Tesis Doctoral

Role of physical activity, fitness and exercise on eating behavior in adults

Rol de la actividad fisica, condicion física y ejercicio sobre la conducta alimentaria en adultos

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Miembros del Tribunal

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A mis padres,

a Alex, Sofía y Jorge, e Iván,

a Sofi, Alina, Ceci, Jimena y Diego.

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LIST OF ABREVIATIONS

ACTIBATE: Activating Brown Adipose Tissue through Exercise
ANCOVA: analysis of covariance
ANOVA: analysis of variance
BES: Binge Eating Scale
BMI: Body mass index
CoEQ: Control of Eating Questionnaire
CR: Cognitive Restraint
CRF: Cardiorespiratory fitness
DXA: Dual-energy X-ray -absorptiometer
EE: Emotional Eating
EI: Energy intake
ENMO: Euclidean norm minus one
FFF: Fat-free-mass
FM: Fat mass
FMI: Fat mass index
HFSA: High fat savoury
HFSW: High fat sweet
HRres: Heart rate reserve
LFPQ: Leeds Food Preference Questionnaire
LFPQ-Sp: Spanish version for the Leeds Food Preference Questionnaire
LFSA: Low fat savoury
LFSW: Low fat sweet
LMI: Lean mass index
LPA: Light-intensity physical activity
MPA: Moderate-intensity physical activity
MS: Muscular Strength
MVPA: Moderate-vigorous-intensity physical activity
PA: Physical activity
SD: Standard deviation
RM: Repetition maximum
RMR: Resting Metabolic Rate
UE: Uncontrolled Eating
VAS: Visual analogue scale
VCO_2: Carbon dioxide volume
VO_2: Oxygen volume
VO_2 max: Maximal oxygen volume
VPA: Vigorous-intensity physical activity


Eating Behavior
Physical Activity
Exercise
Fitness
Doctoral Thesis
Food Reward
Sedentary
Study
Adults
Young
Research
Spanish
CoEQ
TFEQ
LFPQ
BES
Traits
Six-months
Questionnaire
Cardiorespiratory
Time-spent
Appetite
Preference
Population
Effect
Images
System
Instrument
Factors
Training Program
Results
Control
Examine
Healthy
Intervention
Analyzed
Interaction
Clinical
Improve
Tools
Aims
Measured
Intake
Explore
Internal
External
Dimension
Complex
Assessment
Relationship
Health
Stimuli
Consumption
Uncontrolled Eating
Muscular Strength
Knowledge
Quality
Cultural Adaptation
Cognitive Restraint
Dietary
Components
Physiological
Neuropsychobiological
Emotional Eating
Dysregulation
Analysis

ABSTRACT

ROLE OF PHYSICAL ACTIVITY, FITNESS AND EXERCISE ON EATING BEHAVIOR IN ADULTS

Appetite, eating behavior, and dietary intake are regulated by a complex neuropsychobiological system. Several physiological factors and both internal and external stimuli converge on food consumption and food preference, as well as the relationship with food. A dysregulation in this system can lead to physical health problems. It is of clinical interest to identify how the behavioral dimension of appetite control interacts with physical activity, fitness and exercise in adults.

The aims of this Doctoral Thesis were: i) To examine the association between eating behavior traits and the time spent in physical activity of different intensities and sedentary behavior (**study I**); ii) To study the effect of a 6-month exercise intervention on eating behavior traits (**study I**); iii) To explore the association between eating behavior traits and physical fitness in young adults and (**study II**); iv) To validate the cultural adaptation of the Leeds Food Preference Questionnaire (LFPQ) in the Spanish population (**study III**).

The results of section 1 show that binge eating, uncontrolled eating and emotional eating assessed by self-reported questionnaires are inversely related to sedentary behavior and directly associated with time spent in physical activity, objectively measured by triaxial accelerometry, in young healthy adults. However, these eating traits were not modified after a 6-month exercise training program of different intensities in this population (**study I**). Additionally, we found that poorer muscular strength is related to greater cognitive restraint, while greater cardiorespiratory fitness is associated with higher scores on binge eating and uncontrolled eating in young healthy adults (**study II**). On the other hand, in section 2, we have acquired a series of valid food images for use in future research on food reward in different contexts (**study III**).

The results of this Doctoral Thesis contribute to the knowledge about the interaction of eating behavior in healthy young adults in the context of physical activity, fitness and

exercise. In addition, it provides tools to improve an instrument for measuring food reward components in the Spanish population.

RESUMEN

ROL DE LA ACTIVIDAD FÍSICA, CONDICIÓN FÍSICA Y EJERCICIO SOBRE LA CONDUCTA ALIMENTARIA EN ADULTOS

El apetito, la conducta alimentaria y la ingesta dietética están regulados por un complejo sistema neuropsicobiólogico. Diversos factores fisiológicos y estímulos tanto internos como externos confluyen sobre el consumo, preferencia de alimentos, asi como con la relación con la comida. Un desregulación en este sistema puede llevar a problemas de salud física. Es de interés clínico identificar cómo la dimensión comportamental del control del apetito interacciona con la actividad fisica, condifición fisica y el ejercicio en adultos.

Los objetivos de la presente Tesis Doctoral fueron: i) examinar la asociación entre rasgos de la conducta alimentaria y el tiempo dedicado a la actividad física de diferentes intensidades y al comportammiento sedentario (**estudio I**); ii) estudiar el efecto de una intervención de ejercicio de 6 meses sobre los rasgos de la conducta alimentaria (**estudio I)**; iii) explorar la asociación entre los rasgos de la conducta alimentaria y la condición física en adultos jóvenes (**estudio II**) y, iv) validar la adaptación cultural del Cuestionario de Preferencia de Alimentos de Leeds (LFPQ) a la población española (**estudio III**).

Los resultados de la sección 1 muestran que los atracones, la ingesta descontrolada y la ingesta emocional evaluados a través de cuestionarios autoreportados, están inversamente relacionados con el comportamiento sedentario y directamente asociados con el tiempo dedicado a la actividad física, medido objetivamente por acelerometría triaxial, en adultos jóvenes sanos. Sin embargo, estos rasgos alimentarios no se modificaron despues de un programa de entrenamiento físico de 6 meses de diferentes intensidades en esta población (**estudio I**). Además, encontramos que una menor fuerza muscular está relacionada con una mayor restricción cognitiva, mientras que una mayor condición cardiorespiratoria se asocia con puntuaciones más altas en atracones y alimentación descontrolada en adultos jóvenes sanos (**estudio II**). Por otro lado, en la sección 2, hemos adquirido una serie de imágenes alimentarias válidas para su uso en futuras investigaciones sobre la recompensa alimentaria en diferentes contextos (**estudio III**).

Los resultados de esta Tesis Doctoral contribuyen al conocimiento sobre la interacción de la conducta alimentaria en adultos jóvenes sanos en el contexto de la actividad fisica, la condición física y el ejercicio. Además, proporciona herramientas para mejorar un instrumento de medición de los componentes de la recompensa alimentaria en la población española.

1. GENERAL INTRODUCTION

GENERAL INTRODUCTION

1. BIOLOGICAL CONTROL OF APPETITE AND ENERGY INTAKE

For the study of energy balance and the different perspectives in the treatment of excessive body weight, it is necessary to address the topic of energy intake (EI) and appetite control and when and how they encounter. Human EI is modulated by the appetite control system through food consumption and eating behavior. EI is influenced by a combination of internal biological factors such as resting metabolic rate (RMR) and external nutritional factors such as energy density of the food consumed (1). Eating behavior rest on the neurocognitive processing of external stimuli modulated by a constant stream of peripheral-central crosstalk (2). Whereas energy expenditure involves a variable proportion of behavior (say 10–60% depending on the amount of physical activity undertaken), EI is 100 percent behavior (3).

The biological control of appetite is involved in a large structure that involves neurocognitive processes and multiple psychobiological constructs by which it is regulated. Accordingly to Beaulieu and colleagues (1), food intake is regulated by several homeostatics and non-homeostatics processes. The system integrates the events and behaviors that lead to, arise during, terminate and occur after food consumption (4). All these processes are induced by episodic signals that occur on a meal-to-meal basis and their diurnal variations will reflect the size, pattern and frequency of meals and eating episodes. These signals can be excitatory or inhibitory and are related to areas that control meal initiation and termination. Tonic signals arise from body tissues and cellular metabolism and they give information related to energy and nutrients availability and needs to the central nervous system (1). All the physiological and homeostatic mechanisms network with the non-homeostatic system involving eating behavioral traits and food hedonics to couple the manifestation of appetite.

The homeostatic approach

The homeostatic approach on the mechanisms of appetite control is focused on process promoting hunger and fullness. This process comes from biological needs and are

balanced by physiological satiety signaling systems (3). Coordinated by the hypothalamus (5) these includes metabolic and peripheral events and neurotransmitter interactions in the brain which its desynchronization can lead to disruption of appetite (e.g. in eating disorders and perhaps with physical inactivity and obesity) (1).

The non-homeostatic factors

By the other hand, the non-homeostatic factors involve the hedonic component of eating and the concepts of motivation and reward value of food. Individual differences exists in the hedonic part of food intake that can be related to genetic, physiologic, metabolic and psychological factors (5). Hedonics thoughts about food and the sensory appreciation of food characteristics (i.e., salt, sugar and fat content) determine food preference and choice, and consequently meal size and frequency (1).

States and traits

Within psychological aspects of eating motivation, states and traits can be distinguished. States can be identified as sensations (i.e., hunger, fullness and wanting) that oscillate episodically. This fluctuation can be described by a certain of frequency, amplitude and rhythmicity (e.g., hunger's diurnal profile). Conversely, traits represent more enduring influences on behavior and do not fluctuate within a day or on a day-to-day basis. Also, they impact the tendency or selection of food on a habitual long-term basis (3).

Self-reported measures of eating behavior traits have been developed to quantify the extent to which an individual is attracted to food and finds reward on food consumption (6). Some dimensions of these traits include: i) Emotional Eating (EE) which is eating in response to negative clues, ii) Cognitive Restraint (CR) that it restraint dietary intake in order to control body weight, and iii) Uncontrolled Eating (UE) and binge eating that imply a loss of control over intake (6). Also, the urge to eat certain type of food known as cravings (7). Although some difficulty exists regarding obtaining valid data under free-living conditions, the records of the expression of eating behavior or food choice are normally accurate and precise, but not natural (3).

Dual system of liking and wanting

In coordination with brain's reward circuitry, the hedonic appetite system responds to sensory properties and thoughts about food that promote liking and wanting. This system

work to manage short-term "episodic" and long-term "tonic" energy requirements (5) and it is denoted as the major driving of ingestion (8), and regulating body weight in a flexible and adaptative manner (9). Liking underpins the subjective pleasure of food (10) and it is usually understood as the perceived impact of a food, its sensory properties on subjective affect or some judgment of the pleasure it provokes (5). Wanting is the motivational component of reward implied to as a process of incentive salience attribution rewards and their associated cues in the environment (11). It may refer to subjective state of desire, craving or feeling lack of something desirable. Both liking and wanting components can have an explicit (conscious and introspective) and an implicit (subconscious and automatic) level (5). By measuring these components in eating behavior it can be studied by which circumstances they differ or even dissociate, and how this might determine an individual's propensity to overconsume and gain weight (5). The Leeds Food Preference Questionnaire (LFPQ) is an instrument to measure liking and wanting in a plausible way. This tool incorporates the ability to distinct the components of food reward. Also, the LFPQ, which has been developed and refined over the years, represents the best way to measure implicit wanting and explicit liking components according to predetermined dimensions of food (12).

2. PHYSICAL ACTIVITY LEVELS AND SEDENTARY TIME: IMPLICATIONS OVER ENERGY INTAKE AND APPETITE CONTROL

Physical activity (PA) defined as any bodily movement produced by skeletal muscles that results in energy expenditure. The amount of it is largely a matter to personal choice and may vary from person to person and ranges from low to high (13). The relevance and applicability of PA in a great number of medical conditions is well known and its importance in weight management is crucial. There is evidence of the adaptations associated to the effect of PA and exercise on metabolism. Such improvements include better body composition and an enhanced hormone signaling, among others (14). The benefit of regular PA may occur through a combination of mechanisms including enhanced sensitivity to physiological feelings of satiety; adjusting food preferences and altering the hedonic response to food (15). Also, Myers and colleagues, have investigated

the relationship between amount of time in sedentary and active behaviors and measures of body adiposity reflecting a dysregulated appetite (16). This suggests that physical inactivity may lead to dysregulation of appetite and thus a subsequent overconsumption, although differences in active and inactive individuals may not always be clear (14).

On the other hand, sedentary behavior is defined as any waking activities conducted in a sitting, reclining or lying posture that are characterized by an energy expenditure ≤1.5 metabolic equivalents (METs) (17).

3. ROLE OF EXERCISE TRAINING ON BEHAVIORAL CONTROL APPETITE

Exercise, a subset of PA, is planned, structured, repetitive and have a purpose upon maintenance or improvement (13). In this sense, we can differentiate two types of exercise: a) aerobic exercise involves dynamic movements and large muscle groups that predominantly rely on aerobic metabolism for fueling muscle contractions (17) as running or cycling; and b) resistance exercise which is every movement performed against a specific external force that is regularly increased during training (17).

Exercise impacts on the biological mechanisms controlling appetite. Specific variations in motivation to eat and satiety may depend on the intensity and duration of exercise. Therefore, biological responses between individuals vary from person to person and can be explained by the variable effect of exercise on body weight and body composition (from fat-free-mass (FFM) and fat-mass (FM)) (18). However, there could be other psychological processes that cause compensatory eating behaviors such as ingestion of caloric and palatable foods, which impede reaching the weight loss goals through exercise (19). Another point of view consists on new approaches oriented to intuitive eating, as opposed to food restriction, would have better effects on motivation to eat and for PA (20).

4. ROLE OF PHYSICAL FITNESS ON BEHAVIORAL CONTROL APPETITE

Physical fitness is a set of attributes that people have or achieve in order to carry out daily tasks with vigor and alertness, without fatigue and with ample energy (13). These attributes can be cited as i) related to health (i.e., cardiorespiratory and muscular endurance, and muscular strength, among others) and ii) related to skills attaining athletic ability (13).

In this context, cardiorespiratory fitness (CRF) is the capacity of the circulatory systems to supply oxygen to skeletal muscles during sustained physical activity (17). Also, muscular strength (MS) is the ability of the muscle to exert force on physical objects (17). Physical fitness has been shown to be a potent predictor of health (21), although its association with eating behavior is still unknown. Since higher physical fitness could be a marker of physically active lifestyle (22), it could be related to dysregulated appetite.

The evidence regarding the effects of PA, physical fitness and exercise on EI from a behavioral approach of control of appetite are scarce and studies are needed to provide potential explanatory mechanisms and new path for weight control management in adults and healthier eating behavior.

