The Quantified Caveman: A Year-Long Case Study of the Paleolithic Diet

Running title: A Year-Long Case Study of the Paleolithic Diet

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Abstract

This is a detailed study of nutritional and lifestyle data on a single individual who adhered to the Paleolithic diet (PD) for a full year. The dietary intake was compared to evidence-based guidelines and various PD iterations from the research literature and popular diet books. Although the subject's diet aligned with PD book recommendations, several nutrients differed markedly from estimations in the scientific literature, highlighting the importance of relying on evidence-based dietary advice. These findings provide insight into a contemporary PD in practice, the feasibility of nutrition tracking, and how self-tracked dietary data can inform health behavior.

Key words: diet, paleolithic; case reports; nutritional requirements; nutritional status; anthropology

Introduction

Throughout human evolution, up until the modern Homo sapiens, the dietary patterns of our species have undergone several major changes, such as scavenging and hunting for meat, cooking, and agriculture.[1] Compared to hunting and gathering, reliance on agriculture and modern food processing techniques are recent occurrences that has had less time to create diet-related selective pressures. Based on the apparent mismatch between humans and the modern food environment, Eaton and Konner proposed the evolutionary discordance hypothesis, which states that the genome of the modern human evolved under conditions that differs considerably those of the modern day, resulting in an incongruity between the human organism and its habitat and, by extension, an increased risk for several chronic diseases.[2,3] Indeed, agriculture is often highlighted as the catalyst of a widespread change in the human diet that could have major health implications for the human organism,[4,5] and represents what some claim to be a shift in dietary patterns towards the suboptimal.

Building upon Eaton and Konner's work, Loren Cordain emerged as a key figure in the rise of Paleolithic nutrition in the 21st century. He would go on to trademark the term "The Paleo Diet" in an apparent effort to label his interpretation of which foods our pre-agricultural ancestors subsisted on. In 2002, he published a book with the same name,[6] and the Paleolithic diet (PD) was officially primed for modern mass-adoption. Following Cordain's bridging of the research literature and commercial diet book market, numerous authors, bloggers, and ancestrally aligned influencers have opined on the PD. This has resulted in a few notable discrepancies between the original estimations of a hunter-gatherer diet and its more modern iterations, one of which is the shift from carbohydrate to fat as the preferred fuel source.[7-9] However, data are lacking on the dietary patterns of contemporary PD followers, which makes the nutritional composition of the PD challenging to define and predict.[10]

The present study describes a case that meticulously tracked diet- and health-related metrics for a year while following a PD. The aims of this analysis were to provide detailed insight into PD patterns in practice, assess the feasibility of following and tracking this type of diet in a modern environment, and compare mean macro- and micronutrient contents of a PD to both evidence-based dietary guidelines, represented by the current Nordic Nutrition Recommendations (NNR),[11] as well as estimations, observations, and suggestions from both the scientific and commercial PD-related literature. The relationship between dietary intake and health-related variables such as body mass, sleep, physical activity, and perceived somatic stress were also assessed.

Methods

Subject

A comprehensive dataset from a self-quantified male subject was obtained. The data spanned all 12 months of a calendar year, from January through December. The data was not collected with the intention of subsequent systematic statistical analysis, which likely mitigated some sources of bias, such as the trial effect. At the beginning of the tracking year, the subject was 26 years old and 182 cm tall with a body mass of 71.5 kg, calculated as the average over the first week. A normal week consisted of 40 hours of work, ~10-20 hours of studying, and most of the remaining waking hours being spent on physical activity and recreational activities. The study was registered with the Norwegian Centre for Research Data (476978/07-2018) and the subject provided written informed consent prior to data analysis.

Tracking and measurement procedures

Height was measured to the nearest 0.5 cm with a stadiometer. Body mass was measured daily to the nearest 0.1 kg with a commercial diagnostic scale (Beurer GmbH, Ulm, Germany) and bioelectrical impedance analysis (InBody 720, Biospace Co. Ltd., Seoul, Korea) was used to determine body composition. Step count was tracked using an electronic pedometer

(Yamax Digi-Walker SW200, Tokyo, Japan). Perceived daily activity level was graded using the ten-point Borg category-ratio scale (CR10).[12] Average daily pain intensity was graded using the 0-10 numerical rating scale (0-10 NRS).[13] Sleep duration was calculated as the time difference between going to sleep and waking up with 15 minutes being subtracted to account for sleep latency. Wake-up time was registered each morning.

