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The global diversity of eating patterns: Human nutritional health in comparative perspective

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HIGHLIGHTS

- Examines the origins of human nutritional needs and the diversity of human dietary strategies
- Humans evolved distinct nutritional needs tied to the high metabolic costs of our large brains.
- Humans have higher quality diets and greater energy expenditure than other primates of our size.
- Modern human populations display a wide diversity of dietary patterns.
- High energy consumption alone cannot explain the origins of obesity in modern urban societies.

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ABSTRACT

This paper draws on comparative data to explore the evolutionary origins of human nutritional needs and the diverse strategies used by human populations to meet those needs. Humans have evolved distinctive nutritional characteristics associated with the high metabolic costs of our large brains. The evolution of larger hominid brain size necessitated the development of foraging strategies that both provided high quality foods, and required larger ranges and higher levels of energy expenditure. Over time, human subsistence strategies have become ever more efficient in obtaining energy with minimal time and effort. Compared to data from traditional, subsistence-level societies, the US diet differs markedly in its fat and carbohydrate composition, but not in its absolute energy content. Energy expenditure levels of subsistence populations are significantly higher than those of the US and other industrialized societies. These data suggest that rising rates of obesity associated with lifestyle 'modernization' is not simply the product of greater energy intakes, but rather shifts energy balance and diet composition.

1. Introduction

Over the last thirty years, we have witnessed dramatic changes in lifestyle and food consumption in human populations around the world [1,2]. Indeed, in many parts of the rural developing world, we are now seeing the emergence of obesity and chronic metabolic diseases in populations where such problems were unknown a generation ago. We are also seeing the development of the "dual nutritional burden" in these groups — with conditions of both overnutrition and undernutrition co-existing in the same community, and sometimes within the same households [3].

Over the same time, scholars in a number of fields – including nutritional science, anthropology and exercise science – are recognizing the power of comparative and evolutionary approaches for studying human health and nutrition [4–8]. We have come to understand that many of the key features that distinguish humans from other primates (e.g., our bipedal form of locomotion, and large brain sizes) have important implications for our distinctive nutritional needs [8–11]. In addition, we are coming to realize that an evolutionary perspective is useful for understanding the origins of and potential solutions to the growing problems of obesity and associated metabolic disorders [12–14].

The story of human evolution is a nutritional story, and one that is all about the themes of this special issue: eating and foraging patterns, diet quality and energy balance. A hallmark of human evolution has been our ability to increase the efficiency with which we extract food from our environments. Humans show tremendous diversity in their dietary regimes; in reality, what makes us human is our ability to find meal in virtually any environment. Throughout most of our past, human lifestyles were characterized by high levels of physical activity and frequent periods of marginal or negative energy balance. These conditions selected for improvements in the energetic efficiency of human foraging strategies. Today, we are in many respects victims of our own

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evolutionary success. Human populations of the industrialized world live in "obesogenic" environments with low levels of energy expenditure and abundant food supplies contributing to strongly positive energy balances and growing rates of obesity and chronic, metabolic disorders [15].

When we consider the evolutionary history of the human lineage, we find that many of the key distinguishing features of human nutritional ecology arise with the emergence of *Homo erectus* at ~1.8 million years ago (mya) in Africa. This phase of human evolution was associated with major changes in brain size, body size, diet composition and foraging behavior that have had profound influences on shaping the nutritional and energy demands of our species [16,17]. Indeed, the changes that occurred with *H. erectus* established two of the prime drivers of human energy and nutritional needs that persist through time. The first is the need for a high quality (energy and nutrient dense) diet to fuel the energy costs of our large brains. The second is the development of foraging regimes that required movement over wide areas in order to procure those nutritionally dense diets. These expanded foraging ranges were associated with large activity budgets and high levels of daily energy expenditure.

In this paper, I will first consider the nature of our human nutritional and energy needs, and then examine the diverse strategies that human populations use to meet those needs. I first examine the energetic and nutritional correlates of variation in brain and body size among living primates, including humans. Next, I compare patterns of food consumption and energy expenditure in the US and other industrialized populations to those of traditional, subsistence-level population. These comparisons highlight both the diversity of dietary strategies around the globe and how the process of modernization of lifestyles is changing nutritional health of non-western populations. Additionally, these data suggest that rising rates of obesity associated with lifestyle 'modernization' is not simply the product of greater energy intakes, but rather shifts energy balance (i.e., intakes vs. expenditure) and diet composition.

2. Comparative and evolutionary perspectives on human nutrition and metabolism

2.1. Energetic correlates of variation in body and brain size

From a nutritional perspective, what is extraordinary about our large human brains is their high energy costs. Brain tissue has very high energy demands per unit weight, roughly 16 times greater than those of muscle tissue (12 kcal/kg/min vs. 0.75 kcal/kg/min) [18,19] Over the span of a day, the brain accounts for about 400 kcal in an adult human. Yet, despite the fact that humans have much larger brains per body weight than other primates or terrestrial mammals, the total resting metabolic rates (RMR; kcal/day) for the human body are no more than for any other mammal of the same size [7].

