Exiting the Cave: Exploring the Transition from Paleolithic to Omnivorous Dieting

Running title: From Paleolithic to Omnivorous Dieting

Karsten Øvretveit, MSc, BSc[1] and Ingar Mehus, PhD[2]

[1] Department of Public Health and Nursing, Faculty of Medicine and Health Sciences, Norwegian University of Science and Technology

[2] Department of Sociology and Political Science, Faculty of Social and Educational Sciences, Norwegian University of Science and Technology

Correspondence:

Karsten Øvretveit, MSc, BSc, Norwegian University of Science and Technology, Faculty of Medicine and Health Sciences, Department of Public Health and Nursing, Postboks 8905, N-7491 Trondheim, Norway (karsten.ovretveit@ntnu.no).

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Abstract

This is a follow-up of a recent case study of the Paleolithic diet (PD) that investigates dietary changes, including energy intake, food sources, and macro- and micronutrient distribution, associated with a transition from a PD towards a more omnivorous pattern. We observed an over 40% increase in carbohydrate intake, 10% decrease in fat intake, including 20% less energy from saturated fat, less intake of nearly all micronutrients, and a substantially greater energy contribution from non-paleo sources, including ultra-processed foods. This analysis of two full years of nutrition data provides a unique description of changing dietary patterns in a free-living individual.

Key words: diet, paleolithic; case reports; nutritional requirements; nutritional status; ultra-processed foods

Introduction

The Paleolithic diet (PD) is a popular diet trend inspired by assumptions of what our early stone age ancestors ate and the notion of a discordance between the human genome and our modern food environment.[1] The modern PD concept can be traced back to the 1960s, and since then, numerous versions have found their way into the scientific and commercial literature.[2] Yet, the PD lacks a universal definition and reliable estimations of what its contemporary followers actually consume.[3, 4] There are also considerable discrepancies between estimations and observations from anthropological research and recommendations from purportedly ancestrally inspired commercial diets.[5]

In a recent publication, we analyzed nutrition data spanning 12 months from a follower of the PD to characterize the energy intake and macro- and micronutrient distribution of this diet in practice.[6] We observed a noticeably different dietary pattern than what is commonly recommended by dietary guidelines, yet also found evidence for a high micronutrient density and protein content, and general satisfaction with the diet. Following the yearlong adherence to the PD, the subject transitioned into a less strict, more omnivorous diet while still adhering to some of the tenets of the PD. Detailed tracking of nutrient intake, body mass, sleep, and exercise using the same instruments and procedures was maintained throughout for a full second year, resulting in a comprehensive dataset suitable for follow-up analysis. Here, we interrogate these data to explore the shifts in macro- and micronutrient intake that may occur when transitioning from a strict dietary framework to a more omnivorous diet with a greater contribution of post-Neolithic foods.

Methods

Study design and subject

Data collection procedures have previously been described in detail.[6] Briefly, we obtained self-tracked data from a male subject spanning all 12 months of a calendar year, including spreadsheets and access to the food journal software.[7] At the start of the follow-up year, the subject was 27 years old and 182 cm tall with a body mass of 81.5 kg, ~10 kg above the previous baseline, giving a body mass index (BMI) of 24.6. With the exception of step counting and subjective ratings of daily activity and pain levels, all measurement procedures remained the same. The study was conducted in accordance with the original project registration at the Norwegian Centre for Research Data (476978/07-2018), and informed consent was obtained prior to data analysis.

Diet

Some principles from the PD remained central to the subject's diet, such as a reliance on unprocessed animal products and regular consumption of plants, nuts, and seeds. With few exceptions, no strict upper limit to carbohydrate intake for the year was set, but dietary fat was still depended on and often preferred as an energy source. A notable change was less avoidance of non-paleo foods such as grains, as well as processed and ultra-processed foods. Throughout both years, the subject had no predefined calorie target. Weight gain was not an explicit goal during most of follow-up, but the year was characterized by trying to add some lean mass over the first part of the year, similar to the first year, and drop some towards the end. During follow-up, the subject ate what can be described as a transitional diet (TD) that still contained elements from the PD framework, but with greater contribution from non-paleo and convenience foods to support long-term adherence.

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics v28 (Chicago, Illinois). Graphics were made with GraphPad Prism v9 (San Diego, California). A comprehensive dataset was constructed using the information contained within the tracking software and consisted of 30660 observations across 84 variables, not accounting for missing values. We also expanded our micronutrient breakdown to include vitamin K, pantothenic acid, zinc, manganese, and dietary cholesterol. Data are presented as mean ± standard deviation unless otherwise specified.