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2. AIMS

2. AIMS

OVERAL AIM

The overall aim of this Doctoral Thesis is to analyze the interplay of eating behavior with physical activity and fitness, and exercise training in young healthy adults.

SPECIFIC AIMS

Section 1. Eating behavior and physical activity, exercise training and physical fitness

- *Specific aim 1.* To examine the association between eating behavior traits and time spent in physical activity of different intensities and sedentary behavior in young healthy adults (**study I**).
- *Specific aim 2.* To examine the effect of a six-month supervised exercise training program on eating behavior traits in young healthy adults (**study I**).
- *Specific aim 3.* To examine the association between eating behavior traits and physical fitness in young healthy adults (**study II**).

Section 2. Adaption and validation of the Leeds Food Preference Questionnaire

- *Specific aim 4.* To validate the culturally adapted Spanish version of the Leeds Food Preference Questionnaire (**study III**).

3. MATERIAL AND METHODS

3. MATERIAL AND METHODS

The present Doctoral Thesis is composed of three studies organized in different sections:

Section 1: The ACTIBATE Project (**Figure 2.1**)

i. *Cross-sectional*: focused on the association between eating behavior traits and objectively measured time spent in sedentary behavior and physical activity of different intensities in young, healthy adults. We also investigated the relationship between eating behavior traits and muscular strength and cardiorespiratory fitness.

ii. *Longitudinal:* focused on the effect of a six-month intervention exercise program of two different intensities on eating behavior traits in young, healthy adults.

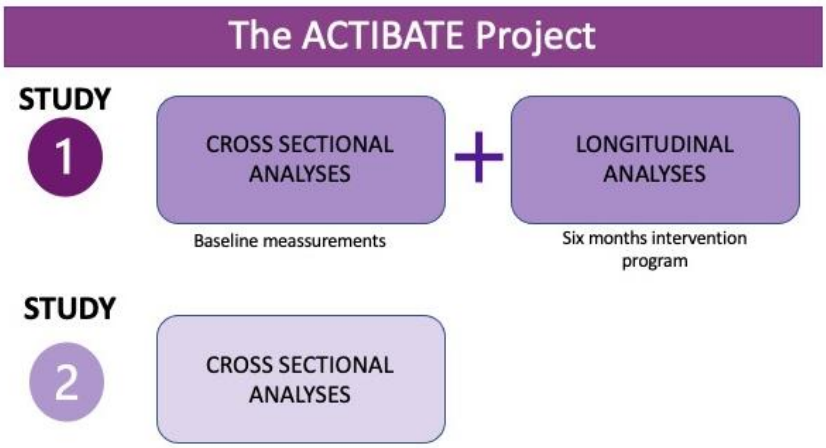

Figure 2.1. Methodological overview of the Study I and Study II.

Section 2: Cultural adaptation and validation of the Spanish version of Leeds Food Preference Questionnaire (**Figure 2.2**)

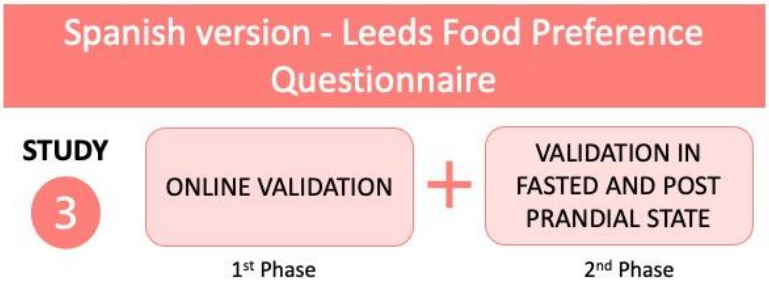

Figure 2.2 Methodological process of the cultural adaptation and validation of the Spanish version of Leeds Food Preference Questionnaire.

METHODOLOGICAL OVERVIEW OF THE STUDIES INCLUDED

Table 2.1 Methodological overview of all studies included in the Doctoral Thesis

STUDY	DESIGN	PARTICIPANTS	INDEPENDENT VARIABLES	DEPENDENT VARIABLES	STATISTICAL APPROACH
STUDY I PART A	Cross-sectional	139 young healthy adults ○ Women *n* = 95 ○ Men *n* = 44 ○ Age: 22.06±2.26	• Time spent in sedentary behavior and PA of different intensities (triaxial accelerometer): ○ LPA ○ MPA ○ MVPA ○ VPA ○ ENMO	• Self-reported questionnaires: ○BES ○TFEQ-R18 ○CoEQ	• Bivariate and partial correlation • Simple and multiple linear regression
STUDY I PART B	Longitudinal - RCT	105 young healthy adults ○ Women *n* = 95 ○ Men *n* = 44 ○ Age: 22.06±2.26	• Control group • Resistance and aerobic exercise intervention: ○ Moderate-intensity group ○ Vigorous-intensity group	• Self-reported questionnaires: ○BES ○TFEQ-R18 ○CoEQ	• Two-factor mixed analysis of variance (ANOVA) • One-factor analysis of covariance (ANCOVA) • between groups
STUDY II	Cross-sectional	140 young healthy adults • Women *n* = 97 • Men *n* = 43 • Age: 22.07±2.22	• Physical fitness ○ Muscular strength ○ Cardiorespiratory fitness	• Self-reported questionnaires: ○BES ○TFEQ-R18	• Bivariate and partial correlation • Simple and multiple linear regression
STUDY III	Validation study	Anonymously collected responses Total *n* = 96 adults ○ Women *n* = 58 ○ Men *n* = 38 ○ Age: 33.42±13.07 Main residence: ○ Granada, Las Palmas, Cadiz, Gipuzkoa and Málaga	Outcomes measures: • Criteria ○ Recognition ○ Liking ○ Taste ○ Fat ○ Appropriateness for the time of the day ○ Healthiness	• 32 food images from 4 different categories ○ HFSA ○ HFSW ○ LFSA ○ LFSW	• Mean & standard deviation

BES: Binge Eating Scale; TFEQ-R18: Three-Factor Eating Questionnaire; CoEQ: Control of Eating Questionnaire; PA: physical activity; LPA: light PA; MPA: moderate PA; VPA: vigorous PA; MVPA: moderate-to-vigorous PA; ENMO: Euclidean norm minus one.

Section 1. The ACTIBATE Project

Study design and location

The ACTIBATE study is a randomized controlled trial (ClinicalTrials.gov ID: NCT02365129). Study design, protocols and informed consent procedures were approved by the Ethics Committee on Human Research of both University of Granada (no. 924) and the Andalusian Health Service and adhere to the Declaration of Helsinki (2013 revision). All the assessment, procedures and intervention that are part of the **Study I** and **Study II** were carried out at the Sport and Health University Research Institute (iMUDS), Granada, Spain. Baseline evaluations were performed between October and November 2015 (n≈60 participants) and 2016 (n≈90 participants).

Participants and selection criteria

The inclusion and exclusion criteria are listed in **Table 2.2**

Table 2.2 Inclusion and exclusion selection criteria in the ACTIBATE Project (1).

Inclusion criteria	Exclusion criteria
• Age: 18–25 years. • BMI: 18.5–35 kg/m^2. • Not engaged in regular physical activity >20 min on >3 days/week. • Not participating in a weight loss programme. • Stable weight over the last 3 months (body weight changes <3 kg). • Normal electrocardiogram. • Participants must be capable and willing to provide consent, understand exclusion criteria and accept the randomized group assignment.	• History of cardiovascular disease. • Diabetes or hypertension. • Pregnancy, or planning to get pregnant during the study period. • Medication for hypertension, hyperlipidemia, • hyperuricemia or other illness. • Beta blockers or benzodiazepines use. • Smoking. • Frequent exposure to cold temperatures • Taking medication for thyroid. • Other significant medical conditions that are life-threatening or that can interfere with or be aggravated by exercise. • Unwillingness to either complete the study requirements or to be randomized into control or training group. • A first-degree relative with history of cancer.

Randomization

After completing the baseline measurements participants were randomly assigned to either (i) a control group (usual lifestyle); (ii) a moderate-intensity exercise training group or (iii) a vigorous-intensity exercise training group. The simple (unrestricted)

randomization was computer generated. Staff were blinded to participant's randomization assignment and participants were explicitly informed upon the group they had been assigned.

Participants' adherence

Participants could withdraw at any time from the study. Nevertheless, to avoid withdrawal and maintain adherence to the intervention training program, participants were allowed to performed exercise out of the center. For this instance, participants received a kit and training session plan to perform the exercises, which contained a heart rate monitor as well as instructions on how to operate it. Also, elastic bands to perform strength exercises.

Physical activity and sedentary behavior assessment

To monitor time spent in physical activity and sedentary behavior all participants were asked to wear two activity monitors, one on the wrist worn GT3X+ model accelerometer (ActiSleep, Actigraph, Pensacola, FL, USA) for 7 consecutive days for 24h to record physical activity levels and patterns. Participants were only allowed to remove the accelerometers to perform water activities such as bathing or swimming.

The protocol to obtain this measure was:

1. All participants came to the research center and were given instructions regarding the wearing of the accelerometer and communicated to remove it only during activities such as bathing or swimming. Also, they were asked to answer and register a diary with the record of their sleeping hours and time in which they did not use the device (see annexes).
2. The accelerometers were initialized to store raw accelerations at a sampling frequency of 100 Hz. Raw accelerations were exported using ActiLife v6.13.3 software (ActiGraph, Pensacola, FL, USA) and converted to *.csv* format.
3. The raw *.csv* files were then imported into R software v3.1.2 (https://www.cran.r-project.org/) and processed using GGIR software v1.5-12 (https://cran.r-project.org/web/packages/GGIR/). This process involved:
    a. Auto-calibration of the data according to local gravity (2)
    b. Calculation of the Euclidean Norm Minus One (ENMO) as the following equation:

$$(x2 + y2 + z2) - 1G \text{ (where } 1G \sim 9.8 \text{ m/ s2)}$$

with negative values rounded to zero

c. Detection of non-wear time based on the raw acceleration of the three axes; briefly each 15-min block was classified as non-wear time if the standard deviation of 2 of the 3 axes was < 13 mG during the surrounding 60 min moving-time window, or if the value range for 2 of the 3 axes was < 50 mG.
d. Detection of sustained abnormally high accelerations, i.e., > 5.5 G, related to malfunctioning of the accelerometers
e. Imputation of detected non-wear time and abnormally high accelerations
f. Identification of waking and sleeping hours via an automated algorithm guided by participants' diary reports (3)
g. Estimation of time spent in sedentary behavior and physical activity using age-specific cut-points for Euclidean norm minus one (ENMO) (4,5)
h. Only participants wearing the accelerometers for ≥16 h/ day and ≤4 h/ night over at least 4 days (including at least 1 weekend day) were included in analyses. Additionally, the time spent in moderate-vigorous PA in bouts of 10 min (MVPA10min), with a drop-down tolerance of 2 min, was calculated. For establishing these categories, we followed the World Health Organization PA recommendations for adults (6). The mean daily ENMO (mG) (only waking time) was used as a general indicator of PA level.

Assessment periods

Studies I and **II** that complement this Thesis are developed within the ACTIBATE Project. Therefore, their period and evaluation process are listed in the next **Figure 2.3**.

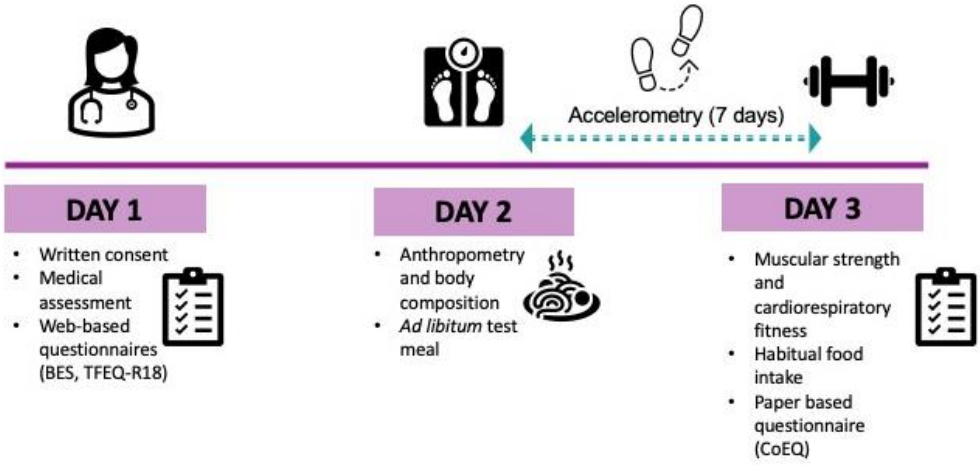

Figure 2.3 Evaluation process of the Study I and Study II.

Energy and food intake

Energy intake was measured by two ways:

i. Habitual food intake: habitual food intake was recorded through three non-consecutive 24 h recalls (two weekdays and one weekend day or bank day) during a face-to-face interview done by a nutritionist. In this interviews, a protocol was followed where food photographs of different portion sizes where shown to the participant to ensure the accuracy of the measurement (7). Energy and nutrients intakes were then determined using EvalFINUT® software which contained the databases of the United Stated Department of Agriculture (USDA) and the Spanish Food Composition (BEDCA).

ii. *Ad libitum* energy intake: the *ad libitum* food intake was performed through a test meal where participants were offered a plate of spaghetti (i.e., spaghetti, tomato sauce, pork tenderloin and virgin oil). The lunch composition was 16% proteins, 38.5% fat and 45.5% carbohydrates of the total energy, with an energy density of 1.54kcal/g. Total amount offered was 1500 g for men and 1000 g for women. For this test, participants were located alone in an empty and quiet room, where they could find the lunch plate and a glass of 450 ml of water. Also, participants were instructed to eat as much as they want until they felt comfortably satisfied. Food intake was measured by differences in spaghetti weight before and after lunch, and the energy intake was therefore calculated. This test was carried out after a period of measurement of energy expenditure after a standardized liquid breakfast (1).

Anthropometry and body composition

Measurements were taken when participants were in fasted state, barefoot and wearing light clothes. Body weight and height were measured using a weighing machine SECA model 799 and stadiometer SECA. Body mass index (BMI) was then calculated as body mass divided by height2 (kg/m^2). Body composition was measured using a Discovery Wi dual-energy X-ray absorptiometer (DXA) (Hologic, Inc., Bedford, MA, USA). The fat mass index (FMI) and lean mass index (LMI) were calculated as fat/lean mass divided by height squared (kg/m^2).