Fig. 1 shows the log–log plot of RMR (kcal/day) versus body weight (kg) for humans, 36 non-human primate species, and 22 non-primate mammalian species. Humans conform to the general mammalian scaling relationship between RMR and body weight (the "Kleiber Relationship" [20]). The Kleiber scaling relationship shows that metabolic rates of mammals of different sizes increase as a function of mass$^{3/4}$, such that RMR can be predicted by the following equation:

$$RMR = 70\left(Mass^{0.75}\right).$$

On average, adult humans have RMRs that fall within 3–4% of the values predicted by the Kleiber relationship. The implication of this is that humans allocate a much larger share of our daily energy budget for brain metabolism than other species.

The disproportionately higher energy costs of our large brains are seen in Fig. 2, which shows the log–log scaling relationship between brain weight (grams) and RMR for the species shown in Fig. 1. The y-intercept of the primate regression is significantly greater ($P < 0.01$) than that of the non-primate mammalian regression, whereas the slopes are comparable. This indicates that for a given RMR, primates have brains that are approximately three times the size of other mammals. Human brain sizes, in turn, are some 2.5 to 3 times those of other primates.

In energetic terms — this means that brain metabolism accounts for ~20–25% of RMR in an adult human body; as compared to about 8–10% in other primate species, and roughly 3–5% for non-primate mammals [7,21]. The large allocation of our energy budget to brain metabolism raises the question of how humans are nutritionally able to accommodate the metabolic demands of our large brains. It appears that humans consume diets that are denser in energy and nutrients than other primates of similar size.

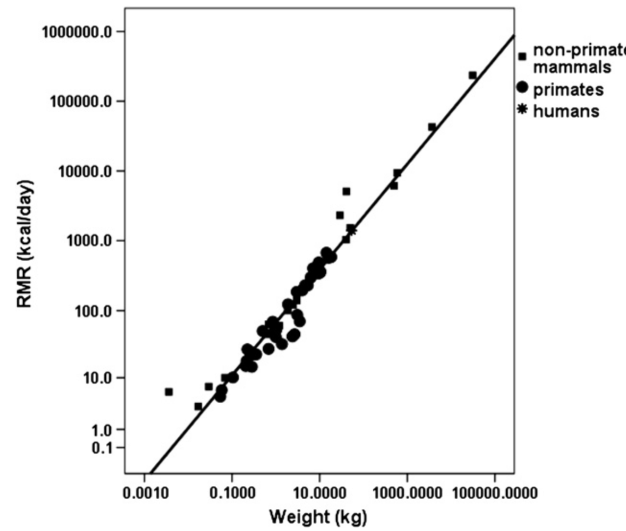

Fig. 1. Log–Log plot of resting metabolic rate (RMR; kcal/day) versus body weight (kg) for humans, 36 other primate species, and 22 non-primate mammalian species. The scaling relationship for the entire sample is $RMR = 65\ (Wt^{0.77})\ (r^2 = 0.95)$ does not differ from that described by Kleiber [20]. Humans conform to the general mammalian scaling relationship, having RMRs with 3–4% of predicted values.

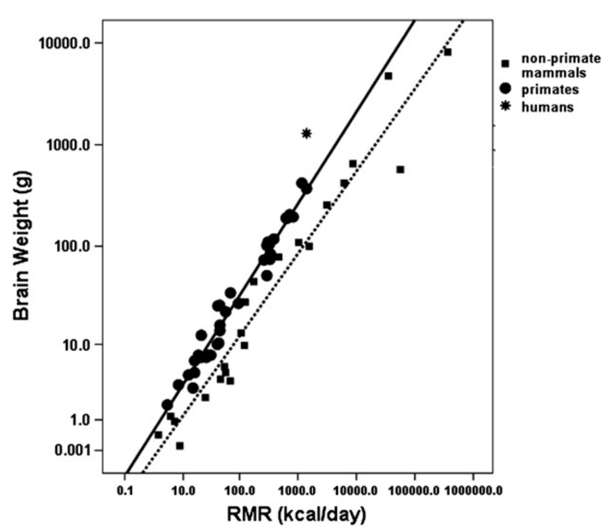

Fig. 2. Log–Log plot of brain weight (BW;g) versus RMR (kcal/day) for humans, 36 other primate species, and 22 non-primate mammalian species. The primate regression line is systematically and significantly elevated above the non-primate mammal regression. The scaling relationship for non-primate mammals is: $BW = 0.14\ (RMR^{0.90})$, $r^2 = 0.93$; that for non-human primates is: $BW = 0.42\ (RMR^{0.94})$, $r^2 = 0.97$. Thus, for a given RMR, primates have brain sizes that are three times those of other mammals, and humans have brains that are 2.5 to 3 times those of other primates.