Results

There were no missing data related to diet, sleep, and exercise. Body mass was logged on 332 days (91%). Like in the preceding year, no significant illness was recorded.

Changes in body mass, energy intake, and macronutrient distribution

The subject gained a total of 9.0 kg, calculated as the difference between first and last week (3x weigh-ins) averages, similar to the first year's gain of 9.5 kg. Plotting daily values for energy intake against body mass for both years revealed a high day-to-day variance in energy intake yet a virtually flat trajectory throughout the years, whereas body mass gradually increased from the beginning to the end of each study period (figure 1). When comparing mean values between years, we observed an increase in absolute energy intake, a decrease in relative energy intake, and a noticeable shift in macronutrient distribution (table 1; figure 2).

[insert figure 1 about here]

[insert figure 2 about here]

[insert table 1 about here]

Changes in micronutrient intake and food sources

Despite a higher energy consumption, the intake of most micronutrients decreased (table 2). This may have been due to less energy coming from micronutrient-dense sources such as meat, vegetables, fruits, nuts, and seeds (figure 3). Compared to the PD, the TD was characterized by a considerable increase in the energy contribution from "non-paleo" foods that likely had a lower micro- and greater macronutrient density. Some of the non-paleo foods consumed regularly were rice, usually white, chocolate, usually dark, as well as oats and pasta, mostly towards the end of the year. Protein bars were also eaten with increasing frequency and there were more visits to fast food restaurants.

[insert table 2 about here]

[insert figure 3 about here]

Changes in physical activity, sleep, supplements, and caffeine and alcohol consumption

Although the total number of training sessions was higher for the first year (455 vs. 388), the biggest difference was in low-effort mobility work, which likely had little metabolic impact (figure 4). In fact, high-intensity modalities such as strength and martial arts training were more frequent during follow-up, suggesting that activity thermogenesis may have been even greater.

[insert figure 4 about here]

Sleep duration increased from 7.3 ± 1.7 hours to 7.6 ± 1.6 hours per night during follow-up. This may have been caused by a changing sleeping window, with the average wake-up time in the first year being 07:49 ± 02:20 compared to 09:40 ± 02:01 in the follow-up year. Consistent with the increased sleep, caffeine consumption decreased from 441 ± 214 mg (5.9 ± 2.9 mg/kg/day) to 395 ± 198 mg (4.6 ± 2.3 mg/kg/day). Alcohol consumption also decreased by approximately one standard drink (14 g ethanol) per week. Supplements were consumed with comparable consistency, with creatine monohydrate and magnesium, in the form of ZMA, which also contains zinc and vitamin B6, being taken on an additional 123 and 120 days, respectively, whereas vitamin D3 and cod liver oil each saw 19 and 29 fewer days of use. Throughout both years, the subject also consumed other supplements, such as vitamin C and B12, but for practical purposes, only those consumed most regularly were compared.

Discussion

Adherence to strict diets is challenging and usually temporary. Despite ultimately failing to fully comply with a given set of dietary recommendations, some desire to continue following a diet based loosely on similar principles in hopes of retaining some of their purported benefits. The present investigation follows up on a longitudinal case study of the PD by analyzing dietary data from the same subject for the entire subsequent year, during which there was a transition towards a more omnivorous way of eating. This enabled us to characterize the shifts in dietary patterns that may occur when transitioning from a PD to a less stringent approach to nutrition where dietary choices are more influenced by accessibility, practicability, and cost.

When examining the trajectories of energy intake and body mass throughout both study periods, we observed at times substantial daily, weekly, and monthly fluctuations in energy and macronutrient intake alongside a relatively steady increase in body mass throughout the years. Fitting a regression line to the data revealed a virtually flat trajectory of energy intake, while body mass increased at a similar rate on both diets. We found that the transition towards omnivorism led to an over 40% increase in the relative energy contribution of carbohydrates, whereas the contribution from fat decreased by 14%. The resulting total energy intake was about 5% higher on the TD, but body mass relative energy intake was 8% lower. Absolute protein intake was practically identical across diets.