Eating behavior traits

Eating traits were measured through self-answered questionnaires (see annexes).

i. Binge Eating Scale (BES): This web-based instrument was used to assess feelings or cognitions and manifestations related to binge eating. It consists of two parts, each one made up of 8 questions adding a total of 16 statements. For the calculation of the total score the weight of each statement which is between 0 and 3 is then summed. A higher total score reflects more severe binge-eating problems (8).

ii. Three Factor Eating Questionnaire-R18 (TFEQ): This web-based questionnaire composed by 18 questions each of them measured on a 4-point response scale (definitely true:1, mostly true: 2, mostly false: 3, definitely false: 4), was used to assess the following three scopes:

- Cognitive Restraint (CR), six questions
- Uncontrolled Eating (UE), nine questions
- Emotional Eating (EE), three questions

Each dimension was summed to obtained total score (9).

iii. Control of Eating Questionnaire (CoEQ): This paper-based questionnaire consisted in 21 questions with visual analogue scale (VAS) responses (0-100) intended to measure the type and intensity of food craving experienced, as well as subjective feelings sensations about appetite and mood on the previous 7 days (10). The subscales are as listened:

- Craving control
- Craving for sweet
- Craving for savoury
- Positive mood

Muscular strength and cardiorespiratory fitness

Muscular strength

Muscular strength was assessed through handgrip strength, using a Takei 5401 digital Grip-D hand dynamometer (Takei, Tokyo, Japan). The subjects were asked to grab the grip manually and continuously as hard as possible. The test was done twice for each hand and the average between both hands was used for analysis.

Upper muscular strength were determined by a leg extension press using a resistance press machine (A300 Leg Press, Model 2531, Keiser Corporation, Fresno CA, USA).

Participants were asked to perform 1 set of 10 repetitions having selected for themselves the light weight for warming up. Then they performed 1 set of 8 repetitions selecting an equivalent load to the one they could lift 15 repetitions maximum. Then after one minute of recovery and aiming to set an intention load by the researcher, the load was increased to perform less than 10 repetitions. The test ended after 3-4 repetitions if the participants felt they could perform more than 10 repetitions with the set of resistance load. For the upper muscular strength bench press, the protocol was similar using a pneumatic power rack (Power rack, Model 3111, Keiser Corporation, Fresno CA, USA). The repetition maximum (RM) was estimated by the equation proposed by Wathen (11).

Cardiorespiratory fitness

This measurement was undertaken when participants were in a fasted state (3-5 hours) and they did not perform any type of exercise 48 hours prior the test. Also, they were asked to not consume any caffeine or stimulant 23 hours before.

The test was determined using a maximum treadmill exercise test (H/P/Cosmos Pulsar treadmill, H/P/Cosmos Sports & Medical GmbH, Nussdorf-Traunstein, Germany), following the modified Balke protocol (12). The test consisted in a warm-up period were participants walked at 3km/h for 1 min, followed by 2 min at 4km/hr with 0% slope. After this, the incremental protocol started at a speed of 5.3km/hr and 0% slope. Incremental phase for the slope was 1% every minute until the participant became exhausted. When exhaustion appeared, participant went through a walking at 4km/hr cooling-down period with 0% slope for 5 min. Respiratory gas exchange [oxygen consumption (VO_2) and carbon dioxide (VCO_2) production] was recorded by indirect calorimetry using a CPX Ultima CardioO_2 metabolic cart (Medical Graphics Corp, St Paul, MN, USA), equipped with a facemask (model 7400 plastic, Hans Rudolph Inc., Kansas City, MO, USA) and a preVent™ metabolic flow sensor (Medical graphics Corp, St Paul, MN, USA).

Exercise program intervention

Participants were randomly assigned to either a) a control group (usual lifestyle); b) a moderate-intensity exercise interventions group; or to c) a vigorous-intensity intervention group. Graduates in sport sciences directed and supervised all the training sessions performed at the Sport and Health University Research Institute (iMUDS), Granada, Spain. In each session there were a maximum of 16 individuals. Likewise, temperature room was controlled.

The basis for the specific exercise dose in ACTIBATE Project is the physical activity recommendations for adults proposed by the World Health Organization (6). Both aerobic and strength training was performed in both intervention groups differing in the intensity of training: moderate-intensity and vigorous-intensity groups.

Volume

For both intervention groups, volume was set on 150 min/week for the aerobic training and ≈80 min/week for strength training. For the aerobic exercise, the vigorous-intensity group performed 75 min/week at moderate intensity (i.e., 60% HRres) and 75 min/week at vigorous intensity (i.e., 80% HRres). The moderate-intensity group performed the total of 150 min/week of aerobic training at 60% HRres. The resistance training was performed at 50% of 1RM for the moderate-intensity group and at 70% RM for the vigorous-intensity group.

To register participants' heart rate during exercise, a heart rate monitor device was used (RS800CX, Polar Electro Öy, Kempele, Finland) in all sessions. Also, rating of perceived effort was collected in each session.

Intensity

The intensity selected for ACTIBATE Project intervention groups was set as follows: for the aerobic training was set 60% HRres for the moderate-intensity group and 80% HRres for the vigorous intensity-group. Meanwhile, the strength training was set as 50% 1RM for the moderate-intensity group, and 70% 1RM for the vigorous-intensity group.

Frequency

The established dose in this study was 3 to 4 sessions per week. Resistance training was performed solely in 2 of those 3-4 sessions/week. Meanwhile, aerobic training was performed in 1 or 2 sessions where aerobic exercise was entirely done.

Participants were encouraged to not to train less than 3 or more than 5 days per week. Also, not to stop training for more than 2 consecutive days. Likewise, if necessary, subjects were allowed to perform their training sessions at home. In such instances, the heart rate monitors were given along with elastic bands for the adapted resistance training.

Type of exercise

For the aerobic training, the exercises performed were using cycle ergometer, treadmill and elliptical ergometer.

The resistance training mainly involved major upper and lower body muscles groups performing the following exercises: squats, horizontal pull, vertical push, hinge, plank, lunge, bridge, bench press, led press, lateral pull down, monster walk. Also, compensatory training was performed, such as core and muscle stabilizers, and flexibility.

Training periodization

The training periodization consisted of 5 phases, where a first phase was entirely of familiarization whose objective was learning. This first phase lasted 4 weeks and consisted of exercises with elastic bands and using weight bearing exercises for the resistance part. For the aerobic exercise the volume increased gradually to avoid overload, damage and to ensure adherence. The following phases (1 to 4) lasted 5 weeks and consisted on a first week that was used to assess resistance training load through indirect RM of the exercises used in each phase. In this first week, aerobic volume was reduced to 120 min per week. **Figure 2.4** (see below) shows training periodization.

	Phases	Familiarization				Phase 1					Phase 2					Phase 3					Phase 4				
	Weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Aerobic training	Aerobic training volume (min)	75	105	135	150	120	150	150	150	150	120	150	150	150	150	120	150	150	150	150	120	150	150	120	150
	Intensity (%HRres) moderate-intensity group	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
	Intensity (%HRres) vigorous-intensity group	60	60	60	60	70	75	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
Strength training	Intensity (%RM) moderate-intensity group	Weight- bearing and elastics bands					50	50	50			50	50	50			50	50	50			50	50	50	50
	Intensity (%RM) vigorous-intensity group						50	60	70			60	70	70			60	70	70			70	70	70	70
	Type of exercises performed	Learning exercises of movement patterns Slow and global movement pattern (light weights)					Exercises localized in major muscle groups					Exercises localized in major muscle groups					Whole body exercises					Exercises localized in mayor muscle groups			Whole body exercises
	Training stimulus aim	Learning of movement patterns					Initial adaptations to resistance training					Session type A: mechanical tension and muscle damage					Session type A: mechanical tension and muscle damage					Session type A: mechanical tension and power			
		Compensatory training: -Core stability - Flexibility - Stabilizers muscles					Compensatory training: -Core stability - Flexibility - Stabilizers muscles					Session type B: Metabolic Stress					Session type B: Metabolic Stress					Session type B: Metabolic Stress			

Figure 2.4 Training periodization. Grey blocks represent weeks where the strength training load is reduced to learn the proper technique of the exercise used in the next phase. Black blocks represent weeks where strength training mostly consisted of repetition maximum (RM) assessment in the different exercises used in the phase. HRres: Heart rate reserve. (1)

Training sessions

Aerobic training was divided considering time and sessions of resistance training. Thus, combined sessions had lower volume of aerobic training in comparison to sessions where

aerobic training was performed solely. Characteristic of the training sessions were as follows:

a) Aerobic sessions: consisted in alternating exercises every 10 minutes:

1. compensatory exercises (mobility, activation, stabilization and balance) and,
2. aerobic training (cyclo ergometer, elliptical ergometer and treadmill)

b) Combined sessions: consisted in:

1. warm up exercises (5 min),
2. mobility and activation (plank, bridge, monster walk) and,
3. aerobic exercise as treadmill and cycle and elliptical ergometer

Each session started with a warm-up and ended with cooling-down period, where aerobic and stretching exercises were performed in a lower intensity.

From 2nd to 4th training phases, two types of sessions were performed (**Figure 2.5,** see below):

SESSION TYPE A

	Exercise	Time/sets
Warm-up		
MAIN PART	Aerobic set 1	10 min
	Strength exercise I	1set x 10reps
	Strength exercise II	1set x 10reps
	Strength exercise III	1set x 10reps
	Strength exercise IV	1set x 10reps
	Aerobic set 2	10 min
	Strength exercise V	1set x 10reps
	Strength exercise VI	1set x 10reps
	Strength exercise VII	1set x 10reps
	Strength exercise VIII	1set x 10reps
	Aerobic set 3	10 min
	Strength exercise I	1set x 10reps
	Strength exercise II	1set x 10reps
	Strength exercise III	1set x 10reps
	Strength exercise IV	1set x 10reps
	Aerobic set 4	10 min
	Strength exercise V	1set x 10reps
	Strength exercise VI	1set x 10reps
	Strength exercise VII	1set x 10reps
	Strength exercise VIII	1set x 10reps
Cooling down		

SESSION TYPE B

	Exercise	Time/sets
Warm-up		
MAIN PART	Aerobic set 1	10 min
	Aerobic set 2	10 min
	Strength exercise I	2sets x 10reps
	Strength exercise VII	2sets x 10reps
	Strength exercise V	2sets x 10reps
	Strength exercise III	2sets x 10reps
	Strength exercise II	2sets x 10reps
	Strength exercise VI	2sets x 10reps
	Strength exercise IV	2sets x 10reps
	Strength exercise VIII	2sets x 10reps
	Aerobic set 3	10 min
	Aerobic set 4	10 min
Cooling down		

Figure 2.5: Example of type of a combined training session for phases 2 to 4(1).

Section 2. Cultural adaptation and validation of the Spanish Leeds Food Preference Questionnaire

To carry out and develop the cultural validation and adaptation, we conducted and follow the procedures (**figure 2.6,** see below) proposed by Oustric et al. (13). However, the **Study III** that encompasses this doctoral Thesis only includes the first phase of this adaptation, which refers to *online validation process*.

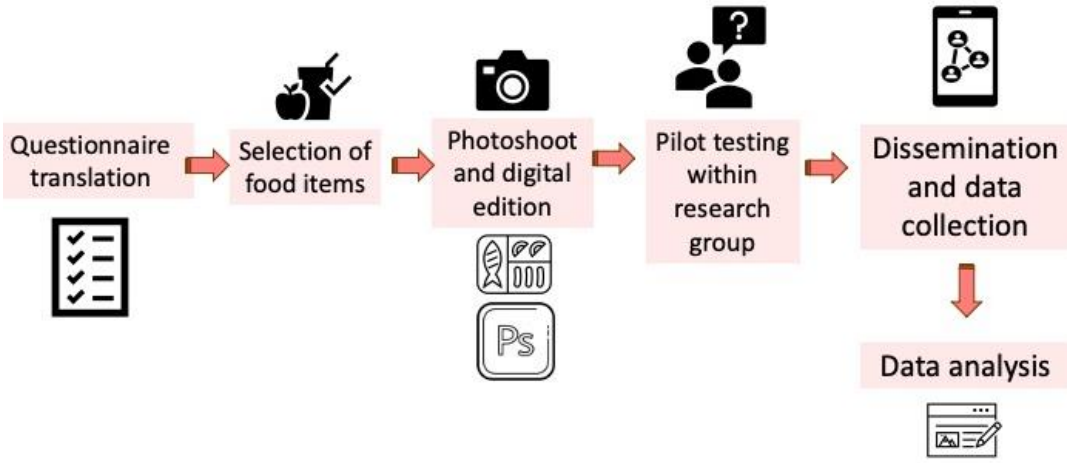

Figure 2.6 Process of the LFPQ-SP online validation phase.

Ethics approval and committee

Study design, protocols and informed consent procedures were approved by the Ethics Committee on Human Research of both University of Granada (no. 924) and adhere to the Declaration of Helsinki (2013 revision).

Online validation process

Questionnaire translation

The original questionnaire was translated into Spanish with the advice of a translation specialist. We also tested the understanding of the questions with native Spanish speakers.

Selection of food items

The team of nutritionists-dietitians oversaw the suitability of a series of foods items proposed for each category. Based on advice for good practice and methods for developing cultural adaptation (13), foods items that complied with criteria proposed were chosen (**Table 2.3** and **Figures 2.7-10**).

Proposed criteria were as follows:

- Ready to eat foods
- Appropriate for Spanish culture and habits
- Frequently consumed by Spanish population
- Nutritionally appropriate for each category (i.e., high – fat >40% energy from fat and low – fat <20% energy from fat, matched in protein content as possible.

Table 2.3 List of food items for each category.

Food categorie	Food item
High-Fat Savoury >60% fat content	Olivier salad / Ensaladilla rusa
	Potato chips / Patatas Chips
	Potato omelette / Tortilla de patatas
	Iberic Ham / Jamón serrano
	Olives /Acetiunas
	Cheese / Queso
	Cold meat / Fuet
	Fried potatoes with sauces / Patatas bravas
Low-Fat Savoury <20% fat content	Bread sticks / Picos-colines
	Chicken breast, grilled / Pechuga de pollo, asada
	Bread / Pan
	Rice w/veggetables / Arroz con vegetales
	Cherry tomato / Tomate
	Veggetable stew / Menestra de verduras
	Carrots / Zanahorias
	Salad / Ensalada
High-Fat Sweet >60% fat content	Cookies / Galletas con chispas de chocolate
	Puff pastry cookies / Palmeritas
	Doughnut / Donus
	Chocolate-filled pie / Napolitana de chocolate
	Apple pastry / Tarta de manzana
	Muffins / Magdalenas
	Waffle / Gofre
	Majorcan sweet bun / Ensaimada
Low-Fat Sweet <20% fat content	Cereal bar / Barrita de muesli
	Apple / Manzana
	Jelly / Gelatina
	Orange / Naranja
	Banana / Plátano
	Vainila custard / Flan de Vainilla
	Kiwi
	Gummies / Gominolas

Creation of food images

Once the food list was created and selected, food items were valued based on the nutritional suitability according to their nutritional content from Spanish Food Composition Database (BEDCA) and nutritional labeling. Food images were created by weighing each serving and portion of food.