Diet

The dietary principles for the study period were derived from popular PD books.[6,8,9] The ideal and acceptable daily carbohydrate goals were < 150 g and < 200 g, respectively.[9] There were no other specific macro- or micronutrient targets and all meals were consumed ad libitum. Notable dietary exclusions were all grains, legumes, and any form of processed food. All food and drink items were weighed and measured prior to consumption then logged using a food tracking software that was developed specifically for the PD.[14] The software gave day-to-day notifications of whether the subject was strict PD, strict primal (PD + some dairy), and free of non-PD ingredients such as legumes, sugar, and grains. For unprepared meals outside the home, the consumed amount was estimated and tracked. As eating out was not a regular occurrence, virtually all meals during the study period were weighed and measured. Any alcohol consumed during the study period adhered to PD recommendations, e.g., the beer consumed was gluten-free and sugary cocktails were avoided entirely.

This was the subject's first exposure to a PD. The subject reported no food allergies, intolerances, metabolic issues, or other diseases. The start of the study period marked a transition from a vegan diet and primarily endurance training, with slightly lower than normal body mass, to PD and primarily resistance training. Thus, the switch to a more energy-dense diet with ad libitum feeding as well as a less energy-demanding exercise regime was expected to lead to some weight gain. One of the motivations for switching to the comparably high-protein PD was to ensure that the weight gain came from predominantly lean mass.

Energy expenditure

To account for the changes in body mass and activity level, a dynamic variable for total daily energy expenditure (TDEE) was created. First, the basal metabolic rate (BMR) was calculated using the Mifflin-St Jeor equation for men.[15] Then, activity factors were applied to determine TDEE. Each day was assigned a specific multiplier based on the CR10 score of that day, i.e., sedentary: 1.2x (1-2 CR10); lightly active: 1.375x (3-4 CR10); moderately active: 1.55x (5-6 CR10); very active: 1.725x (7-8 CR10); and extremely active: 1.9 (9-10 CR10). This gives the final equation: TDEE = BMR × activity multiplier. In addition to TDEE, a variable for daily kcal difference (Δkcal) was created: Δkcal = daily energy intake – TDEE. This variable made it possible to quantify the total estimated kcal difference, as well as count the number of days spent in a surplus and deficit, respectively.

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics v. 27 (Chicago, IL, USA). Graphics were made with GraphPad Prism v. 7 (San Diego, CA, USA). Data for each day were extracted from the various software solutions used by the subject and compiled in SPSS. The complete dataset included 34,675 possible datapoints divided across 95 unique variables. Data normality was assessed with the Shapiro-Wilk test. Means were compared using the Mann-Whitney U test. Data are presented as mean ± standard deviation (SD) in tables and text and mean ± standard error (SE) in figures. The α level was set at $p \leq 0.05$.

Results

Tracking adherence was 98% for nutrition, activity, and pain ratings (357/365 days), 92% for weighing (337/365), 93% for step count (341/365), and 100% for sleep (365/365). The subject reported subjective feelings of improved gastrointestinal health, high energy levels, and overall satisfaction with the diet in terms of both taste and effects. No significant illness was recorded at any point over the course of the study period.