The energy balance model is considered the most established explanatory framework for body mass regulation.[8] Among its critics are those that have proposed the carbohydrate-insulin model as a more biologically informed paradigm.[9] It could be argued that observations in the present study support both models, depending on their interpretation. Based on the visual appearance of figure 2, one might posit that the convergence of fat and carbohydrate resulted in weight gain, with their directions implicating carbohydrates as the main cause. However, in our first publication,[6] we estimated the subject’s total daily energy expenditure to be approximately 2700 kcal, which is likely similar for both years. This is considerably below the observed mean daily energy intake, which points to excess calories as the driver of weight gain, in accordance with the energy balance model. Moreover, given the self-imposed restriction of carbohydrates on the PD, days with higher intakes were typically less strict and associated with alcohol consumption and an overall higher energy intake.[6] If one were to give the carbohydrate-insulin model credence in the interpretation of these data, the impact of fatty acids on glucose metabolism must be taken into account, as circulating free-fatty acids can inhibit glucose transport and phosphorylation in human skeletal muscle, highlighting the role of dietary fat consumption in the development of insulin resistance.[10] As the subject remained in a caloric surplus for the majority of the study period, it is not possible to disentangle energy intake from other potential contributors to weight gain. However, given the well-established governing role of calories, it may be more prudent to consider factors that directly affect energy intake rather than speculate in determinants with unique and energy-independent influences on body mass.

Despite being generally healthy throughout both diet periods, the subject went from having a BMI of 21.6 in the first week of the first year to 27.3 in the last week of the transitional year, representing an increase of more than 26% and a reclassification from normal to overweight. The initial weight gain did not result in excess adipose tissue as indicated by bioelectrical impedance analysis but maintaining the same rate of weight gain will eventually lead to unfavorable changes in body composition. Given that the subject mostly ate ad libitum on both diets yet consumed on average 144 kcal/day more on the TD, some of the dietary changes may have influenced factors such as palatability and feeling of fullness, causing the subject to overeat. Indeed, an emerging player in the pathogenesis of overweight and obesity is ultra-processed foods. In ad libitum conditions, these foods have been shown to increase energy intake by approximately 500 kcal per day compared to an unprocessed diet.[11] In the present study, we observed a notable increase in the energy contribution of non-paleo foods, a category that included ultra-processed foods. This is further substantiated by the virtually unchanged fiber intake despite a relative increase in carbohydrate consumption by more than 40%. We suspect that the substitution of unprocessed, protein-rich meat with hyperpalatable processed and ultra-processed foods led to an increase in energy intake and consequently weight gain exceeding the normal BMI range despite an active lifestyle.

The higher energy intake on the TD did not result in an increased micronutrient intake. In fact, with few exceptions, the intake of all micronutrients was reduced, some of them considerably. For instance, the consumption of fat-soluble vitamins A, D, E, and K fell between 27% and 77%. However, the subject still approached or exceeded the recommendations for most micronutrients.[12] Despite veering from the PD, the subject still perceived his diet to be reasonably healthy, mainly because it remained inspired by supposed evolutionary nutrition principles. Meat continued to be a dietary staple providing 36% of total energy, not including the contribution of processed meats, and thus was an important contributor to meeting macro- and micronutrient requirements.

The substantial dietary variety among hunter-gatherers discredits the idea of a single 'optimal' human diet.[13] However, some consider the PD more of a general framework that argues for the health-promoting properties of the pre-Neolithic food environment. This claim is based on an assumed compatibility between the human genome and foods that were available throughout most of human evolution, which again assumes that certain diet-related selection pressures shaped our current genome. Although humans have certainly been subjected to dietary selection pressures throughout history, natural selection is mainly concerned with reproductive probability and less so with post-reproductive health. In some cases, genes that increase evolutionary fitness early in life may increase disease risk later on.[14] Consequently, even if the PD increased reproductive success and thus could be promoted as 'evolutionary compatible', this would not guarantee health and longevity beyond the reproductive years.

Compared to our early ancestors, most modern human beings have access to a greater variety and amount of food. The degree to which we have domain over what and how much we eat is still a topic of debate,[15] but the modern obesogenic environment clearly has a differentiating impact on the population depending on genetic susceptibility.[16] National estimates from the subject's food environment show a daily energy intake of ~2800 kcal, 46% of which stems from carbohydrate, 37% from fat, and 15% from protein.[17] Thus, the observed macronutrient shift from the PD to the TD indicates a shift towards a dietary pattern more common in the general population. This may suggest that modern humans, despite their ancient genetics and aspirations to follow strict diets, are prone to influence from their local food environment, which may not always lead to adaptive responses but also maladaptive ones, like excessive weight gain. The increasing prevalence of overweight and obesity is often considered evidence of failure of national dietary guidelines to improve and maintain population health. However, this argument assumes population-wide adherence to guidelines, which is simply not the case.[18] Indeed, comparisons of those who follow guidelines to those who do not show that the former have substantially lower mortality risk.[19]