Photoshoot and digital edition

Food images were created using a digital camera Nikon D7200, AF-S DX NIKKOR 18-105mm f/2.5-5.6G ED VR (Nikon, Tokyo, Japan). Once the photoshoot was done, each photograph was digitally edited using Adobe Photoshop® software.

Online questionnaire

The online validation was done through a questionnaire distributed electronically by the LimeSurvey platform and using the University of Granada's server. The responses were collected anonymously.

Dissemination

For the collection of responses, the online questionnaire was electronically distributed through social networks and the university's institutional mail.

Food items pictures

Figure 2.7. High-fat savoury food images.

Figure 2.8. Low-fat savoury food images.

Figure 2.9. High-fat sweet food images.

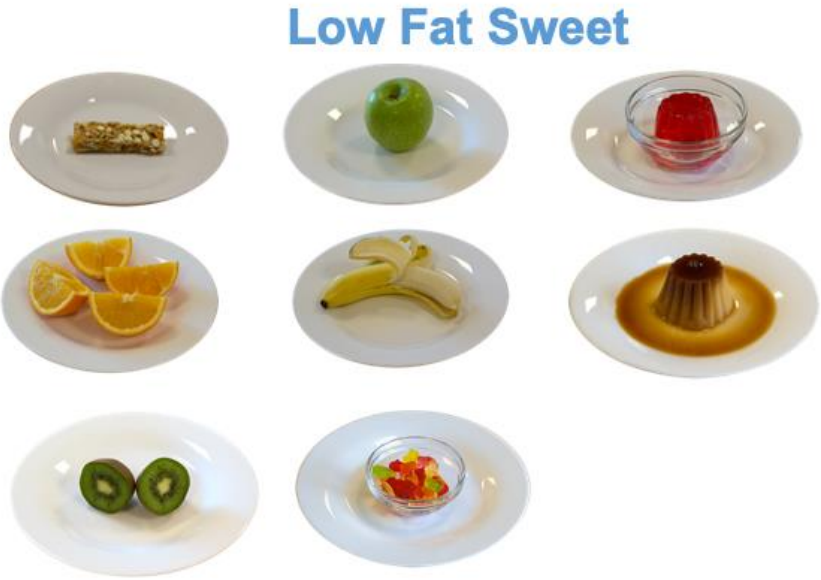

Figure 2.10. Low-fat sweet food images.

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4. RESULTS

4.1 Study I

EATING BEHAVIOR, PHYSICAL ACTIVITY AND EXERCISE TRAINING: A RANDOMIZED CONTROLLED TRIAL IN YOUNG HEALTHY ADULTS

STUDY I

Eating behavior, physical activity and exercise training: a randomized controlled trial in young healthy adults

1. INTRODUCTION

Obesity is an important risk factor for the development of diabetes, cardiovascular disease and other non-communicable conditions. An increased energy intake, a sedentary lifestyle, and a lack of physical activity (PA) are the major causes of obesity (1). Regular PA can contribute to improvements in energy and macronutrient balance (1) and is recommended for weight loss. However, PA increases energy expenditure, which can act as a driver of energy intake thereby inducing compensatory responses in energy intake and appetite regulation, commonly resulting in very little weight being lost.

Appetite influences the selection of food items, meal size and the frequency of eating (2). However, eating behavior is also influenced by internalized multidimensional traits that include behavioral, cognitive and affective components (3). Since eating occurs in a variety of complex situations with varying social and cultural influences, energy intake can be notably altered by an individual's psychological state and cognitive factors (4). Restraint and disinhibition are two of the main cognitive characteristics that exert an effect on appetite regulation and food intake (5). Dietary restraint refers to behaviors adopted to avoid weight gain (e.g., avoiding fattening foods, eating smaller portions), while disinhibition is the tendency towards overeating and eating opportunistically (6). Further, food cravings and the urge to eat a certain type of food are components of the hedonistic control of appetite (7) which is activated by the thought of the sensorial pleasure of eating palatable food (5). These eating behavior traits can be measured through psychometric tools such as the Binge Eating Scale (BES) (8) for binge behavior, the Three-Factor Eating Questionnaire (TFEQ) (9,10) for cognitive restraint, emotional eating and uncontrolled eating, and the Control of Eating Questionnaire (CoEQ) (11) for food cravings and mood.

Regular PA influences eating behavior by enhancing the sensitivity of the physiological satiety signaling system, adjusting macronutrient food choices and requirements, and changing the hedonic response to food stimuli (12,13). However, low levels of PA do not drag down food consumption to match the associated low energy expenditure (14). For

instance, individuals who undertake only low-level PA are reported to have a weaker satiety response to food intake (13). Drenowatz et al. indicate that specific types of exercise influence the frequency and intensity of food cravings (7). However, it remains unclear how PA could be associated and influence eating behavior traits in young adults. The present work examines the relationship between objectively measured time spent in sedentary behavior/PA of different intensity and eating behavior traits in young, healthy adults. It also examines the effect of a six-month exercise training program of different intensity on the eating behavior traits of the same group of subjects.

2. MATERIALS AND METHODS

2.1 Participants and Design

A total of 139 young adults (age 18–25 years, 22 ± 2 years; 68.6% women), all non-smokers, were enrolled in the present study (the ACTIBATE study; ClinicalTrials.gov ID: NCT02365129) (15). Their Body Mass Index (BMI) lay between 18.5 and 35 kg/m^2. None took any medication, all reported a stable body weight over the preceding 3 months (<3 kg change), and all had a normal electrocardiogram. They reported themselves to be sedentary (<20 min physical activity on <3 days/week). Subjects were recruited via social networks and local media. Interested parties came to information meetings at which the aims of the main study were explained, together with the measurements to be taken, the requirements of the participants, and the types of intervention. Those who wished to take part provided written informed consent to that effect and underwent a medical examination before entering the study. The study protocol and design were approved by the Ethics Committee on Human Research of the University of Granada (no. 924) and the Andalusian Health Service (SAS), and adhere to the Declaration of Helsinki (2013 revision). Figure 1 shows the study flow-chart.

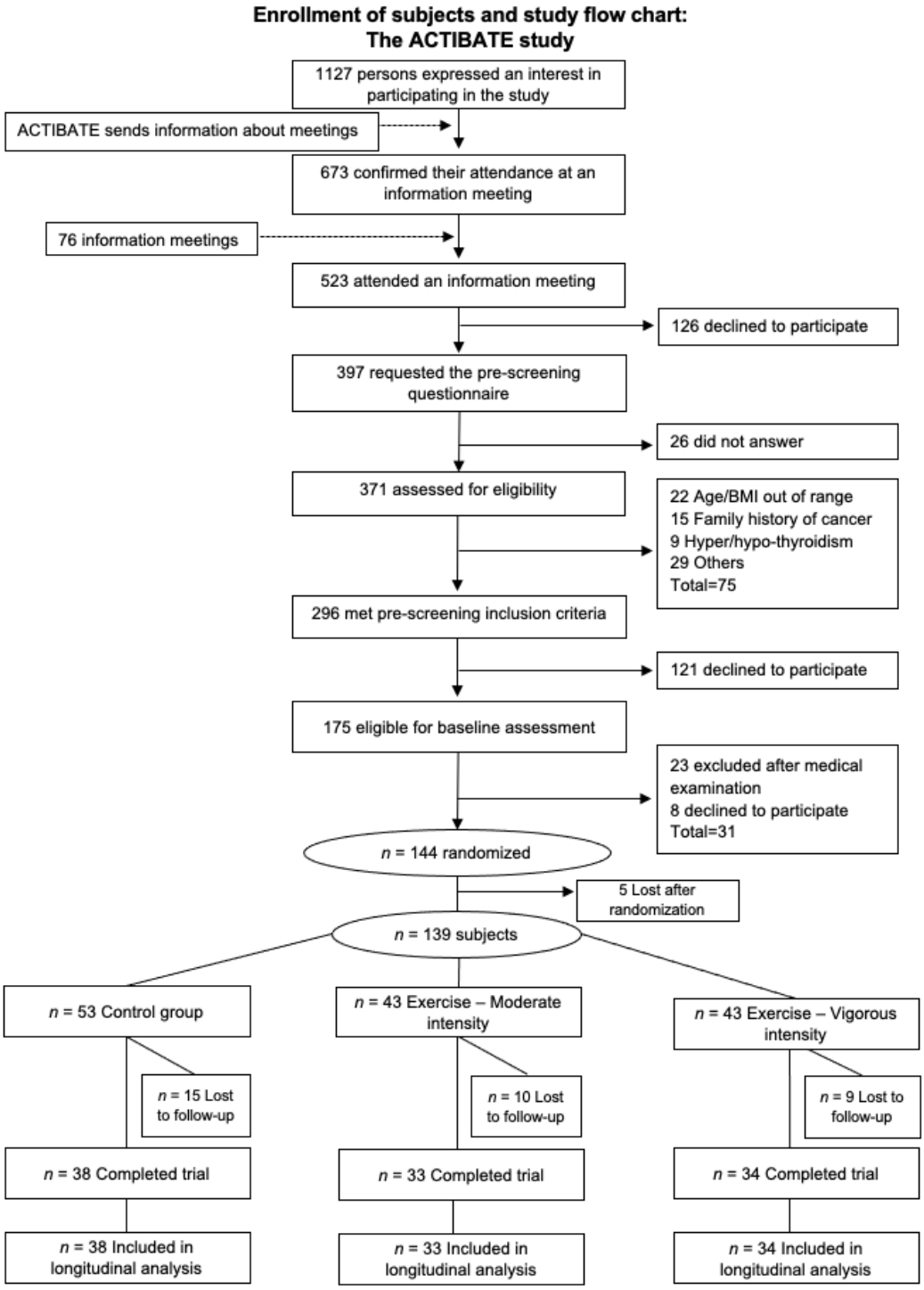

Figure 1. Enrollment of subjects and study flow chart. BMI—body mass index.

2.2. Assessment of Time Spent in Sedentary Behavior and in Physical Activity

To objectively measure the time the subjects spent in sedentary behavior and in PA, participants were asked to wear a wrist-worn GT3X+ model accelerometer (ActiGraph, Pensacola, FL, USA) for 7 consecutive days (24 h/day). Subjects came to the research centre and were given instructions regarding the wearing of the accelerometer and told to

remove it only during activities such as bathing or swimming. The accelerometers were initialized to store raw accelerations at a sampling frequency of 100 Hz. Raw accelerations were exported using ActiLife v6.13.3 software (ActiGraph, Pensacola, FL, USA) and converted to .csv format. The raw .csv files were then imported into R software v3.1.2 (https://www.cran.r-project.org/) and processed using GGIR software v1.5-12 (https://cran.r-project.org/web/packages/GGIR/). The latter involved: 1) auto-calibration of the data according to local gravity (16); 2) calculation of the Euclidean Norm Minus One (ENMO) as Equation: $(\sqrt{(x^2 + y^2 + z^2)}) - 1G$ (where $1G \sim 9.8$ m/s^2) with negative values rounded to zero; 3) Detection of non-wear time based on the raw acceleration of the three axes; briefly each 15-min block was classified as non-wear time if the standard deviation of 2 of the 3 axes was <13 mG during the surrounding 60 min moving-time window, or if the value range for 2 of the 3 axes was <50 mG; 4) Detection of sustained abnormally high accelerations, i.e., >5.5 G, related to malfunctioning of the accelerometers; 5) imputation of detected non-wear time and abnormally high accelerations; 6) identification of waking and sleeping hours via an automated algorithm guided by participants' diary reports (17); and 7) estimation of time spent in sedentary and PA behavior using age-specific cut-points for Euclidean norm minus one (ENMO) (18,19). Only participants wearing the accelerometers for ≥16 h/day and ≥4 h/night over at least 4 days (including at least 1 weekend day) were included in analyses. Additionally, the time spent in moderate-vigorous PA in bouts of ≥10 min (MVPA10min), with a drop-down tolerance of 2 min, was calculated. These categories were established according to the World Health Organization PA recommendations for adults (20) . The mean daily ENMO (mG) (only waking time) was used as a general indicator of PA level.

2.3 Eating Behavior Traits

Eating behavior traits were recorded using the following self-answered questionnaires:

A. The Binge Eating Scale (BES). This was used to assess eight feelings/cognitive actions (e.g., guilt, worry over excess eating of certain foods) and eight behavioral manifestations (e.g., eating rapidly, eating in secret) related to binge eating. The weight of each statement (0–3) is then summed. A higher total score reflects more severe binge-eating problems (8).
B. The Three-Factor Eating Questionnaire-R18 (TFEQ). This was used to assess three "dimensions" of eating behavior: i) cognitive restraint (six questions), i.e., the conscious restriction of food intake in order to control body weight or to

promote weight loss; ii) uncontrolled eating (nine questions), i.e., the tendency to eat more than usual due to a loss of control over intake, accompanied by subjective feelings of hunger, and iii) emotional eating (three questions), characterized by the inability to resist emotional cues, or eating as a response to different negative emotions. This questionnaire involves 18 questions each measured on a 4-point response scale (definitely true: 1, mostly true: 2, mostly false: 3, definitely false: 4). The scores are summed for each dimension. This shortened version of the original questionnaire maintains its validity and internal consistency (10).

C. Control of Eating Questionnaire (CoEQ). This questionnaire comprises 21 questions designed to assess the type and intensity of food cravings experienced, as well as subjective sensations regarding appetite and mood (11). Subjects answered according to their experiences over the previous seven days; all answers were provided using a visual analogue scale (0–100). The scores for the subscales Craving Control, Craving for Sweet, Craving for Savoury and Positive Mood were then calculated.

2.4 Anthropometric and Body Composition Assessments

Body weight and height were measured using a SECA model 799 scale and stadiometer (SECA, Hamburg, Germany). Both measurements were taken with subjects barefoot and wearing light clothes. BMI was calculated as body mass divided by height^2 (kg/m^2). Body composition was measured using a Discovery Wi dual-energy X-ray absorptiometer (DXA) (Hologic, Inc., Bedford, MA, USA). The fat mass index (FMI) and lean mass index (LMI) were calculated as fat/lean mass divided by height^2 (kg/m^2).

2.5 Energy Intake

Habitual food intake was recorded via three non-consecutive 24 h recalls (two weekdays and one weekend day/holiday) during face-to-face interviews with a trained dietician. The interviews were meal-sequence-based and involved a detailed assessment and description of all foods consumed. During the interviews, photographs of different portion sizes were used to improve the accuracy of food quantification (21). Energy and nutrient intakes were then determined using EvalFINUT® software, which is based on the United States Department of Agriculture (USDA) and Spanish Food Composition (BEDCA) databases.