Energy intake, total energy expenditure, and weight gain

Body mass increased by a total of 8.9 kg (difference between the average of the first and last week of the study period). Bioelectrical impedance analysis showed a body fat percentage of 10.8% near the end of the tracking period. The difference between TDEE and energy intake indicated a mean energy surplus of 422 ± 1071 kcal/day. If we assume that 1 kg of body mass contains 7716 kcal (3500 kcal per pound),[16] this surplus predicts a body fat gain of approximately 20 kg = (422 × 365) / 7716. However, given the amount of exercise training performed throughout the study and the low body fat percentage at the end of the year, it is reasonable to assume that a considerable part of the excess calories was expended in lean tissue accretion. Moreover, neither intestinal nutrient absorption nor the thermic effect of food is accounted for in the surplus calculation. While the former is difficult to quantify, the latter can be estimated using reasonable constants to represent the thermic effect of each macronutrient, e.g., 1.5% for fat, 7.5% for carbohydrate, and 25% for protein.[17] The estimated thermic of food was 252 ± 63 kcal/day, or 8.2 ± 1.6%, and thus the estimated energy surplus was reduced to 170 ± 1031 kcal/day. If we assume that each kg of added mass requires 7716 kcal, this predicts a weight gain of ~8 kg, which is closer to the amount gained by the subject. However, since the distribution of the gained tissue, i.e., adipose vs. lean tissue, is unknown, it is not possible firmly establish the predictive quality of these numbers.[18] Typically, active individuals engaged in resistance training are advised to initially implement a conservative energy surplus of 360 – 478 kcal/day to induce hypertrophy[19] which, incidentally, approximately reflects the average unadjusted surplus that resulted from the ad libitum approach in the present study.

Since energy intake on a given day cannot affect the body mass value obtained on the morning of that day, the relationship between the intake of a given day and body mass the following morning was assessed. Interestingly, the correlation between energy intake and body mass, independent of the adjustment of weighing timing, was negative. The correlation coefficient between energy intake and same day weight was larger ($r = –0.21$, $p < 0.001$) compared to between intake on the day preceding each weighing ($r = –0.18$, $p < 0.001$). This relationship also held when looking at weekly values ($r = –0.32$, $p < 0.05$). Although this may appear to be counterintuitive, energy intake exceeded TDEE throughout the study period, which explains why the subject gained weight on “low” calorie days; most days was spent in a surplus (figure 1). The statistical significance of the inverse relationship likely materialized between April and November when the total daily energy intake was trending downwards while the subject kept gaining mass. Throughout this downtrend, an energy surplus was maintained, as illustrated by the area between the energy intake and TDEE curves.

[Insert Figure 1 here]

Unsurprisingly, energy intake correlated with all macronutrients ($p < 0.001$). However, relative fat intake ($r = –0.26$, $p < 0.001$) and relative protein intake ($r = –0.47$, $p < 0.001$) correlated negatively with energy intake, while no such relationship was observed for relative carbohydrate intake ($p > 0.05$). However, a positive correlation was found between relative carbohydrate intake and body mass ($r = 0.18$, $p < 0.001$).

Nutritional content, value, and comparisons

Most of the energy intake was derived from unprocessed animal products, including fish and fowl, at 46.2%. Vegetables and fruits provided 14.1% in about equal amounts, nuts and seeds provided ~11.4%, and dairy provided 6.4%. The remaining calories (~22%) were consumed from various other sources, some according to PD principles, e.g., unprocessed animal or plant foods that were not available in the tracking software and had to be manually registered by the subject, and some from occasional processed food products and alcoholic beverages. Other examples include field rations during extended stays outside, which were carefully selected to be gluten- and lactose-free. Figure 2 show the relative relationship between macronutrients and energy intake. Table 1 and 2 present the dietary macro- and micronutrient distributions compared to the current NNR recommended intake (RI).[11]

[Insert Figure 2 here]

[Insert Table 1 here]

[Insert Table 2 here]

Caffeine and alcohol consumption

The mean daily caffeine intake was 441 ± 214 mg, giving a relative intake of 5.9 ± 2.9/kg/day. On average, the subject consumed alcohol between once and twice per week. 34 of these days were related to traveling and vacation. If considering these occasions exceptions, the typical frequency of alcohol consumption was once per week. On drinking days, the subject ate considerably more calories (4387 ± 1167 kcal vs. 2869 ± 684 kcal, $p < 0.001$). A similar occurrence was observed on days after drinking (3587 ± 1450 vs. 3075 ± 815, $p < 0.05$). Most of the additional energy intake came from carbohydrates (247 ± 14 vs. 156 ± 5, $p < 0.001$). Drinking also appeared to lower perceived levels of physical activity (4.6 ± 1.7 vs 5.6 ± 1.5, $p < 0.001$) and somatic stress (4.2 ± 1.4 vs. 4.8 ± 1.4, $p < 0.001$). Additionally, the subject slept less following alcohol consumption (6.9 ± 1.9 vs. 7.4 ± 1.7, $p < 0.001$) and woke up weighing slightly less (75.1 ± 2.6 kg vs. 76.0 ± 2.6 kg, $p < 0.01$), which is likely associated with alcohol-induced diuresis.