Although the PD has been shown to have beneficial effects on anthropometric and cardiometabolic outcomes,[20, 21] the lack of an operational definition of the diet limits the generalizability of such findings. When analyzing the current subject's dietary intake in the context of established risk relationships, the high intake of red meat and saturated fat, and relatively low intake of vegetables and fiber is likely to increase disease risk given sufficient exposure time. Thus, the observed shift from PD to TD, which involved a decrease in red meat and saturated fat consumption, has potential benefits. Yet, the intake of both these remained above desirable levels, vegetable and fiber intake did not improve, the contribution of ultra-processed foods was greater, and the total energy intake was higher, reflecting an overall suboptimal dietary pattern.

Limitations related to the case study design and measurement procedures have been discussed previously.[6] Additional concerns with the present analysis are the limited exposure contrast between the two years and lack of data detail in the non-paleo category. Although the subject logged each consumed item, it would be unfeasible to construct additional food categories, e.g., grains and legumes, and manually distribute the items day-by-day into the appropriate category. We instead relied on the default classifications in the food tracking software, resulting in a less nuanced description of non-paleo foods. Moreover, due to the lack of activity rating and step count, we were unable to estimate general physical activity and thus total daily energy expenditure. In general, analyzing data from a free-living subject not actively participating in a study has both benefits and drawbacks. The lack of a trial effect likely improved the validity of the data. Conversely, free-living conditions, including transient personal goals and sub-goals that may affect the exposures, can obfuscate and confound outcomes. However, the comprehensive, longitudinal data collected in these conditions are also among the strengths of this study and provide a unique perspective on daily dietary patterns. Other strengths include using the same measurement procedures and instruments as the first study, resulting in reliable data suitable for comparison. Lastly, taking both years into account in a case-crossover fashion is more informative than a simple case study, albeit with similar limitations.

Conclusions

This study expands upon our single-subject dietary analysis of the PD by exploring data from the subsequent year in which the subject had a less strict approach to nutrition. Exploring the transition from an ostensibly Paleolithic diet to a more omnivorous eating approach revealed changes in the macro- and micronutrient intake towards a distribution more common in the general population. A reasonably strict form of PD appears to have a high micronutrient density, but is also higher in saturated fat, sodium, and dietary cholesterol than the less strict, more omnivorous version. We also observed the latter to include more ultra-processed foods and less unsaturated fat and micronutrients, particularly fat-soluble vitamins. The comparable ad libitum eating approach led to a 5% increase in average daily energy intake on the TD, possibly due to a greater fraction of calories coming from energy-dense and hyperpalatable ultra-processed foods. Weight gain was remarkably similar on both diets despite variations in the quantity, quality, and distribution of calories, implicating energy balance as the fundamental driver of body mass regulation and highlighting the role of metabolic adaptation to fluctuations in energy consumption, here in the context of intakes above total daily energy expenditure.

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Tables

Table 1. Macronutrient intake and distribution comparison

	Paleo Diet	Transitional Diet	Mean change	% change
Energy intake				
Absolute energy intake (kcal)	3194 ± 1021	3338 ± 1090	+ 144	↑ 5
Relative energy intake (kcal/kg)	41.75 ± 13.70	38.34 ± 12.60	– 3.41	↓ 8
Carbohydrate				
(g)	180 ± 99	258 ± 118	+ 78	↑ 43
(E%)	22 ± 9	31 ± 9	+ 9	↑ 41
Fiber (g)	25 ± 11	24 ± 11	– 1	↓ 4
Protein				
(g)	176 ± 51	177 ± 53	+ 1	↑ 1
(g/kg)	2.3 ± 0.7	2.1 ± 0.6	– 0.2	↓ 9
(E%)	23 ± 7	22 ± 7	– 1	↓ 4
Fat				
(g)	173 ± 56	155 ± 53	– 18	↓ 10
(E%)	50 ± 12	43 ± 10	– 7	↓ 14
Fat distribution (of total kcal)				
Saturated fat (%)	17.1 ± 6.0	13.7 ± 4.3	– 3.4	↓ 20
Monounsaturated fat (%)	18.6 ± 5.5	15.4 ± 4.6	– 3.2	↓ 17
Polyunsaturated fat (%)	8.2 ± 4.3	7.5 ± 4.1	– 0.7	↓ 9
P-S ratio	0.54 ± 0.35	0.59 ± 0.40	+ 0.05	↑ 9
n-6 fatty acids (%)	6.9 ± 3.7	6.0 ± 3.4	– 0.9	↓ 13
n-3 fatty acids (%)	1.0 ± 0.8	1.0 ± 1.0	0	↓ 0
n-6:n-3 ratio	9.5:1 ± 5.9:1	9.3:1 ± 5.4:1	– 0.2:1	↓ 2

Data presented as mean ± standard deviation. Mean change expressed in absolute and relative (%) values. E%, fraction of total energy intake; P-S, polyunsaturated-saturated; n-6, omega-6; n-3, omega-3.