2.6 Exercise Intervention

The subjects were assigned (by simple randomization with the researchers blinded to the process) to either 1) a control group (usual lifestyle); 2) a moderate-intensity exercise intervention group in which subjects undertook 150 min/week of aerobic exercise at 60% of the heart rate reserve (HRres), plus two sessions per week of resistance training at 50% of the 1 repetition maximum (RM), for six months; 3) a vigorous-intensity exercise intervention group, in which subjects performed 75 min/week aerobic exercise at moderate intensity (60% HRres) and 75 min/week at a vigorous intensity (80% HRres) plus two sessions per week of resistance training at 70% of the 1 repetition maximum (RM), for six months (15).

All subjects were asked to attend 3–4 training sessions per week. Resistance training was performed only in two sessions, while aerobic exercise was performed in every session. Aerobic exercise included the use of a cycle ergometer, treadmill and elliptical ergometer. The strength-training programme was mainly focused on the major upper and lower body muscle groups (15). To achieve the required volume and intensity of activity, the training programme involved gradual progression towards the assigned exercise intensities, starting with a familiarization period followed by four incremental phases until the assigned intensities were reached (15). Subjects were asked to wear a heart rate monitor (RS800CX, Polar Electro Öy, Kempele, Finland) during all training sessions to ensure compliance. Graduates in sport sciences directed all the training sessions at the Sport and Health University Research Institute (iMUDS), Granada, Spain (max. 16 subjects per session), except when—if necessary—subjects were allowed to perform their training exercise sessions at home. In such instances, the heart rate monitors were used to assess compliance to the aerobic training and resistance training was adapted to elastic band and weight-bearing exercises and its compliance self-reported. All subjects were asked to maintain their habitual diet and not to undertake additional sporting activities. Subjects could withdraw at any time. At the end of the intervention period, the subjects completed the above-mentioned questionnaires once more. Detailed information about the exercise programme can be found elsewhere (15).

Statistical Analysis

Descriptive data are presented as means ± standard deviations and were subject to analyses of normality, skewness and kurtosis. Bivariate correlations and simple linear

regression (model 0) were used to study the association between eating behavior traits and objectively measured time spent in sedentary behavior/PA of different intensity. Partial correlations were also performed adjusting for sex. Multiple linear regression adjusted for sex (model 1), for sex and habitual energy intake (model 2), for sex and BMI (model 3), and for sex and lean mass (model 4) were also performed.

Two-factor (stage (i.e., pre/post intervention) and group) mixed analysis of variance (ANOVA) was used to study changes in eating behavior traits after the exercise intervention. Additionally, a one-factor analysis of covariance (ANCOVA) was performed to compare the change (post/pre) in eating behavior traits (dependent variable) between groups (fixed factor), adjusting for the corresponding baseline values. Bonferroni post hoc tests with adjustment for multiple comparisons were used to study the differences in post/pre-intervention values between intervention groups. Significance was set at $p < 0.05$. All calculations were performed using the Statistical Package for Social Sciences (SPSS, v. 22.0, IBM SPSS Statistics, IBM Corporation). The GraphPad Prism 5 package (GraphPad Software, San Diego, CA, USA) was used to construct plots.

3. RESULTS

Table 1 shows the characteristics of participants at baseline, including eating behavior traits as determined by BES, TFEQ and CoEQ.

		All (*n* = 139)	**CG (*n* = 53)**	**MIIG (*n* = 43)**	**VIIG (*n* = 43)**
Women [*n*, (%)]		95, (68.35)	34, (64.20)	31, (72.10)	30, (69.80)
Men [*n*, (%)]		44, (31.65)	19, (35.80)	12, (27.90)	13, (30.20)
Age (years)		22.06 ± 2.26	21.8 ± 2.17	22.08 ± 2.19	22.35 ± 2.45
Body composition					
BMI (kg/m^2)[a]		24.95 ± 4.57	24.47 ± 5.03	25.58 ± 4.13	24.91 ± 4.40
Lean mass (kg)[b]		41.22 ± 9.15	41.43 ± 10.11	40.90 ± 8.05	41.28 ± 9.12
Fat mass (kg)[b]		25.03 ± 8.65	23.87 ± 8.75	26.90 ± 8.77	24.65 ± 8.29
Fat mass (%)[b]		36.08 ± 7.45	34.95 ± 7.34	37.95 ± 8.04	35.65 ± 6.76
Eating behavior traits					
Binge Eating (BES)		8.10 ± 7.25	7.81 ± 7.87	9.4 ± 6.27	7.16 ± 7.35
TFEQ	Cognitive Restraint	12.07 ± 3.78	12.34 ± 3.39	12.56 ± 4.15	11.26 ± 3.82
	Uncontrolled Eating	19.32 ± 5.43	19.09 ± 5.49	19.79 ± 4.89	19.14 ± 5.95
	Emotional Eating	6.17 ± 2.43	6.08 ± 2.48	6.16 ± 6.16	6.28 ± 2.36
CoEQ	Craving control	60.34 ± 20.60	62.34 ± 20.82	57.83 ± 19.50	60.40 ± 21.56
	Craving for sweet	36.65 ± 24.23	36.64 ± 25.03	36.61 ± 23.11	36.71 ± 24.90

Craving for savoury	44.47 ± 19.96	44.35 ± 22.89	44.85 ± 17.18	44.23 ± 19.12
Positive mood	58.15 ± 11.72	61.07 ± 12.43	54.89 ± 10.81	57.80 ± 11.02
Time spent in sedentary behavior/habitual PA intensity				
Valid days (days)	6.77 ± 0.54	6.77 ± 0.54	6.74 ± 0.58	6.79 ± 0.51
Wear time (min/day)	19.91 ± 25.59	19.30 ± 24.02	18.80 ± 29.37	21.80 ± 23.85
Waking time (min/day)	995.86 ± 49.56	992.47 ± 57.30	1009.66 ± 45.45	986.22 ± 40.42
Sedentary time (min/day)	785.40 ± 63.88	788.38 ± 71.10	788.71 ± 63.50	778.43 ± 55.18
LPA (min/day)	119.40 ± 27.85	114.90 ± 28.08	124.72 ± 27.48	119.64 ± 27.63
MPA (min/day)	88.19 ± 30.02	86.63 ± 33.59	92.87 ± 26.91	85.43 ± 28.42
VPA (min/day)	2.86 ± 3.50	2.57 ± 3.28	3.36 ± 4.25	2.71 ± 2.83
MVPA (min/day)	91.05 ± 31.61	89.19 ± 35.24	96.23 ± 28.37	88.15 ± 30.02
MVPA B_{10} (min/day)	24.00 ± 20.64	26.20 ± 22.10	23.49 ± 15.34	21.80 ± 23.44
Overall PA (ENMO, mG/5s)	32.56 ± 8.06	31.72 ± 8.76	33.68 ± 7.45	32.49 ± 7.81

Data are presented as means and standard deviation. [a] n = 135; [b] n = 124. CG—control group; MIIG—moderate-intensity intervention group; VIIG—vigorous-intensity intervention group; BMI—body mass index; BES—binge eating scale; TFEQ—Three-Factor Eating Questionnaire; CoEQ—Control of Eating Questionnaire; PA—physical activity; LPA—light PA; MPA—moderate PA; VPA—vigorous PA; MVPA—moderate-to-vigorous PA; MVPA B_{10}—moderate-to-vigorous PA in bouts of ten minutes; ENMO—Euclidean norm minus one. All baseline data are similar across study groups (all $p > 0.05$).

3.1 Cross-Sectional Analyses

Table 2 shows the associations between the time spent in sedentary behavior/habitual PA of different intensity and eating behavior traits.

Table 2. Bivariate correlations between eating behavior traits and time spent in sedentary behavior and habitual physical activity (PA) intensities.

		TFEQ			**CoEQ**			
	Binge Eating	**CR**	**UE**	**EE**	**Craving Control**	**Craving for Sweet**	**Craving for Savoury**	**Positive Mood**
Sedentary Time	−0.181*	−0.031	−0.286**	−0.127	0.111	−0.073	−0.025	−0.071
LPA	0.270**	0.107	0.340***	0.218*	−0.133	0.090	0.088	0.028
MPA	0.317***	0.095	0.359***	0.264**	−0.188*	0.115	0.121	−0.071
VPA	0.001	−0.001	0.060	−0.018	0.075	−0.061	−0.050	0.091
MVPA	0.302***	0.091	0.346***	0.245**	−0.170*	0.105	0.109	−0.059
MVPA B_{10}	0.167*	0.152	0.140	0.180*	−0.055	0.124	−0.014	−0.092
Overall PA (ENMO, mG/5s)	0.275**	0.059	0.321***	0.204*	−0.152	0.085	0.071	−0.015

Values are Pearson correlation coefficients (*r*); *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$; TFEQ—Three-Factor Eating Questionnaire; CR—cognitive restraint; UE—uncontrolled eating; EE—emotional eating; CoEQ—Control of Eating Questionnaire; LPA—Light Physical Activity; MPA—Moderate Physical Activity; VPA—vigorous Physical Activity; MVPA—moderate-to-vigorous Physical Activity; MVPA B_{10}—moderate-to-vigorous Physical Activity in bouts of ten minutes; ENMO—Euclidean norm minus one.

Sedentary behavior was inversely associated with binge eating ($p < 0.05$) and uncontrolled eating ($p = 0.001$). Light PA ($p = 0.001$), moderate PA ($p < 0.001$), moderate-to-vigorous PA ($p < 0.001$), moderate-to-vigorous in bouts of 10 min ($p < 0.05$) and overall PA ($p = 0.001$), were positively associated with binge eating, uncontrolled eating and emotional eating (Table 2). Moreover, Moderate PA ($p < 0.05$) and Moderate-to-vigorous PA ($p < 0.05$) were inversely associated with craving control. No associations were found with other dimensions of eating behavior traits (i.e., cognitive restraint, craving for sweet, craving for savoury and positive mood). VPA was associated with none of the eating behavior-trait dimensions. Figure 2 shows the dispersion values for those eating behavior traits variables that were significantly correlated with time spent in sedentary behavior/PA of different intensity. All associations remained significant after adjusting for sex (model 1), sex and energy intake (model 2), sex and BMI (model 3), and sex and lean mass (model 4) (Supplementary Table S1).

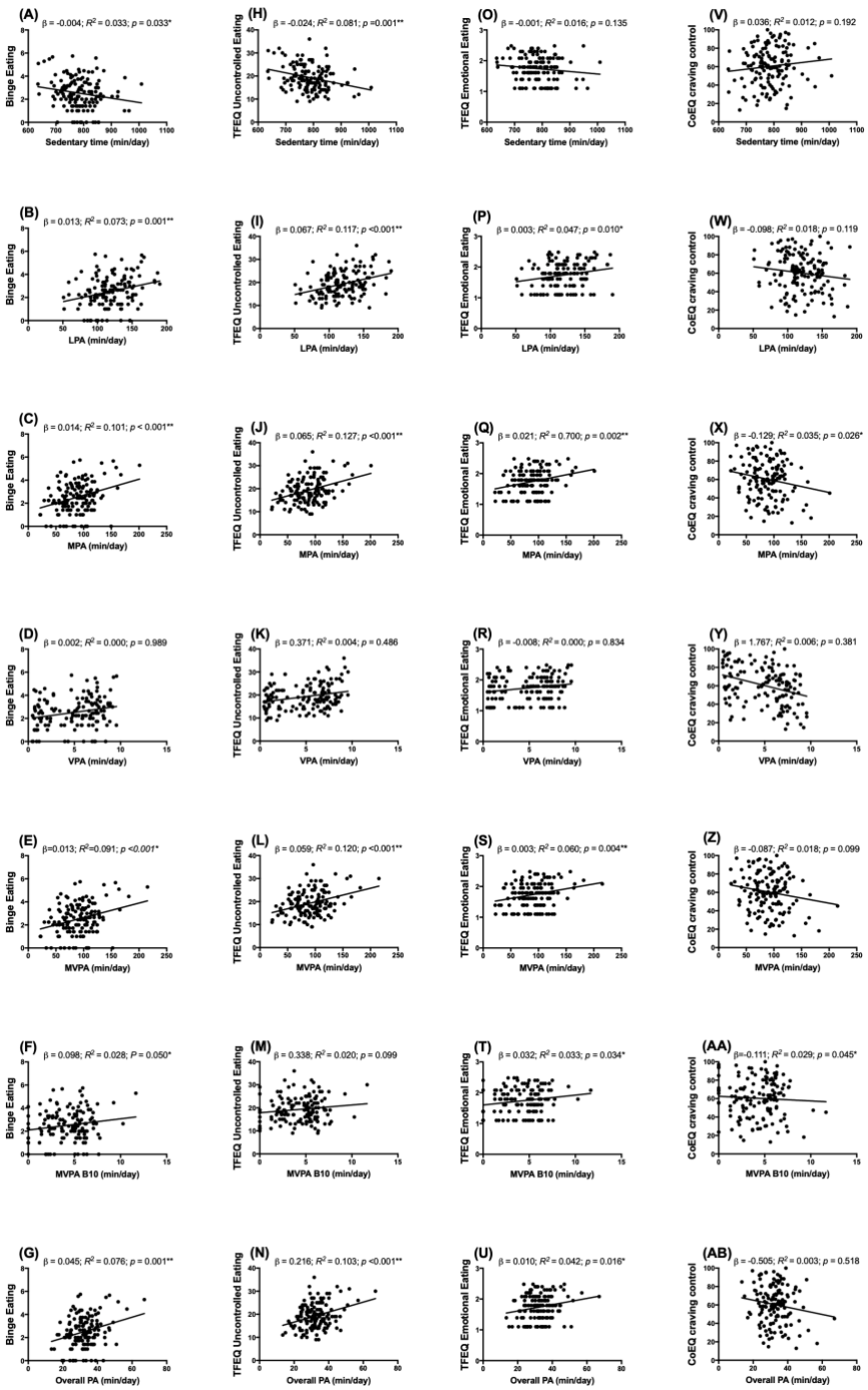

Figure 2. Association between Binge Eating (Panel **A** to **G**)**,** Three-Factor Eating Questionnaire Uncontrolled Eating (Panel **(H** to **N),** and Emotional Eating (Panel **(O** to **U),** and Control of Eating Questionnaire Craving Control (Panel **V** to **AB)** and time spent in sedentary behavior and Physical Activity of different intensity. Unstandardized simple regression coefficient (β) and standardized coefficients of determination (R^2) are provided. LPA—Light Physical Activity; MPA—Moderate Physical Activity; VPA—Vigorous Physical Activity; MVPA—Moderate-to-vigorous Physical Activity; MVPA B10—Moderate-to-vigorous Physical Activity in bouts of ten minutes. (Model 0, n = 139). *$p < 0.05$, **$p < 0.01$.