Sleep, supplements, physical activity, and lifestyle factors

On average, the subject slept 7.3 ± 1.7 hours per night, walked 11820 ± 4236 steps per day, and subjectively rated daily physical activity and somatic stress as 5.4 ± 1.6 and 4.7 ± 1.4

(both out of 10), respectively. Four supplements were consumed regularly: creatine monohydrate (5 g/day, n = 124 days), vitamin D3 (100 µg/day, n = 224 days), cod liver oil (5 – 15 ml/day, 265 days), and magnesium (500 mg/day, n = 188 days). The subject engaged in various forms of physical activity and exercise throughout the year. A total of 455 separate training sessions were logged, giving an average of ~9 sessions per week, mainly divided between strength training, mobility work, running, combat sports, and hiking. On strength training days, the subject consumed more protein (187 ± 49 g vs. 169 ± 53 g, $p < 0.01$), walked more steps (12442 ± 3187 steps vs. 11128 ± 4265 steps, $p < 0.001$), and had a higher perceived activity level (6.1 ± 1.2 vs. 4.8 ± 1.6, $p < 0.001$) compared to non-strength training days. Table 3 displays correlations between various diet and lifestyle factors.

[Insert Table 3 here]

Proximity to estimated and suggested Paleolithic diets

The observed macronutrient distribution differed markedly from both the original[3] and revised[2] estimations by Eaton and Konner. However, it closely aligned with diet book examples.[6,8,9] The implementation of an upper limit to carbohydrate intake likely contributed to a more fat- and less carbohydrate-dominant version of the diet than what is often outlined in the research literature (table 4). Although the macronutrient distributions from PD books are examples and not necessarily recommendations, they are purported to reflect the nutritional intake on a PD and thus perceived as templates for how a reader can structure his or her diet.

[Insert Table 4 here]

Discussion

Proponents of the PD advise that changing our modern environment to one that more closely resembles that of our stone age predecessor may lead to better human health and performance. By analyzing the observed dietary intake from a free-living individual following a PD, it is possible to glean the practical, long-term nutritional value of this approach. The present study analyzed a comprehensive dataset containing multiple dietary and lifestyle aspects from a subject that adhered to the PD, which in the modern food environment can be described as fairly restrictive. Although leveraging data from case studies to determine the effects of a PD is not a new approach, this is, to the best of the author's knowledge, the first case study that provides a year-long detailed day-to-day macro- and micronutrient breakdown of the PD and compared it to both evidence-based RIs and multiple PD nutritional ranges.

Approximately 22% of the total energy intake came from food that were not considered paleo or primal by the tracking software. However, a non-trivial amount came from "approved" foods that were not found in the software registry and thus had to be manually entered by the subject. When taking this into consideration, an estimated 85% of the overall energy intake came from food sources aligned with the selected dietary principles. Incidentally, the 85/15 distribution of paleo/non-paleo foods is found as a suggestion in Cordain's original PD book.[6] Given the typical high energy density of non-approved consumables, such as ultra-processed foods and alcoholic beverages, their contribution may have appeared even lower than their energy fraction indicates. This is an example of how diet tracking can help objectively quantify the energy contribution of different foods, which may differ from their subjectively perceived role in the overall diet. Alcohol was one of the non-paleo constituents that were consumed with some regularity and seemed to be a driver of energy intake, mainly through an increase in carbohydrate intake. Although the lack of alcohol in paleolithic times excludes it from the evolutionary template, it appears as though the majority of PD followers do not abstain from alcohol[20] and moderation rather than total abstinence is commonly practiced, even in interventional studies.[21]

The common claim that the PD has a high micronutrient density is supported by the present findings. Compared to the NNR,[11] the subject exceeded, often considerably, the RI for all micronutrients available for analysis. The subject did not make a conscious effort to meet any of the RIs, suggesting that a PD leads to ample micronutrient intake when consumed ad libitum. Based on 26,433 random food journals, the tracking software used by the subject reported the most common nutrient deficiencies in PD to be folate, calcium, magnesium, and iron.[22] Interestingly, with the exception of iron, this list represents some of the nutrients that the subject had a comparably moderate intake of and the overall high energy intake may have been an important reason for securing a sufficient intake.