Table 2. Comparison of micronutrient intakes from diet only

	Paleo Diet	Transitional Diet	Mean change	% change
Vitamin A (μg)	10388 ± 9105	4293 ± 7108	– 6095	↓ 59
Vitamin D (μg)	11 ± 12	8 ± 10	– 3	↓ 27
Vitamin E (mg)	17 ± 11	12 ± 8	– 5	↓ 29
Thiamin (mg)	1.7 ± 0.7	2.0 ± 0.9	+ 0.3	↑ 18
Riboflavin (mg)	3.9 ± 1.6	3.7 ± 1.6	– 0.2	↓ 5
Niacin (mg)	43 ± 23	38 ± 25	– 5	↓ 12
Vitamin B_6 (mg)	4.2 ± 3.3	3.6 ± 3.3	– 0.6	↓ 14
Folate (μg)	425 ± 172	369 ± 157	– 56	↓ 13
Vitamin B_{12} (μg)	12.3 ± 10.6	10.0 ± 7.1	– 2.3	↓ 19
Vitamin C (mg)	147 ± 163	78 ± 73	– 69	↓ 47
Calcium (mg)	805 ± 432	863 ± 506	+ 58	↑ 7
Phosphorus (mg)	2231 ± 598	2188 ± 688	– 43	↓ 2
Magnesium (mg)	521 ± 175	494 ± 181	– 27	↓ 5
Sodium (mg)	2865 ± 1683	2764 ± 1818	– 101	↓ 4
Potassium (mg)	5113 ± 1594	4683 ± 1584	– 430	↓ 8
Iron (mg)	21 ± 7	21 ± 11	0	0
Copper (mg)	2.2 ± 1.2	2.1 ± 1.0	– 0.1	↓ 5
Selenium (μg)	206 ± 70	200 ± 86	– 6	↓ 3
Vitamin K (μg)	391 ± 423	91 ± 239	– 300	↓ 77
Pantothenic acid (mg)	12.8 ± 4.4	12.0 ± 4.6	– 0.8	↓ 6
Zinc (mg)	22.9 ± 9.6	22.3 ± 10.6	– 0.6	↓ 3
Manganese (mg)	4.3 ± 2.1	4.3 ± 2.3	0	0
Cholesterol (mg)	1037 ± 505	964 ± 350	– 73	↓ 7

Data presented as mean ± standard deviation. Mean change expressed in absolute and relative (%) values.