Supplementary Table S2 shows the relationships between eating behavior traits and body composition. Binge eating was correlated with BMI, lean mass, fat mass and visceral

adipose tissue mass (all $p < 0.05$). Cognitive restraint was only associated with fat mass. Supplementary Table S3 shows the associations between eating behavior traits and PA intensity by sex. In women, binge eating, and uncontrolled eating were associated with sedentary behavior and PA intensity. Uncontrolled eating and emotional eating were associated with sedentary behavior and PA intensity in men (all $p < 0.05$).

3.2. Longitudinal analysis

A total of 105 participants were included in the longitudinal analyses (loss to follow-up = 24.5%) (**Figure 1**). It includes 105 subjects who attended at least 70% of the training sessions.

The intervention treatments had no significant effect on binge eating (**Figure 3**), cognitive restraint (**Figure 4A** and **4B**) or uncontrolled eating (**Figure 4C** and **4D**) but did have a significant effect on emotional eating (**Figure 4E** and **Figure 4F**) ($p = 0.008$ two-factor mixed ANOVA, and $p = 0.003$ ANCOVA). Post-hoc analyses revealed significant differences between the control and vigorous-intensity groups with respect to emotional eating, which was increased in the latter group (mean difference 1.53, 95% confidence interval [CI] 0.452–2.619, $p = 0.002$).

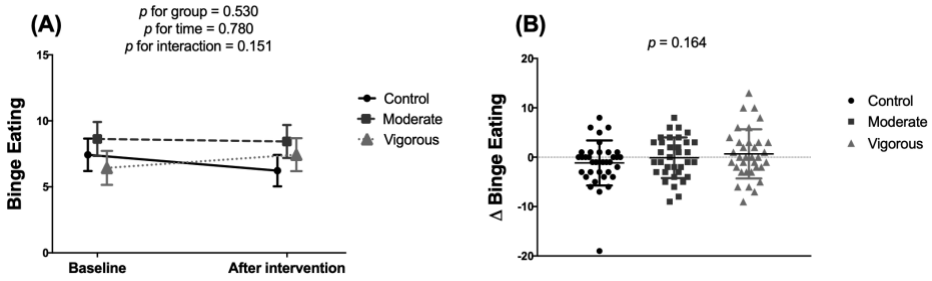

Figure 3. Effects of exercise intervention on Binge Eating in young adults. Panel (**A**) shows the results of two-factor mixed analysis of variance (ANOVA). Panel (**B)** shows a one-factor analysis of covariance (ANCOVA) comparing post-pre differences (adjusted for the baseline value). Control group $n = 35$; Moderate-intensity group $n = 32$; Vigorous-intensity group $n = 32$. Values are adjusted means and standard error.

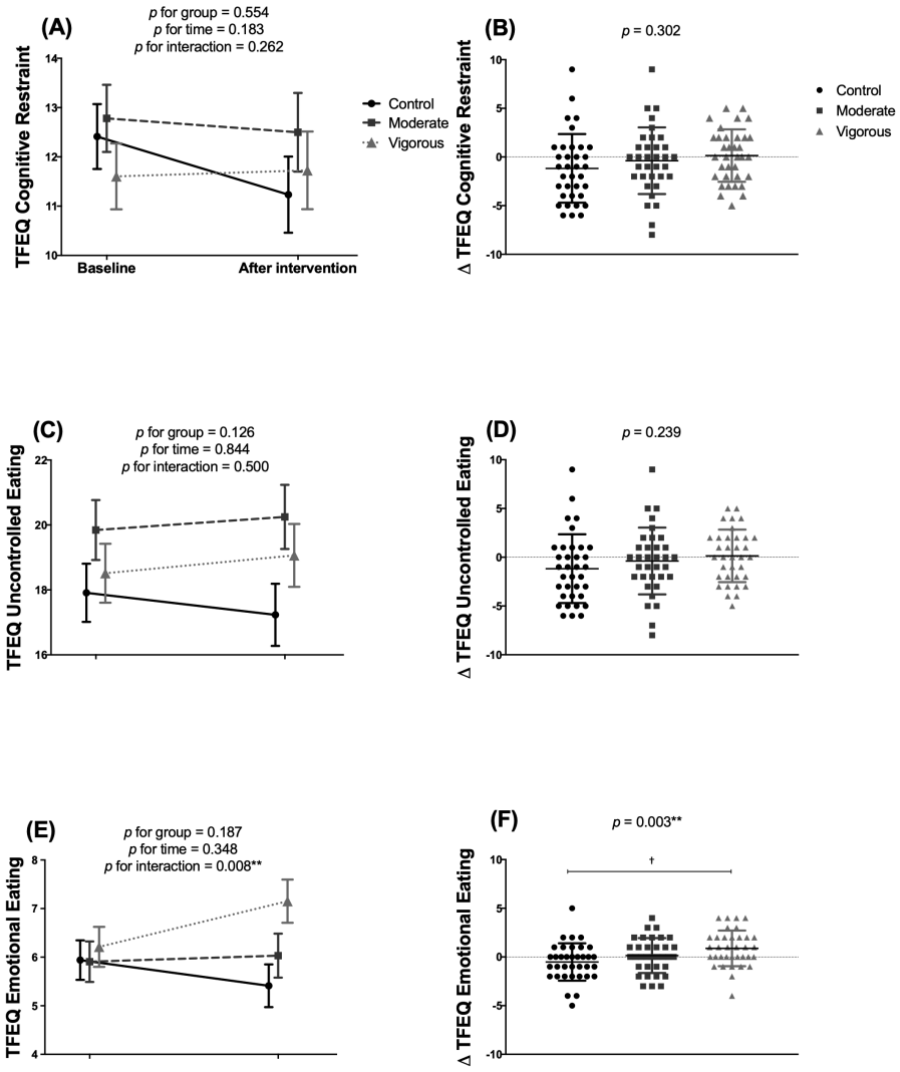

Figure 4. Effects of exercise intervention on Three-Factor Eating Questionnaire variables in young adults. Panels (**A, C, E**): two-factor mixed ANOVA. Panels (**B, D, F**): a one-factor one-factor analysis of covariance (ANCOVA) comparing post-pre differences, adjusted for baseline value. Control group *n* = 34; Moderate intensity group *n* = 32; Vigorous-intensity group *n* = 33. Values are adjusted means and standard error. † Simbol indicates significant differences (post-hoc comparisons). **p* < 0.05, ***p* < 0.01

No significant effect of either intervention treatment was seen on the CoEQ subscales as examined by two-factor mixed ANOVA (**Figure 5A**, **5C**, **5E**, and **5G**). ANCOVA detected no effect on craving for sweet (**Figure 5C** and **5D**), craving for savoury (**Figure 5E** and **5F**), or positive mood (**Figure 5G** and **5H**), but revealed significant differences between the control and moderate exercise groups in terms of craving control (mean difference 11.03, 95%CI 0.846–21.205, *p* = 0.019) (**Figure 5B**).

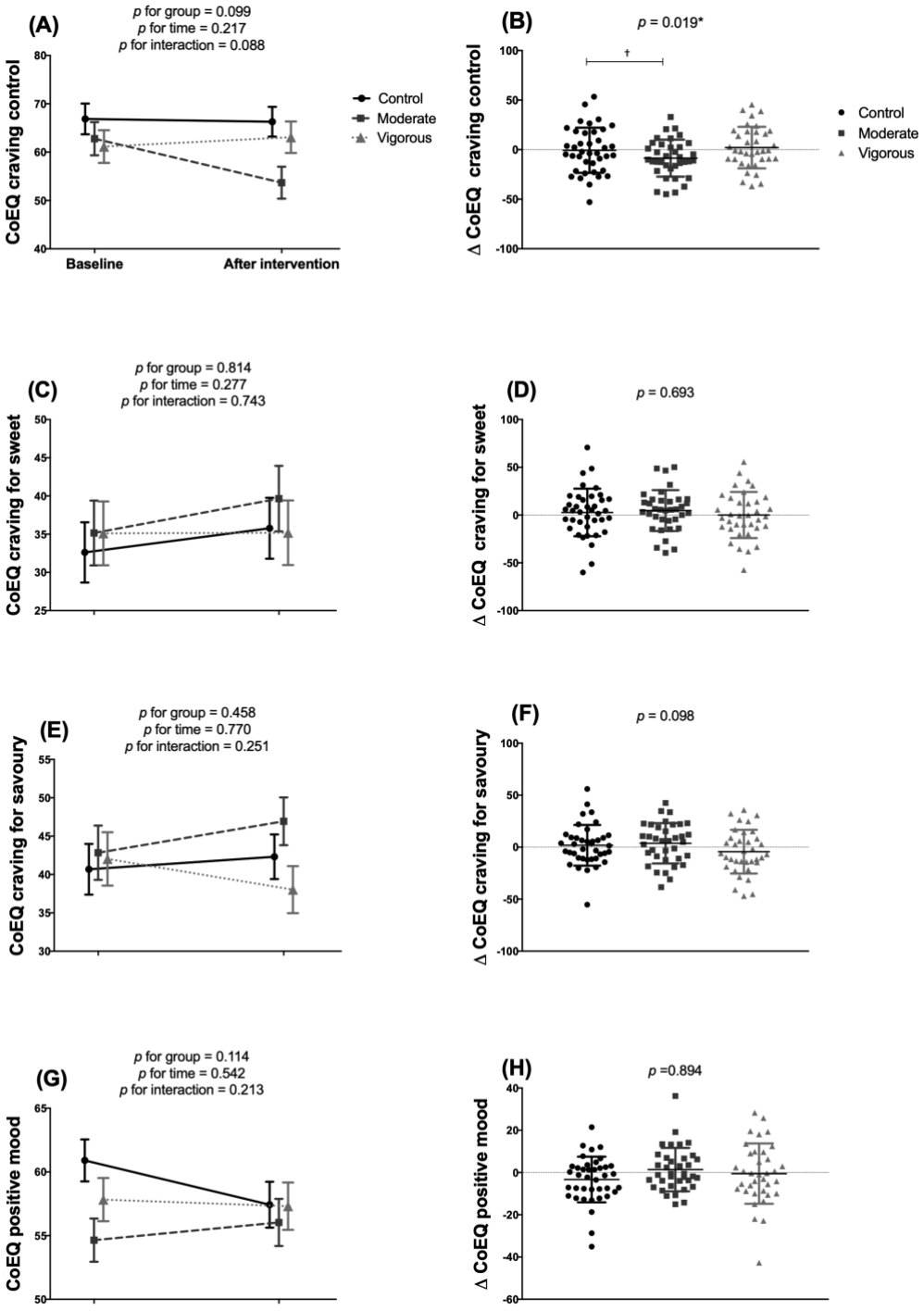

Figure 5. Effects of exercise intervention on Control of Eating Questionnaire variables in young adults. Panels (**A, C, E, G**) two-factor mixed ANOVA. Panels (**B, D, F, H**): one-factor ANCOVA comparing post-pre differences, adjusted for baseline value. Control group $n = 38$; Moderate intensity group $n = 33$; Vigorous-intensity group $n = 34$. Values are adjusted means and standard error. † Simbol indicates significant differences (post-hoc comparisons). * $p < 0.05$, ** $p < 0.01$.

4. DISCUSSION

The present results show that binge eating, uncontrolled eating and emotional eating are inversely associated with time spent in sedentary behavior, and directly associated with time spent in PA, especially MVPA and overall PA in young, healthy adults. However,

these eating behavior traits were not altered by a six-month exercise training intervention (combining aerobic and resistance training at different intensities), which even significantly increased emotional eating in those following the vigorous-intensity exercise program. The lack of exercise-induced effects on binge and uncontrolled eating suggests that PA did not influence these psychological markers, maybe due to their lasting nature.

4.1. Association of Eating Behavior Traits with Time Spent in Sedentary Behavior and Physical Activity

In the present work, sedentary behavior was inversely associated with questionnaire reports of binge eating and uncontrolled eating. This study also shows that young healthy adults who are more physically active, are more likely to consciously self-report a tendency to binge eat and eat uncontrollably—perhaps because they understand PA as deserving of reward (22). According to a study done by Sim et al. (23), inactive overweight restrained-eaters appear to adjust their eating behavior depending on the perceived healthiness of activities like exercising. It follows the Compensatory Health Beliefs model by Rabiau et al. which states that the negative effects of an unhealthy behavior can be compensated for another healthy behavior (24). Our findings disagree however with those by Shook et al. (25) who reported low-level PA to be associated with higher levels of appetite-related disinhibition, and that less active individuals show significantly more intense cravings for savoury foods (e.g., chips, burgers and pizza). The relationship between physical activity and appetite control may vary from culture to culture and between geographical regions and needs further research. The present results show body composition to be associated with binge eating. This is similar to that reported by Myers et al. (26), who concluded that a relationship exists between adiposity and uncontrolled and binge eating.

4.2. Effect of the Exercise Intervention on Eating Behavior Traits

The only eating behavior trait modified by the exercise intervention was emotional eating (assessed by the self-reported TFEQ), which increased in the vigorous-intensity exercise group. It suggests that exercise might have negatively affected the ability to resist emotional cues or eating as a response to different negative emotions. This might be explained by the effect of training on emotional state and mood. Hormonal changes that occur during exercise can affect mood positively and reduce stress indicators (27).

Although the response may differ between individuals. Emotional eating has been associated with individuals with lower self-esteem and poorer perception of their physical fitness (10). Emotional eating can manifest as either increased food intake or food avoidance (28). In the present work, the subjects of the moderate-intensity exercise group showed a trend towards reduced craving control, suggesting overeating may be more likely than food avoidance (11).

We did not find any other effect of this intervention in this population. This suggests that the numerous associations between eating behavior traits and physical activity levels observed at baseline are not reflecting a cause–effect relationship and are likely spurious or explained by other confounders. It is also relevant to consider that the eating behavior traits represent more lasting and resilient influences on the tendency to eat or on food selection, and are not modified on a daily basis, and they influence food consumption in different ways and through different processes (29).

The present work suffers from the possible limitation that the paper-based CoEQ was completed during the baseline and post-intervention measurement visit in the presence of a nutritionist whom the subjects may have tried to please, introducing a certain bias into their answers. In addition, all subjects saw all three questionnaires twice, once at baseline and again after the intervention. This may have introduced some ‘learning’ bias. Not previously validated Spanish versions of the BES and CoEQ were used.

5. CONCLUSIONS

The findings of this study have revealed counterintuitive associations between eating behavior traits of binge eating, uncontrolled eating and emotional eating with sedentary behavior and physical activity in this population. In contrast, these self-reported eating behaviors were not modified by an exercise program training, which suggests that the aforementioned counterintuitive associations were not reflecting a cause–effect relationship. Further studies are needed to better understand these findings between the enduring nature of eating traits and physical activity.

