MEASURING THE PALAEOLITHIC LIFE

A BIOENERGETIC APPROACH

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RESUMEN La dificultad de conocer ciertos aspectos del pasado debido a la falta de pruebas y restos arqueológicos hace que surjan nuevas metodologías para comprender comportamientos pretéritos. Nacido de esta problemática surge la bioenergía como una nueva aproximación a la evolución humana. Esta se construye a través de sofisticados protocolos experimentales como la antropometría, la composición corporal y el gasto energético. Estos diseños son llevados a cabo con sujetos in vivo para reconstruir aspectos de la paleobiología de los homininos ya extintos. Para conocer estas cuestiones, medimos el gasto energético simulando actividades prehistóricas como el transporte de carcasas, la recolección de recursos vegetales o la obtención de materia prima. El principal objetivo de estos estudios será recrear escenarios sobre aspectos cotidianos del pasado, sus requerimientos energéticos y las limitaciones ambientales a través del uso de herramientas matemáticas.

PALABRAS CLAVE Bioenergía, gasto energético, actividades prehistóricas, calorimetría indirecta, acelerometría

ABSTRACT Due to the difficulty of finding remains and past clues, new and recent methodologies and approaches are getting importance to understand past behaviours. We present the Bioenergy as a new research domain in Human Evolution. This approach is built by sophisticated experimental protocols such as anthropometry, body composition and energy expenditure. These designs are used by recent humans as in vivo subjects to reconstruct some features of hominin paleobiology. Thus, we carry out the experimental programs measuring the energy requirements of prehistoric activities with the volunteers, such as carcass transport, gather vegetable resources and raw material catchment. The main aim of this approach is to recreate scenarios of past daily behaviours, their energy requirements and the environmental constraints by the use of mathematical tools.

KEYWORDS Bioenergy, energy expenditure, Prehistoric activities, indirect calorimetry, accelerometry

INTRODUCTION

The classical approach of the Archaeology allowed us to know the daily behaviours of past individuals, bands, or societies. Ease by this knowledge, new questions remains unsolved because the classical studies cannot tackle them. Thanks to the technological revolution and the democratization of the new technologies, we can deal with these important unsolved questions. Energy is a key factor necessary to understand the relationships between an organism and their environment. The scarcity or the surplus of energy makes an organism to fail or to have success materialized in reproduction, maintenance or growth. The same pattern could be applied in our species. Therefore, being able to understand the energetic dynamics in humans we can understand the biological and cultural patterns of adaptation in past humans.

The field research focused in these topics is the Human Bioenergy, which concentrates in the energetic dynamics of living humans. But anthropology and energy were linked since the beginnings of the past century. In the early 20s bioenergetic studies began to be applied to some populations (Harris and Benedict, 1919, p. 266; Kleiber, 1947, p. 511-541; Shephard and Aoyagi, 2012, p. 2785-2815), but it was through the last decades of the past century when these studies acquired an evolutionary approach. Most of the studies tried to solve issues as the efficiency of locomotion (Leonard and Robertson 1995, p. 77-88; Wall-Scheffler, 2012, p. 71-85), the importance of energy in growth and development (Aiello and Key, 2002, p. 551-565; Aiello and

Wells, 2002, p. 323-338; Mateos *et al.*, 2014, p. 167-178) or the influence of energy in encephalization (Aiello and Wheeler, 1995, p. 199-220; Leonard and Robertson, 1994, p. 77-88; Snodgrass and Leonard, 2009, p. 220-237), or in subsistence patterns (Churchill, 2006, p. 113-133; Froehle and Churchill, 2009, p. 96-116; Sorensen and Leonard, 2001, p. 483-495). However, these works rely heavily on predictive equations established by international organisms as the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) to estimate the energy requirements (FAO/WHO/UNU, 2004), not as accurate as current methods.

New technologies and recent methods that rose from other areas like biomedicine or physical activity sciences allow us to test new questions on paleobioenergy. For instance, devices as the accelerometers, pedometers or heart rates devices and a gold standard method in the clinical medicine, as Direct and Indirect Calorimetry (IC), help us with the recent problems in the paleobiology of human extinct populations. Recently, the research group on Paleophisiology and Human Ecology of the National Research Centre on Humana Evolution (CENIEH) at Burgos (Spain) is working on these questions, designing a broad experimental program (Zorrilla-Revilla *et al.*, 2017, in press). We simulate the prehistoric activities to measure their energetic costs to understand the energetic constraints in the past populations (Prado-Nóvoa *et al.*, 2017, p. 131-141).

AIMS

The main purpose of this research line is assessing the energy expenditure derived from the physical activities typical of a hunter-gatherer way of life. We try to simulate all the parameters that can affect the performance of those activities.

