60	−1.55	0.17
Sweetness	−112.06	−317.49 to 93.36	−1.29	0.24
Location	−148.32	−626.45 to 329.81	−0.73	0.49
Familiarity	−44.92	−204.21 to 114.38	−0.67	0.53
Heat	−47.86	−235.69 to 139.97	−0.60	0.57
No. of others consuming	9.55	−29.48 to 48.58	0.58	0.58
Alertness	3.32	−227.60 to 234.24	0.03	0.97
Energy expenditure	0.11	−0.01 to 0.23	2.26	0.06

*Significant predictor ($p < 0.05$).

so be of practical value to those in an expedition situation. It is accepted that many characteristics of the participants (e.g. gender, age, BMI, dietary restraint), foods consumed (e.g. energy density, macronutrient composition) and activities undertaken (e.g. intensity of activity, weight carried) will have large effects on DEI and EB (13, 17, 19, 20, 21).

A word of caution should also be added. Concerns over the collection of data on energy intake and expenditure using self-report diaries are highly valid. It has been suggested that energy intake in adolescents can be underestimated using food diaries by as much as 20% (14). Inaccuracies in reporting, however, are likely to be lower in this study, since diaries were quick and easy to complete through the use of limited prepackaged foods and Likert scales, and were likely to be completed at the time of consumption; furthermore, participants were interested in the study and its outcomes, but were unable to predict study findings. Procedures to identify underreporting were also implemented, and days where missing data were suspected were subsequently removed from all analyses (17). Importantly, however, any inaccuracies in reporting were likely to be independent of all internal, external and food-related factors. Owing to the unsystematic nature of any inaccuracies, concerns over the collection of data by food diaries should not undermine the potential value of the findings of this study. Inaccuracies in reporting energy expenditure are also possible, and these could not be understood more clearly because of failures in the use of accelerometry. Reporting of activities, however, was good, with hours of activity totalling 24 h per day. Inaccuracies in reporting energy expenditure are also likely to be independent of all variables of interest (13). Concerns over the use of diaries should again not reduce the value of the findings of this study. The study was also conducted on a limited sample of lean adolescents. Sample size here is unfortunately small, but could not be increased owing to the nature of the work and the environment in which the work was conducted. Some of the effects of small sample size were likely to have been remedied by the large amount of data collected from each individual, but generalization from this small sample could be hazardous. The adolescents involved in this study, however, were taken at random from approximately 60 adolescents who volunteered for the expedition, and effects may generalize to other adolescents in similar situations. Effects, however, may easily differ in different populations, e.g. depending on age, body weight, fitness and dietary restraint (17, 19, 20).

In summary, the results of this study suggest that greater DEI during a 28 day expedition is associated with a greater number of eating occasions, greater time spent eating, greater happiness before consuming and greater pleasantness of the food consumed. These data suggest that DEI on expedition may be enhanced by providing plenty of occasions and plenty of time for consuming, and ensuring that individuals remain happy and that provided foods are perceived as pleasant. These considerations could be borne in mind in a number of expedition situations, with considerable potential impact on the health and well-being of those taking part.

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