Figure legends

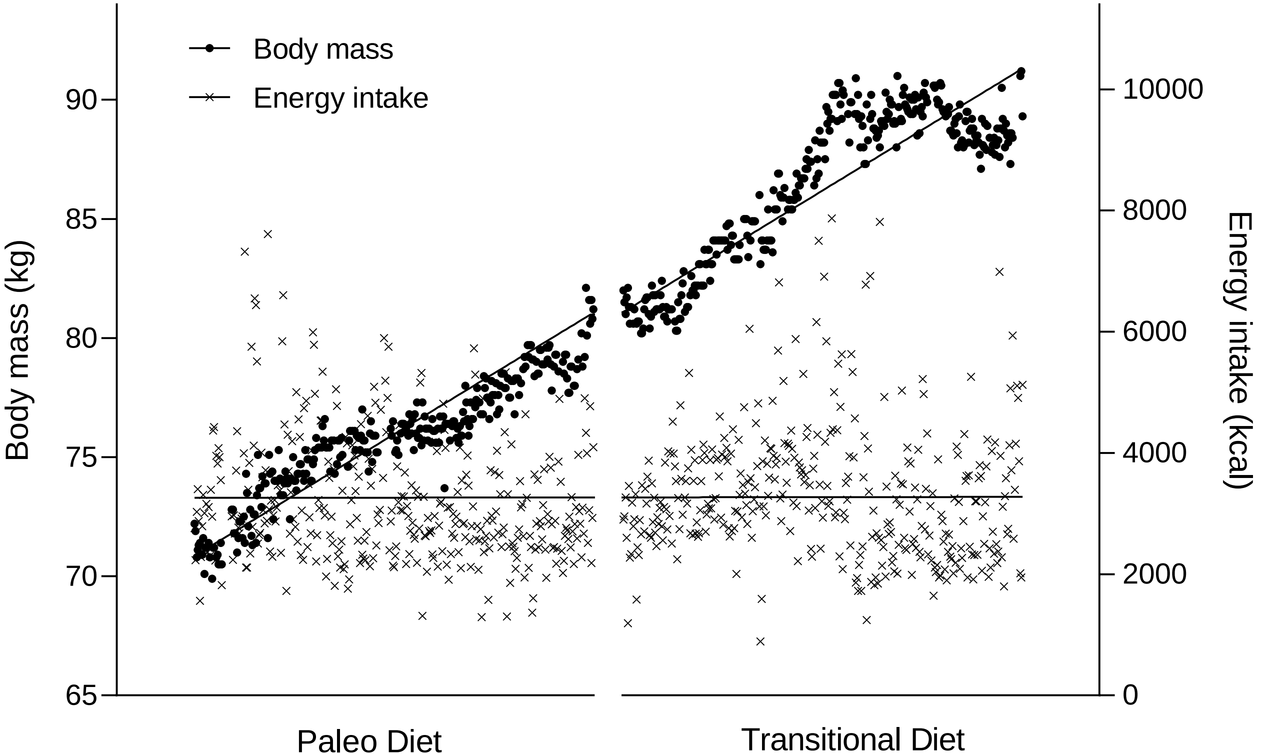
Figure 1. Comparison of body mass and energy intake trajectories

Figure 2. Comparison of the energy contribution from fat and carbohydrate

Figure 3. Comparison of food sources. *Data presented as means with 95% confidence intervals.*