SUPPLEMENTARY MATERIAL

Supplementary Table 1. Relationships between times spent in sedentary behavior and habitual PA at different intensity and eating behavior traits.

Binge eating scale

	Model 0			Model 1			Model 2			Model 3			Model 4		
	β	R^2	P	β	R^2	P	β	R^2	P	β	R^2	P	β	R^2	P
Sedentary time (min/day)	-0.004	0.033	**0.033**	-0.004	0.033	**0.035**	-0.006	0.123	**0.012**	-0.005	0.118	**0.006**	-0.004	0.117	**0.026**
LPA (min/day)	0.013	0.073	**0.001**	0.013	0.075	**0.001**	0.015	0.134	**0.008**	0.013	0.138	**0.001**	0.012	0.131	**0.009**
MPA (min/day)	0.014	0.101	**0.000**	0.014	0.101	**0.000**	0.018	0.239	**0.000**	0.014	0.170	**0.000**	0.012	0.147	**0.003**
VPA (min/day)	0.002	0.000	0.989	0.000	0.000	0.999	0.023	0.024	0.885	0.030	0.065	0.815	0.003	0.080	0.981
MVPA (min/day)	0.013	0.091	**0.000**	0.013	0.091	**0.000**	0.016	0.215	**0.000**	0.013	0.161	**0.000**	0.011	0.142	**0.004**
MVPA B_{10} (min/day)	0.098	0.028	0.050	0.097	0.028	0.052	0.133	0.079	0.063	0.105	0.096	**0.033**	0.060	0.090	0.246
Overall PA (ENMO, mG/5s)	0.045	0.076	**0.001**	0.046	0.076	**0.001**	0.052	0.157	**0.003**	0.049	0.152	**0.000**	0.042	0.141	**0.004**

Three Factor Eating Questionnaire - Cognitive Restraint

	Model 0			Model 1			Model 2			Model 3			Model 4		
	β	R^2	P	β	R^2	P	β	R^2	P	β	R^2	P	β	R^2	P
Sedentary time (min/day)	-0.002	0.001	0.715	0.000	0.029	0.956	0.004	0.048	0.634	-0.002	0.042	0.686	0.000	0.029	0.965
LPA (min/day)	0.015	0.012	0.208	0.010	0.034	0.399	0.002	0.045	0.909	0.009	0.045	0.428	0.011	0.034	0.420
MPA (min/day)	0.012	0.009	0.268	0.010	0.034	0.375	0.004	0.046	0.783	0.009	0.046	0.405	0.005	0.030	0.657
VPA (min/day)	-0.005	0.000	0.989	-0.049	0.029	0.895	0.117	0.046	0.806	0.009	0.046	0.405	0.016	0.029	0.969
MVPA (min/day)	0.011	0.008	0.289	0.009	0.009	0.404	0.005	0.047	0.747	0.008	0.045	0.425	0.005	0.030	0.649
MVPA B_{10} (min/day)	0.255	0.023	0.075	0.239	0.049	0.092	0.280	0.071	0.197	0.237	0.061	0.096	0.159	0.037	0.303
Overall PA (ENMO, mG/5s)	0.028	0.003	0.492	0.016	0.030	0.689	0.004	0.045	0.938	0.019	0.042	0.641	0.010	0.029	0.819

Three Factor Eating Questionnaire - Uncontrolled Eating

	Model 0			Model 1			Model 2			Model 3			Model 4		
	β	R^2	P	β	R^2	P	β	R^2	P	β	R^2	P	β	R^2	P
Sedentary time (min/day)	-0.024	0.081	**0.001**	-0.025	0.085	**0.001**	-0.033	0.172	**0.001**	-0.026	0.093	**0.000**	-0.025	0.103	**0.001**
LPA (min/day)	0.067	0.117	**0.000**	0.071	0.126	**0.000**	0.075	0.183	**0.001**	0.076	0.143	**0.000**	0.068	0.122	**0.000**
MPA (min/day)	0.065	0.127	**0.000**	0.066	0.133	**0.000**	0.075	0.218	**0.000**	0.070	0.146	**0.000**	0.060	0.123	**0.000**
VPA (min/day)	0.371	0.004	0.486	0.379	0.004	0.478	0.970	0.052	0.144	0.416	0.008	0.448	0.200	0.017	0.735
MVPA (min/day)	0.059	0.120	**0.000**	0.061	0.123	**0.000**	0.071	0.217	**0.000**	0.064	0.136	**0.000**	0.055	0.114	**0.000**
MVPA B_{10} (min/day)	0.338	0.020	0.099	0.342	0.020	0.097	0.515	0.064	0.090	0.343	0.023	0.106	0.218	0.024	0.323
Overall PA (ENMO, mG/5s)	0.216	0.103	**0.000**	0.223	0.108	**0.000**	0.270	0.215	**0.000**	0.233	0.118	**0.000**	0.207	0.104	**0.001**

Three Factor Eating Questionnaire - Emotional Eating

	Model 0			Model 1			Model 2			Model 3			Model 4		
	β	R^2	P	β	R^2	P	β	R^2	P	β	R^2	P	β	R^2	P
Sedentary time (min/day)	-0.001	0.016	0.135	-0.001	0.031	0.208	-0.001	0.036	0.197	-0.026	0.093	**0.000**	-0.001	0.054	0.108
LPA (min/day)	0.003	0.047	**0.010**	0.003	0.056	**0.023**	0.005	0.124	**0.007**	0.076	0.143	**0.000**	0.003	0.072	**0.027**
MPA (min/day)	0.021	0.700	**0.002**	0.003	0.081	**0.003**	0.005	0.134	**0.005**	0.003	0.091	**0.002**	0.003	0.084	**0.011**
VPA (min/day)	-0.008	0.000	0.834	-0.012	0.020	0.758	0.014	0.010	0.782	-0.009	0.025	0.824	0.012	0.034	0.788
MVPA (min/day)	0.003	0.060	**0.004**	0.003	0.072	**0.006**	0.004	0.117	**0.009**	0.003	0.082	**0.005**	0.003	0.080	**0.014**

MVPA B_{10} (min/day)	0.032	0.033	**0.034**	0.031	0.049	**0.041**	0.014	0.014	0.553	0.032	0.056	**0.039**	0.027	0.056	0.088
Overall PA (ENMO, mG/5s)	0.010	0.042	**0.016**	0.009	0.054	**0.028**	0.012	0.077	**0.039**	0.010	0.064	**0.021**	0.011	0.076	**0.019**

Control of Eating Questionnaire - Craving Control

	Model 0			Model 1			Model 2			Model 3			Model 4		
	β	R^2	P	β	R^2	P	β	R^2	P	β	R^2	P	β	R^2	P
Sedentary time (min/day)	0.036	0.012	0.192	0.030	0.025	0.276	0.057	0.064	0.195	0.038	0.045	0.182	0.033	0.044	0.266
LPA (min/day)	-0.098	0.018	0.119	-0.081	0.028	0.207	-0.111	0.059	0.212	-0.075	0.042	0.248	-0.070	0.042	0.332
MPA (min/day)	-0.129	0.035	**0.026**	-0.120	0.046	**0.039**	-0.143	0.080	0.106	-0.126	0.066	**0.032**	-0.120	0.063	0.058
VPA (min/day)	1.767	0.006	0.381	1.950	0.023	0.332	2.801	0.055	0.310	2.175	0.041	0.281	1.657	0.038	0.460
MVPA (min/day)	-0.087	0.018	0.099	-0.102	0.040	0.066	-0.116	0.069	0.165	-0.107	0.059	0.055	-0.105	0.058	0.081
MVPA B_{10} (min/day)	-0.111	0.029	**0.045**	-0.438	0.018	0.574	-0.225	0.039	0.860	-0.622	0.037	0.428	-0.586	0.038	0.487
Overall PA (ENMO, mG/5s)	-0.505	0.003	0.518	-0.348	0.034	0.112	-0.301	0.053	0.350	-0.354	0.051	0.108	-0.384	0.054	0.110

Control of Eating Questionnaire - Craving for Sweet

	Model 0			Model 1			Model 2			Model 3			Model 4		
	β	R^2	P	β	R^2	P	β	R^2	P	β	R^2	P	β	R^2	P
Sedentary time (min/day)	-0.003	0.005	0.390	-0.001	0.073	0.705	-0.003	0.135	0.465	-0.001	0.073	0.703	-0.001	0.096	0.732
LPA (min/day)	0.007	0.008	0.293	0.002	0.073	0.716	0.001	0.127	0.955	0.003	0.073	0.695	0.002	0.095	0.770
MPA (min/day)	0.009	0.013	0.177	0.006	0.079	0.312	0.009	0.141	0.329	0.007	0.080	0.291	0.005	0.100	0.423
VPA (min/day)	-0.154	0.004	0.478	-0.195	0.078	0.353	-0.209	0.135	0.456	-0.222	0.079	0.300	-0.242	0.103	0.305
MVPA (min/day)	0.007	0.011	0.219	0.005	0.078	0.378	0.007	0.138	0.392	0.005	0.077	0.363	0.004	0.098	0.480
MVPA B_{10} (min/day)	0.122	0.015	0.146	0.107	0.084	0.190	0.196	0.161	0.126	0.114	0.085	0.171	0.103	0.105	0.246
Overall PA (ENMO, mG/5s)	0.023	0.007	0.322	0.013	0.074	0.587	0.012	0.129	0.711	0.012	0.073	0.609	0.011	0.096	0.668

Control of Eating Questionnaire - Craving for Savoury

	Model 0			Model 1			Model 2			Model 3			Model 4		
	β	R^2	P	β	R^2	P	β	R^2	P	β	R^2	P	β	R^2	P
Sedentary time (min/day)	-0.001	0.001	0.771	-0.001	0.016	0.602	-0.004	0.026	0.323	-0.001	0.014	0.665	0.000	0.041	0.853
LPA (min/day)	0.005	0.008	0.302	0.007	0.028	0.164	0.005	0.017	0.495	0.006	0.022	0.261	0.004	0.046	0.440
MPA (min/day)	0.007	0.015	0.155	0.007	0.033	0.108	0.008	0.030	0.261	0.007	0.029	0.141	0.005	0.050	0.280
VPA (min/day)	-0.095	0.003	0.555	-0.082	0.016	0.610	-0.149	0.017	0.509	-0.104	0.016	0.524	-0.063	0.042	0.721
MVPA (min/day)	0.006	0.012	0.202	0.006	0.030	0.143	0.007	0.025	0.332	0.006	0.026	0.184	0.005	0.050	0.304
MVPA B_{10} (min/day)	-0.010	0.000	0.866	-0.005	0.014	0.931	-0.041	0.012	0.693	0.001	0.013	0.983	-0.009	0.041	0.891
Overall PA (ENMO, mG/5s)	0.014	0.005	0.408	0.018	0.022	0.292	0.012	0.013	0.639	0.016	0.019	0.367	0.015	0.046	0.442

Control of Eating Questionnaire - Positive Mood

	Model 0			Model 1			Model 2			Model 3			Model 4		
	β	R^2	P	β	R^2	P	β	R^2	P	β	R^2	P	β	R^2	P
Sedentary time (min/day)	-0.013	0.005	0.404	-0.016	0.030	0.261	-0.007	0.009	0.731	-0.013	0.017	0.427	-0.10	0.028	0.542
LPA (min/day)	0.012	0.001	0.740	0.027	0.025	0.461	-0.004	0.007	0.940	0.013	0.013	0.729	0.018	0.027	0.640
MPA (min/day)	-0.028	0.005	0.409	-0.021	0.02	0.528	-0.010	0.008	0.817	-0.028	0.017	0.401	-0.040	0.036	0.239
VPA (min/day)	1.216	0.008	0.289	1.335	0.031	0.242	0.844	0.014	0.528	1.261	0.021	0.267	0.257	0.025	0.831
MVPA (min/day)	-0.022	0.003	0.491	-0.016	0.023	0.624	-0.005	0.007	0.904	-0.022	0.015	0.494	-0.036	0.035	0.261

MVPA B_{10} (min/day)	-0.476	0.008	0.284	-0.433	0.028	0.327	0.184	0.008	0.764	-0.326	0.016	0.461	-0.795	0.050	0.077
Overall PA (ENMO, mG/5s)	-0.022	0.000	0.857	0.009	0.021	0.940	-0.015	0.007	0.926	-0.015	0.012	0.907	-0.088	0.029	0.499

Linear regression analyses were performed without adjusting for any covariate (model 0), and adjusting for sex (model 1), for sex and energy intake (model 2), for sex and BMI (model 3), and for sex and lean mass (model 4). The unstandardized β coefficient, R^2 and P values are provided. PA physical activity, LPA light-PA, MPA moderate-PA, VPA vigorous-PA, MVPA moderate-to-vigorous-PA, MVPA B_{10} moderate-to-vigorous PA in bouts of ten minutes, ENMO Euclidean norm minus one.

Supplementary Table 2. Bivariate correlations between eating behavior traits and body composition in young adults.

		TFEQ			CoEQ			
	Binge Eating	Cognitive restraint	Uncontrolled eating	Emotional eating	Craving control	Craving for sweet	Craving for savoury	Positive Mood
BMI (kg/m^2)	0.259**	0.097	-0.052	0.084	-0.069	-0.098	0.085	0.072
Lean mass (kg)	0.186*	0.001	0.142	0.061	-0.010	-0.105	0.170	0.137
Fat mass (kg)	0.290***	0.174*	-0.073	0.107	-0.071	-0.023	0.046	0.006
Fat mass (%)	0.183*	0.189*	-0.159	0.071	-0.077	0.041	-0.046	-0.008
VAT mass (g)	0.228**	0.128	-0.043	0.057	-0.023	-0.156	0.102	0.110

Values are Pearson correlation coefficients (*r*); * p <0.05); ** p <0.01; *** p <0.001. TFEQ Three-Factor Eating Questionnaire; CoEQ Control of Eating Questionnaire; BMI body mass index; LM lean mass; FM fat mass; VAT visceral adipose tissue.

Supplementary Table 3a. Bivariate correlations between eating behavior traits and time spent in sedentary behavior and habitual physical activity of different intensity in young men and women.