The 22% energy intake stemming from carbohydrate is less than half the amount typically recommended by dietary guidelines.[11] Conversely, the 50% from fat is 25% higher than the recommended upper limit. Protein intake was generally close to the absolute recommended amount, but mass-relative intake exceeded the recommendations. Although definitions differ, this distribution can be interpreted as a low-to-moderate carbohydrate diet. Interestingly, despite the PD often being considered low-carb, traditional low-carb approaches, which can be comparably low in both fiber and protein, does not necessarily fit the so-called evolutionary template.[2,6] This highlights the fact that the PD originated as a relatively macronutrient agnostic framework with an emphasis on specific foods and their quality rather than strict macronutrient splits. Indeed, in Eaton and Konner's seminal work,[3] a 3000 kcal/day diet was thought to consist of an estimated 334 g/day of carbohydrate, almost twice the amount observed in the subject's diet. Curiously, this carbohydrate intake outlined in the table above resides firmly in what popular PD proponent Mark Sisson calls "the danger zone".[9] This level of intake, he suggests, is a catalyst for obesity and type 2 diabetes. Eaton and Konner,[3] on the other hand, proposed that the diet of the late paleolithic human consisted of 45% carbohydrate, similar to the average US intake at the time, and that this likely was protective against certain lifestyle diseases. An important distinction, however, is the source of carbohydrates, which they suggested typically came from beans, which is interesting given that beans are considered non-paleo, as well as roots, nuts, tubers, and fruits.

Fat comprised half of the subject's overall energy intake throughout the year, which exceeds most, if not all, official dietary guidelines, as well as Eaton and Konner's estimates of what hunter-gatherers consumed.[2,3] Unsurprisingly, this resulted in an intake of saturated fat markedly above the recommended upper limit of 10% of total energy intake. Interestingly, in the first edition of his first PD book,[6] Cordain largely aligns with the general consensus that saturated fat intake should be limited, while in his subsequent book published a decade later, "The Paleo Answer",[23] he includes a chapter called "The Truth About Saturated Fat", where he shares that his perspective on saturated fat has changed. The softening stance on saturated fat was a theme that had been emerging and still remains in the ancestral health community, a stance that may be partly based on fundamental misunderstandings of earlier research.[24]

Conclusions

The present study describes in detail the dietary intake of a long-term follower of the PD in a modern environment. Although the data stems from a single subject, the dietary principles that led to the observed intake are well-established in the PD community. The PD in many ways originated as a legitimate scientific hypothesis that had some support from both biological and anthropological research, yet popular current iterations of the PD are at times far removed from both estimations of what hunter-gatherers actually consumed, as well as evidence-based dietary guidelines. Nutrition tracking, which is growing in popularity, represents a valid, reliable, and feasible tool that can be used together with specific diets, such as the PD, to tailor the nutritional intake according to individual needs and preferences.

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Tables

Table 1. Mean daily dietary macronutrient intake and distribution

	Mean ± SD	RI
Energy intake		
Absolute energy intake (kcal)	3194 ± 1021	
Mass-relative energy intake (kcal/kg)	41.75 ± 13.70	
Expenditure-relative intake (kcal/TDEE)	1.17 ± 0.44	
Carbohydrate		
(g)	180 ± 99	
(E%)	22 ± 9	45 - 60
Fiber (g)	25 ± 11	25 - 35
Protein		
(g)	176 ± 51	
(g/kg)	2.3 ± 0.7	1.1
(E%)	23 ± 8	10 - 20
Fat		
(g)	173 ± 56	
(E%)	50 ± 13	25 - 40
Fat distribution (of total kcal)		
Saturated fat (%)	17 ± 6	< 10
Monounsaturated fat (%)	19 ± 6	10 - 20
Polyunsaturated fat (%)	8 ± 4	5 - 10
P-S ratio	0.54 ± 0.35	
n-6 fatty acids (%)	6.9 ± 3.7	
n-3 fatty acids (%)	1.0 ± 0.8	> 0.5
n-6:n-3 ratio	9.4:1 ± 5.9:1	