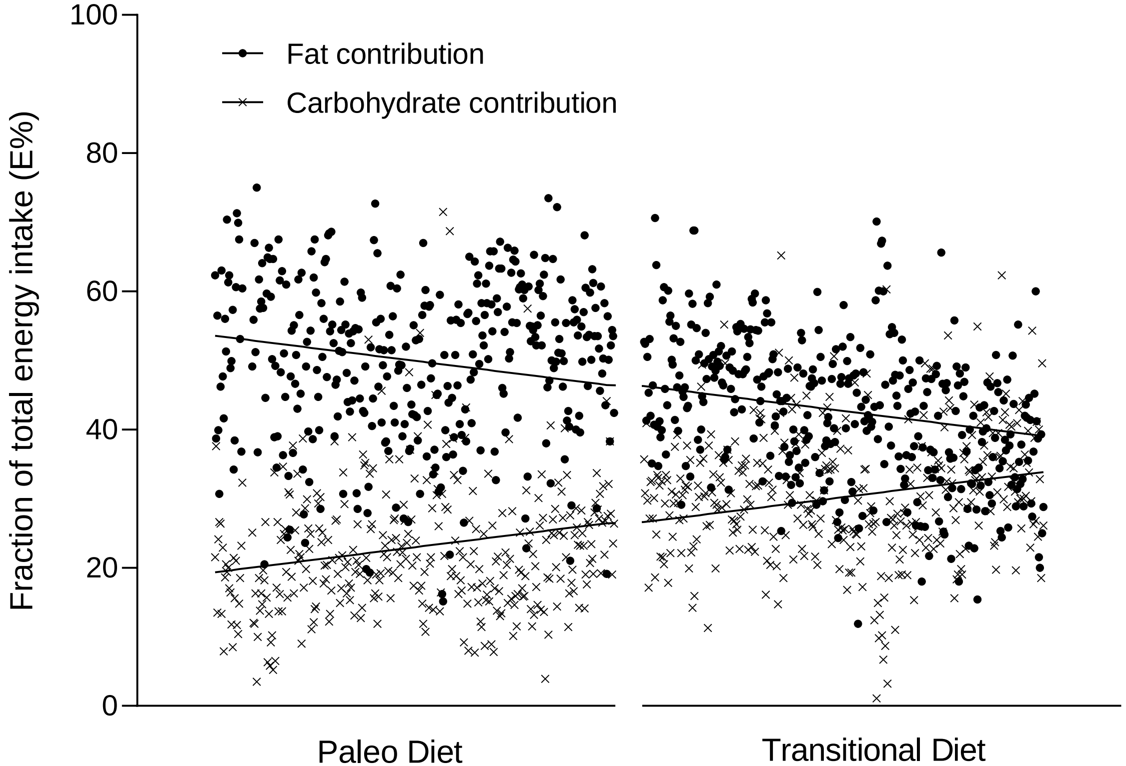
Figure 4. Comparison of exercise habits

Figure



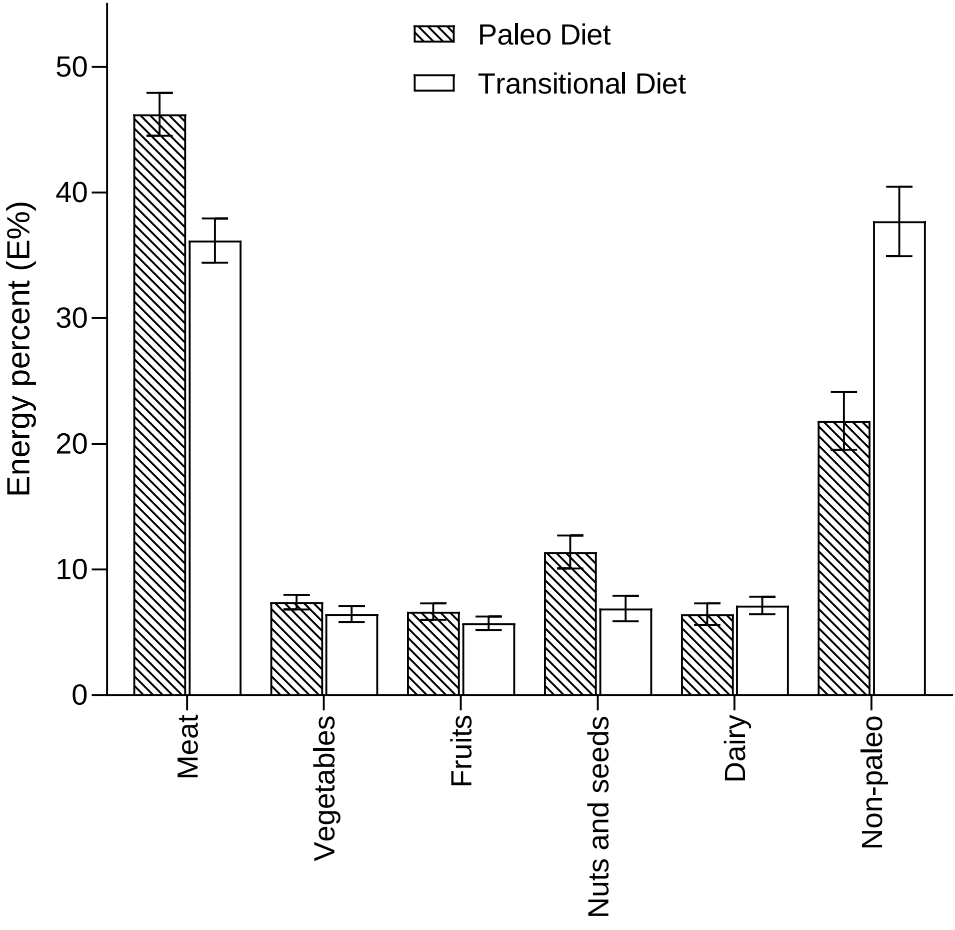
Body mass
Energy intake
90
85
80
75
70
65
Body mass (kg)
10000
8000
6000
4000
2000
0
Energy intake (kcal)
Paleo Diet
Transitional Diet