MATERIAL AND METHODS

SAMPLE

To perform our experimental designs we worked with a significant sample of participants to avoid homogeneous features. The tests are performed both at the CENIEH Bioenergy Laboratory and the Sierra de Atapuerca archaeo-palaeontological sites (Burgos, Spain). All volunteers should accomplish several criteria of inclusion to perform the trials (see detailed description in Vidal-Cordasco *et al.*, 2017, p. 179-188). Then, we applied several protocols to each volunteer.

ANTHROPOMETRY PROTOCOL

Anthropometric variables are measured in each participant at the beginning of the morning session at the CENIEH facility. Volunteers are assessed shoeless. Stature is measured to the nearest 0.1 cm using a Harpenden Stadiometer Holtain Limited, weight is determined to the nearest 0.1 kg using a digital scale, and corporal portions were measured to the nearest 0.1 cm using a portable Harpenden Anthropometer Holtain Limited. Body portions collected are those that could influence the trial performed. For example: waist circumference, femur length or thoracic depth.

1. Example of the anthropometric protocol measured on volunteers. © J. Rodríguez

BODY COMPOSITION PROTOCOL

Body composition is measured with Bioelectrical impedance, BIA 101 AKERN® device and the BodyGram Pro® software (v2010). This method reflects the corporal tissues contained in human body. The method is based on the dissimilar conductivity of the body tissues when an alternate current is applied (Heymsfield *et al.*, 2005). The lean tissue is highly conductive due to the amount of water and electrolytes contained, however, fat or bone are low conductive tissues displaying high resistance (Vargas *et al.*, 2011, p. 43-58). Standardized protocol established in the Consensus Conference of the National Institutes of Health (NIH, 1996, p. 524-532) was followed to develop the analysis of BIA. Participants lay down in decubitus supine position. The legs and arm need to be separated from the body trunk and two pairs of electrodes are located in metacarpals and metatarsals of the right side of the body. The low alternating current of 50 KHz is driven through the body. Body variables studied are fat mass, fat free mass, muscle mass, for instance.

INDIRECT CALORIMETRY AND ACCELEROMETRY PROTOCOLS

To assess the energy expenditure of the designed tests we applied two noninvasive procedures: the Accelerometry (AC) and the Indirect Calorimetry (IC). The CENIEH Bioenergy laboratory contains a small tri-axial accelerometer device (SenseWear Armband™, Model MF-SW, BodyMedia Inc.) that includes physiological sensors (galvanic skin response, heat flux and skin near body temperature). These measures, together with the own characteristics of the individuals as gender, age, height, body weight and handedness are processed by specific algorithms to estimate energy expenditure. Moreover, the facility contains equipment for Indirect Calorimetry (MasterScreen CPX JAEGER™ and Oxycon Mobile portable device). This method is one of the gold standard techniques in energy measurement (Pinheiro *et al.*, 2011, p. 430-440). This allows us to estimate the production of energy and the oxidation rate of the energetic substrata from the caloric equivalent of the volume of oxygen consumed and carbon dioxide produced (Leonard, 2010, p. 221-230; Leonard, 2012, p. 372-384).

Both devices are employed to measure the resting metabolic rate (RMR) and the physical activity rate of each volunteer. Resting metabolic rate is the amount of energy necessary to maintain the basic physiological functions. All volunteers come to the Laboratory in fast, and keep lying down over a stretcher resting during 30 minutes. Then, we recreate some Palaeolithic activities, based on ethnographical references. All the participants replicate hunter-gatherer daily activities wearing both devices for indirect calorimetry and accelerometry techniques.

At field (Sierra de Atapuerca, Burgos, Spain) we carried out the vegetal resources gathering (only with females) and the quartzite boulders catchment and transport (with both males and females). At the laboratory, we performed the trials on locomotion carrying loads. In this experimental procedure all the external and atmospheric parameters (temperature, humidity, etc.) were controlled. Also, we controlled the speed and the slope of the treadmill where participants walked. Furthermore, we tested the accuracy of both methods, AC and IC.

2. Carcass transport was simulated using a backpack in a controlled environment on the National Research Centre of Human Evolution (CENIEH). © O. Prado-Nóvoa

RESULTS AND CONCLUSIONS

Experimental energetics provides us an accurate methodology to test our questions on palaeophisiology of fossil populations by means of the simulations and mathematical models. Our combination of new methods and protocols provides a newly point of view about the past societies studies in Human Evolution. This approach gives us recent raw metabolic data of the Palaeolithic activities and allows us to recognize the body parameters and other physiological conditions influencing the energy requirements. These human constraints can explain some key palaeobiological aspects related to reproductive and survival rates of human past populations.

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