RI, recommended intake from the Nordic Nutrition Recommendations (NNR);[11] kcal, kilocalories; TDEE, total daily energy expenditure; E%, fraction of total energy intake; P-S, polyunsaturated-saturated; n-6, omega-6; n-3, omega-3.

Table 2. Mean daily dietary micronutrient intake

	Mean ± SD	RI	%RI
Vitamin A (RE)	10388 ± 9105	900	1154
Vitamin D (µg)	76 ± 11	10	760
Vitamin E (α-TE)	17 ± 11	10	170
Thiamin (mg)	16.0 ± 204.8	1.4	1143
Riboflavin (mg)	3.9 ± 1.6	1.6	244
Niacin (NE)	192 ± 43	19	1011
Vitamin B_6 (mg)	5.0 ± 16.7	1.5	333
Folate (µg)	425 ± 172	300	142
Vitamin B_{12} (µg)	12.3 ± 10.6	2.0	615
Vitamin C (mg)	147 ± 163	75	196
Calcium (mg)	805 ± 432	800	101
Phosphorus (mg)	2231 ± 598	700	319
Magnesium (mg)	521 ± 175	350	149
Sodium (mg)	2865 ± 1683	2400	119
Potassium (mg)	5113 ± 1594	3500	146
Iron (mg)	42 ± 231	9	467
Copper (mg)	2.2 ± 1.2	0.9	244
Selenium (µg)	206 ± 70	60	343

RI, recommended intake from the Nordic Nutrition Recommendations (NNR);[11] *%RI, fraction of recommended intake.*

Table 3. Correlation matrix of various lifestyle factors

	1	**2**	**3**	**4**	**5**	**6**	**7**
1. Energy intake	–						
2. Alcohol	0.71**	–					
3. Sleep	-0.17**	-0.21**	–				
4. Wake-up time	-0.07	0.06	0.30**	–			
5. Steps	0.13*	0.05	-0.11*	-0.51**	–		
6. CR10	-0.17**	-0.33**	0.13	-0.31**	0.46**	–	
7. 0-10 NRS	-0.16	-0.23**	0.02	-0.19**	0.22**	0.25**	–

CR10, Borg's ten-point category-ration scale; 0-10 NRS, 0-10 numerical rating scale; $p < 0.05$; ** $p < 0.01$

Table 4. Comparison of Paleolithic diet compositions

	Subject	Konner & Eaton[2]	Lindeberg et al.[21]	Pontzer et al.[25]	Cordain[6]	Wolf[8]	Sisson[9]
Carbohydrate (E%)	22	35-40	40	65	26	23	15
Fat (E%)	50	20-35	27	11	44	39	57
Protein (E%)	23	25-30	28	24	35	38	25
Saturated fat (E%)	17	7.5-12	7.7	N/A	9	7	N/A
Sodium (mg/d)	2865	< 1000	1900	N/A	813	726	N/A
Potassium (mg/d)	5113	7000	N/A	N/A	8555	9062	N/A
Calcium (mg/d)	805	1000-1500	N/A	N/A	890	691	N/A
Cholesterol (mg/d)	1037	500+	397	N/A	N/A	461	N/A
Fiber (g/d)	25	>70	21.4	80-150	47	42.5	N/A
Vitamin C (mg/d)	147	500	N/A	N/A	559	748	N/A
Vitamin D (IU/d)	3040	4000 (sunlight)	N/A	N/A	0	N/A	N/A