Figure



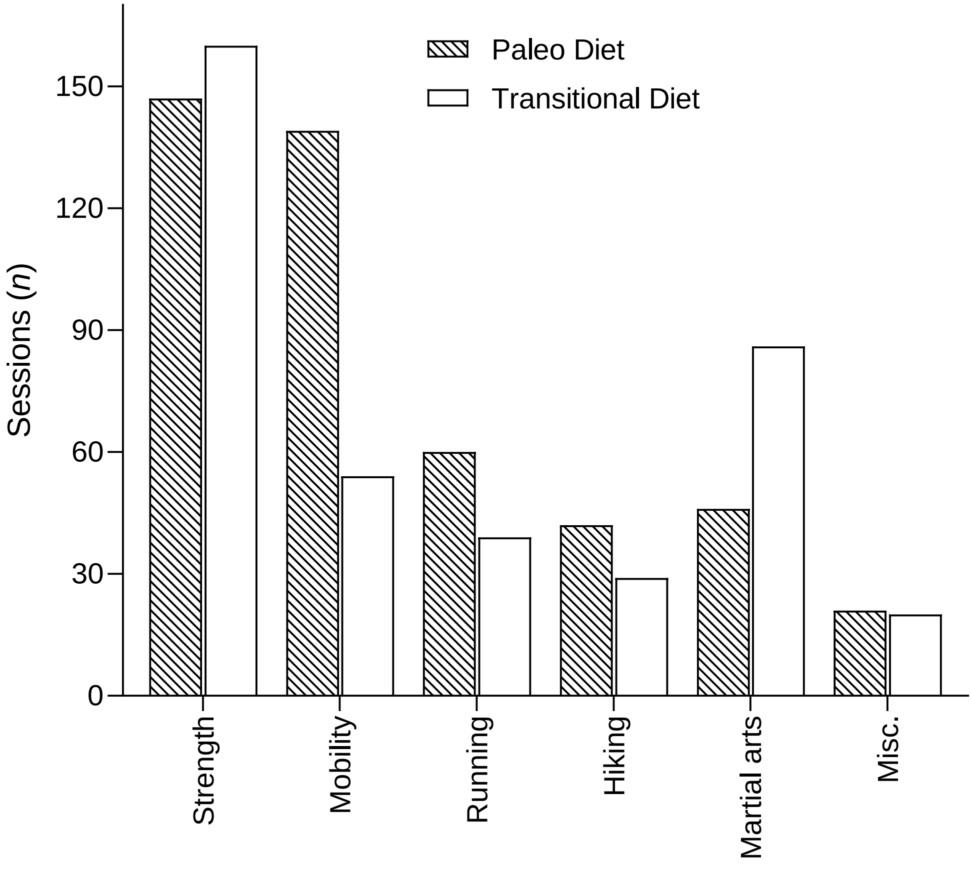
100
80
60
40
20
0
Fraction of total energy intake (E%)
Fat contribution
Carbohydrate contribution
Paleo Diet
Transitional Diet

Figure



Paleo Diet
Transitional Diet
Energy percent (E%)
0
10
20
30
40
50
Meat
Vegetables
Fruits
Nuts and seeds
Dairy
Non-paleo

Figure


Paleo Diet
Transitional Diet
Sessions (n)
150
120
90
60
30
0
Strength
Mobility
Running
Hiking
Martial arts
Misc.

Karsten Øvretveit, MSc, BSc, is a physiologist and PhD research fellow in Medicine and Health Sciences at the Norwegian University of Science and Technology.

Ingar Mehus, PhD, is an associate professor of sport science at the Department of Sociology and Political Science at the Norwegian University of Science and Technology.

Dear Editor,

The manuscript "Exiting the Cave: Exploring the Transition from Paleolithic to Omnivorous Dieting" is a follow-up study to the recently published "The Quantified Caveman: A Yearlong Case Study of the Paleolithic Diet" (doi: 10.1097/NT.0000000000000533). The first study was restricted to dietary data from a subject that followed a strictly defined Paleolithic diet. However, the subject kept track of his diet for two consecutive years, the second of which was not characterized by a specific dietary framework. Given the importance of a clear and concise research aim, and the considerable amount of work required to process and analyze the data material, all efforts were initially devoted to specific observations on the Paleo diet, which meant excluding the data from year two.

Following the publication of the first paper, we began analyzing the subsequent year in which the diet was tracked just as meticulously and with the same instruments. This enabled us to explore the transition between a strict 'ancestrally inspired' way of eating to a contemporary diet that relied more on modern foods, including ultra-processed ones, which is an emerging topic of interest in nutrition science. This follow-up study provides a unique perspective on the situation most dieters eventually find themselves in – transitioning away from strict self-selected principles of eating and towards something more sustainable.

We believe this paper is of interest to the nutrition professional for several reasons. By investigating the differences between two years' worth of detailed dietary data, which included plotting the energy intake on every single day to detect trends, we show that the shifts that may occur when eating 'less strict' seem to be towards dietary patterns more common in the society. We also discuss the possible causes of the observed steady increase in body mass from the 'normal' into the 'overweight' range, and which framework is best suited to explain not only the subject's weight gain, but also the ever-increasing global prevalence of overweight and obesity. We also touch upon the perception that certain diets have a 'protective effect' unrelated to energy intake and the claim that dietary guidelines are a contributing cause rather than a solution to the obesity epidemic.

Sincerely,
Karsten Øvretveit and Ingar Mehus