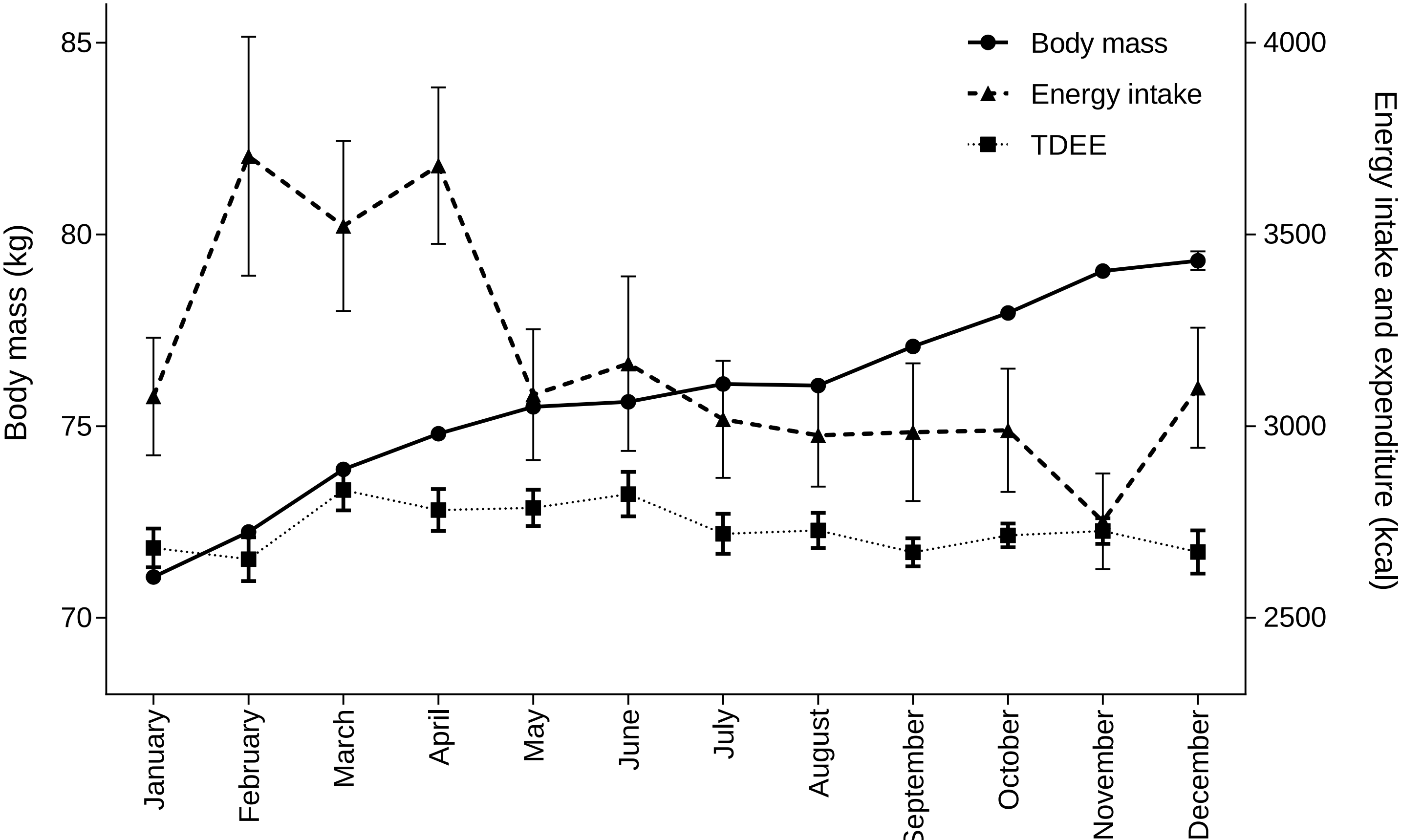
E%, fraction of daily total energy intake.

Figure legends

Figure 1. Trajectories of body mass, energy intake, and total daily energy expenditure (TDEE)

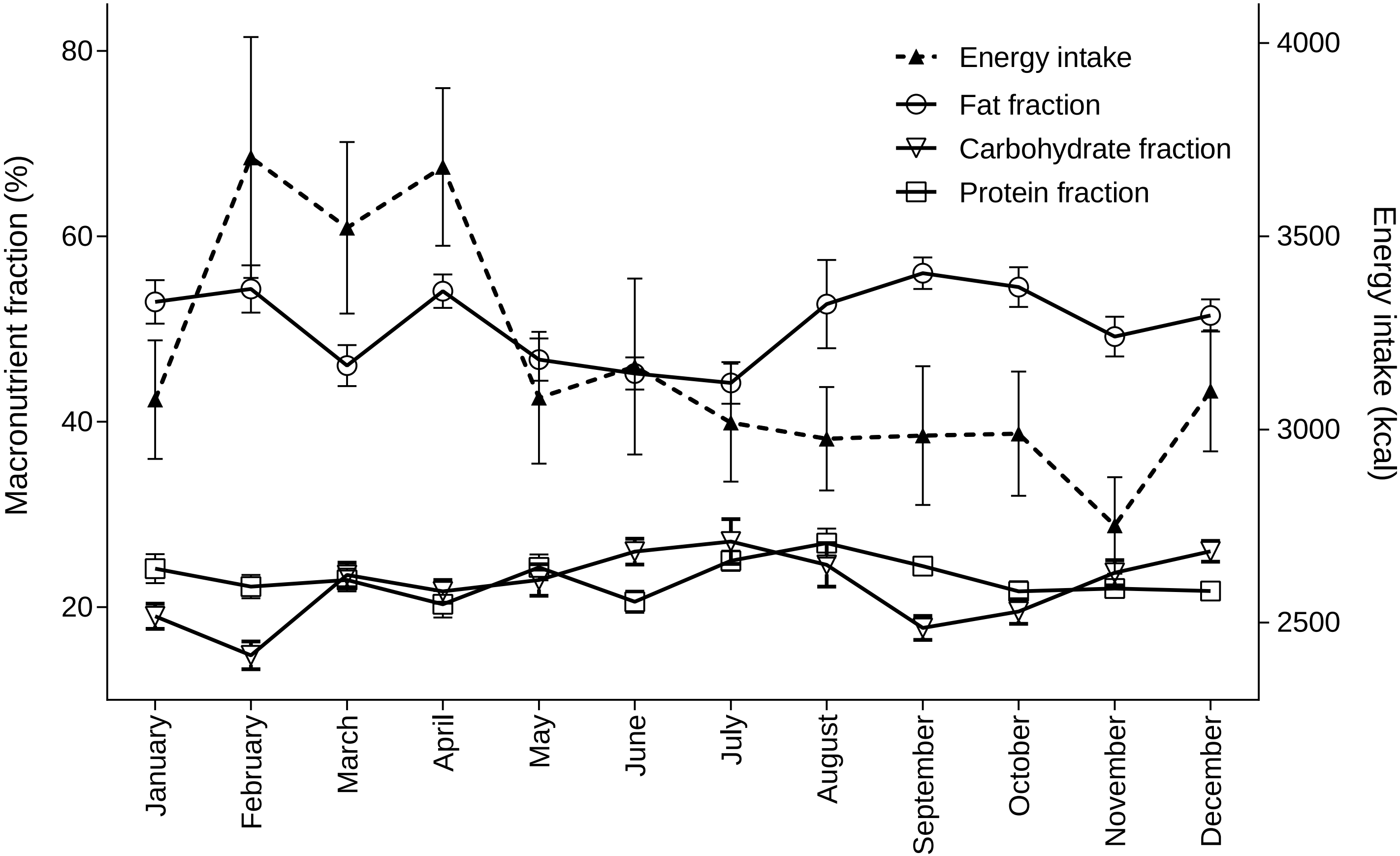
Figure 2. Macronutrient distribution and energy intake

Figure



Body mass
Energy intake
TDEE
Body mass (kg)
Energy intake and expenditure (kcal)
85
80
75
70
4000
3500
3000
2500
January
February
March
April
May
June
July
August
September
October
November
December

Figure



Energy intake
Fat fraction
Carbohydrate fraction
Protein fraction
Macronutrient fraction (%)
Energy intake (kcal)
80
60
40
20
4000
3500
3000
2500
January
February
March
April
May
June
July
August
September
October
November
December