	Binge eating		TFEQ					
			Cognitive restraint		Uncontrolled eating		Emotional eating	
	Men	Women	Men	Women	Men	Women	Men	Women
n	44	95	44	95	44	95	44	95
Sedentary time	-0.140	-0.210*	-0.138	0.074	-0.322*	-0.274**	-0.128	-0.097
LPA	0.262	0.280**	0.190	0.016	0.403**	0.325**	0.285	0.143
MPA	0.351*	0.303**	0.228	0.003	0.347*	0.375***	0.399**	0.170
VPA	0.096	-0.036	-0.064	0.008	0.181	0.008	0.098	-0.079
MVPA	0.334*	0.288**	0.208	0.007	0.346*	0.354***	0.379*	0.153
MVPA B_{10}	0.206	0.148	0.285	0.084	0.067	0.181	0.230	0.146
Overall PA (ENMO, mG/5s)	0.247	0.291**	0.169	-0.028	0.329*	0.328**	0.268	0.144

Values are Pearson correlation coefficients (*r*); *p <0.05); ** p <0.01; ***P<0.001. PA physical activity, LPA light-PA, MPA moderate-PA, VPA vigorous-PA, MVPA moderate-to-vigorous-PA, MVPA B_{10} moderate-to-vigorous-PA in bouts of ten minutes, ENMO Euclidean norm minus one; TFEQ Three-Factor Eating Questionnaire.

Supplementary Table 3b. Bivariate correlations between eating behavior traits and time spent in sedentary behavior and habitual physical activity of different intensity in young men and women.

	CoEQ							
	Craving control		Craving for sweet		Craving for savoury		Positive Mood	
	Men	Women	Men	Women	Men	Women	Men	Women
n	44	95	44	95	44	95	44	95
Sedentary time	0.018	0.143	-0.082	-0.007	0.016	-0.087	-0.072	-0.117
LPA	-0.106	-0.11	0.179	-0.035	0.198	0.075	0.086	0.048
MPA	-0.133	-0.199	0.146	0.061	0.124	0.146	-0.118	-0.01
VPA	0.010	0.112	-0.063	-0.086	0.029	-0.075	0.178	0.063
MVPA	-0.117	-0.179	0.129	0.053	0.110	0.134	-0.100	-0.003
MVPA B_{10}	0.086	-0.111	-0.014	0.164	-0.119	0.049	-0.219	-0.002
Overall PA (ENMO, mG/5s)	-0.082	-0.163	0.108	0.020	0.072	0.100	-0.007	0.015

Values are Pearson correlation coefficients (*r*); **p* <0.05); ** *p* <0.01; ***P<0.001. PA physical activity, LPA light-PA, MPA moderate-PA, VPA vigorous-PA, MVPA moderate-to-vigorous-PA, MVPA B_{10} moderate-to-vigorous-PA in bouts of ten minutes, ENMO Euclidean norm minus one; CoEQ Control of Eating Questionnaire.

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4.2 Study II

ASSOCIATION BETWEEN PHYSICAL FITNESS AND EATING BEHAVIOR TRAITS IN YOUNG HEALTHY ADULTS

Study II

Association between physical fitness and eating behavior traits in young healthy adults

1. INTRODUCTION

The current obesogenic environment of food consumption in excess and physical inactivity represent modifiable factors of energy balance (1). In this way, diet and physical activity are important elements that influence health and disease (2) and thus well-being. Interventions with both nutritional counseling and physical activity have been shown to be effective on weight management and with favorable changes in eating behavior (3). Studies have shown that intuitive eating or increasing reliance on physiologic hunger and satiety cues are effective weight management strategies in a variety of populations (4).

An impaired appetite regulation as in psychiatric eating disorders (i.e. Binge eating disorder (BED)) characterized by frequent and persistent episode of binge eating accompanied by feelings of loss of control is associated with comorbidity (5), sedentary lifestyle and poorer physical fitness (6). Some eating behavior traits (binge eating, uncontrolled eating, emotional eating and cognitive restraint) are often screened and measured using self-reported questionnaires (7,8). These eating traits have predicted greater weight gain or weight fluctuations in prospective studies and are likely to play a causal role in the development of adiposity (9).

Psychological factors related to diet and physical activity could be the cause of weight gain (10). Self-efficacy in physical activity (i.e., a person's confidence in his or her ability to be physically active on a regular basis (11) has been demonstrated as a predictor of success in weight control (12). In this sense, physical fitness is a measurable attribute that people have or achieve and it reflects the individual's capacity to perform daily tasks and physical activity (13). Health-related components of physical fitness are cardiorespiratory endurance, muscular endurance and strength, body composition and flexibility. Muscular strength refers to the amount of external force that a muscle can exerts, and it is measured through hand grip dynamometer test. By the other hand, cardiorespiratory fitness relays

on the maximum oxygen uptake on treadmill or cycle ergometer (13). A greater cardiorespiratory fitness represents a better capacity to perform exercise.

In addition, eating behaviors as attending to food cues and distracted eating are associated with body mass index (14). Therefore, behavior dictating how to eat impacts on health and physical performance (15) and so on the optimization of fitness. We hypothesized that a poorer physical fitness measured through muscular strength and cardiorespiratory fitness could be associated with eating traits reflecting a dysregulation of appetite. This cross-sectional study aimed to analyze the association between muscular strength and cardiorespiratory fitness and eating traits in young healthy adults.

2. METHODS

2.1 Participants

This cross-sectional study was conducted under the frame work of the ACTIBATE study (ClinicalTrials.gov ID: NCT02365129) (16). A total of 140 young healthy adults (age 22.07±2.22 years, 69.2% women, body mass index (BMI) 24.88 ±4.58 kg/m^2) were enrolled in the study. All participants declared themselves to be sedentary (>20 min of physical activity on less than 3 days per week). All participants were non-smokers, none took any medication, all reported stable body weight over the previous 3 months, and all had a normal electrocardiogram. The study protocol and design were approved by the Ethics Committee on Human Research of the University of Granada (no. 924) and the Andalusian Health Service (SAS), and adhere to the Declaration of Helsinki (2013 revision).

2.2 Body composition and anthropometric outcomes

Body weight was measured using a SECA model 799 scale and height was determines using a stadiometer (SECA, Hamburg, Germany). Both measures were determined when participants were wearing light clothes and barefoot. BMI was calculated as body mass divided by height^2 (kg/m^2). Body composition was determined using a Discovery Wi dual-energy X-ray absorptiometer (DXA) (Hologic, Inc., Bedford, MA, USA).

2.3 Eating behavior traits

Eating traits were measured through self-answered questionnaires.

i) Binge Eating Scale (BES): This web-based instrument was used to assess feelings or cognitions and manifestations related to binge eating. It consists of two parts, each one made up of 8 questions adding a total of 16 statements. For the calculation of the total score the weight of each statement which is between 0 and 3 is then summed. A higher total score reflects more severe binge-eating problems (7).

ii) Three-Factor Eating Questionnaire (TFEQ-R18): This web-based questionnaire composed by 18 questions each of them measured on a 4-point response scale (definitely true:1, mostly true: 2, mostly false: 3, definitely false: 4), was used to assess the following three scopes:

- Cognitive Restraint (CR), six questions
- Uncontrolled Eating (UE), nine questions
- Emotional Eating (EE), three questions

Each dimension was summed to obtained total score (8).

2.4 Physical fitness outcomes

Muscular strength - Estimation of 1-RM for upper and lower body

Upper and lower body strength were determined by a supine bench press and leg extension press using resistance weight machines (KEISER®). As participants were sedentary, we used Wathen equation, which is valid to estimate the 1RM for bench and leg press in not trained people (17). 1RM = (Weight lifted per repetition (kg))/((48.8+ 53.8e*(-0.075^{x}number of repetitions))/100).

Participants had two attempts for exercise for a successful estimation. After a familiarization try without weight as warm-up, participants performed the first attempt. Researchers increased the weight after the first attempt. The examination lasted until participant performed less than 10 repetitions at her/his maximum strength capacity. The data acquired was then analyzed using the Wathen equation to obtain the 1 RM estimation for bench and leg press.

Muscular strength - Handgrip

Hand grip strength was measured using a digital hand dynamometer (T.K.K. 5401 Grip-D; Takey, Tokyo, Japan) when participants were in a standing position maintaining the tested arm straight down with no elbow flexion. Each participant was asked to perform the test twice for each arm. The test consisted in squeezing the dynamometer gradually

and continuously for at least 2 s. Then, the average for both arms in both attempts were calculated in kg.

Cardiorespiratory fitness - maximal oxygen consumption

Participants were not allowed to perform any type of exercise 48 hours before the test nor consume caffeine or tea 23 hours before. Cardiorespiratory fitness was assessed by indirect calorimetry using a metabolic cart CPX Ultima CardioO2 (Med-graphics Corp, Minnesota, USA) when participants were using a plastic facemask (model 7400, Hans Rudolph Inc, Kansas City, MO, USA) and equipped with a prevent™ metabolic flow sensor (Medgraphics Corp, Minnesota, USA). A maximum treadmill exercise test (H/P Cosmos, Italy) was performed following the modified Balke protocol (16).

VO2 and VCO_2 were measured with the metabolic cart using a breath-by-breath technique for determining the gas exchange. VCO_2 measurement was performed using a non-disperse infrared analyzer, and VO_2 was measured using a galvanic fuel cell (18). Diodes for registering the electrocardiogram before, during and after the endurance exercise were placed by a medical doctor on the participants chest. The test consisted of a warm-up of 1 minute at 3km/h and 2 more minutes at 4km/h. In the minute 4 the speed of the treadmill increased up to 5.3 km/h with the slope at 0% (the maximal speed of the treadmill). The slope was increased every minute by 1% until the participant reached his/her maximum volume of oxygen (VO_2 max). The criteria for a VO_2max achieved were i) respiratory exchange ratio $\geq$ 1.1; ii) a plateau in VO_2 (change of <100 ml/min in the last 3 consecutives 10 seconds stage), and iii) a heart rate within 10 beats/min of the age predicted maximal heart rate (209–0.73*age) (19). The time that participants were calculated took to achieve their VO_2max (time to exhaustion in seconds).

Statistical analyses

Normal distribution of all variables was tested with the Kolmogorov-Smirnov test. Those variables that had a non-normal distribution were transformed. After that, we conducted analyses of simple linear regression analyses (model 0) to examine the association between muscular fitness outcomes and cardiorespiratory fitness with eating behavior traits. We performed multiple linear regression models to test these associations adjusting for sex (model 1) and for FFM (model 2). We also performed bivariate and partial Pearson correlations. All analyses were conducted using the Statistical Package for Social

Sciences (SPSS, v. 22.0, IBM SPSS Statistics, IBM Corporation) and the level of significance was set at <0.05.

3. RESULTS

Descriptive characteristics of study participants are summarized in **table 1**. Muscular strength specifically lower and upper body outcomes (i.e., leg and bench press) were associated with cognitive restraint (**Figure 1E**: β =-0.0.803; R^2 = 0.072; *p* = 0.003, **Figure 1F**: β = -0.974; R^2 = 0.034, *p* = 0.043, respectively). However, there was no association between muscular strength measured by handgrip, with eating behavior traits as binge eating, uncontrolled eating or emotional eating in this unadjusted model.

Similarly, cardiorespiratory fitness was associated with binge eating (**Figure 2A**: β =0.047; R^2 = 0.057; *p* = 0.007) and with uncontrolled eating (**Figure 2C**: β =0.023; R^2 = 0.067; *p* = 0.003). Likewise, the association of cardiorespiratory fitness relative to body weight remained with uncontrolled eating (**Figure 3C**: β =2.161; R^2 = 0.096; *p* = 0.000). Nevertheless, we did not find any other association between cardiorespiratory fitness and eating traits as cognitive restraint and emotional eating (**Figure 3A**: β =0.303; R^2 = 0.002; *p* = 0.593; **Figure 3D**: β =0.163; R^2 = 0.001; *p* = 0.748, respectively).

Table 2 shows associations between physical fitness outcomes and eating behavior. In model 1 (adjusted for sex), there was an association between handgrip and binge eating scale, uncontrolled eating, and emotional eating (β =0.590; R^2 = 0.038; *p* = 0.0.033; β =0.273; R^2 = 0.036; *p* = 0.039; β =0.230; R^2 = 0.059; *p* = 0.029, respectively). Nevertheless, these associations between muscular strength and eating behavior did not persist after controlling for FFM (model 3). Comparably, associations between cardiorespiratory fitness and uncontrolled eating persisted after adjusting for sex (model 1, Table 2) (β =2.164; R^2 = 0.096; *p* = 0.001) and adjusting for FFM (model 2, Table 2) (β =2.245; R^2 = 0.105; *p* = 0.001). Particularly, VO_2 max in relative terms to body weight.

We also performed bivariate (**Table S1**) and partial correlations controlling for sex (**Table S2**) and FFM (**Table S3**) and we found that muscular strength and cardiorespiratory fitness (i.e., maximal oxygen consumption, both in absolute and relative terms) are associated with all eating behavior traits.

Table 1. Descriptive characteristic of participants.

	n	All	*n*	Men	*n*	Women
	140		43	(30.7%)	97	(69.2%)
Age	140	22.07 ±2.22	43	22.40 ±2.27	97	22.01 ±2.19
Body composition						
BMI (kg/m^2)	140	24.88 ±4.58	43	26.76 ±5.32	97	23.99 ±3.85
FFM (kg)	128	43.64 ±9.58	39	55.31 ±6.75	89	38.47 ±5.11
Fat mass (kg)	128	24.74 ±8.67	39	24.63 ±11.18	89	24.80 ±7.39
Fat mass (%)	128	35.74 ±7.68	39	29.53 ±7.83	89	38.47 ±5.83
Self-reported eating behavior traits						
Binge Eating Scale	140	8.12 ±7.34	43	7.88 ±7.33	97	8.18 ±7.20
TFEQ Cognitive Restraint	140	12.18 ±3.81	43	11.49 ±3.78	97	12.53 ±3.82
TFEQ Uncontrolled Eating	140	19.51 ±5.47	43	19.86 ±6.16	97	19.22 ±5.30
TFEQ Emotional Eating	140	6.12 ±2.42	43	5.67 ±2.43	97	6.34 ±2.40
Physical fitness parameters						
Hand grip strength (kg)	136	31.62 ±8.14	43	40.6 ±6.8	93	27.01 ±3.77
Lower body (1MR)	126	2.84 ±0.63	40	3.33 ±0.56	86	2.60 ±0.51
Upper body (1MR)	126	0.43 ±0.15	40	0.59 ±0.12	86	0.36 ±0.08
VO2 max (ml/min)	135	2877.1 ±764.50	41	3681.4 ±739.2	94	2526.3 ±444.4
VO2 max (ml/kg/min)	135	41.33 ±7.8	41	45.40 ±9.3	94	39.6 ±6.4

Data are presented as mean and standard deviation. BMI: Body mass index; FFM: Fat-free-mass; BES: Binge Eating Score; TFEQ: Three Factor Eating Score; CR: Cognitive Restraint; UE: Uncontrolled Eating; EE: Emotional Eating; 1RM (1 Repetition Maximum) VO_2 max: maximal oxygen consumption.

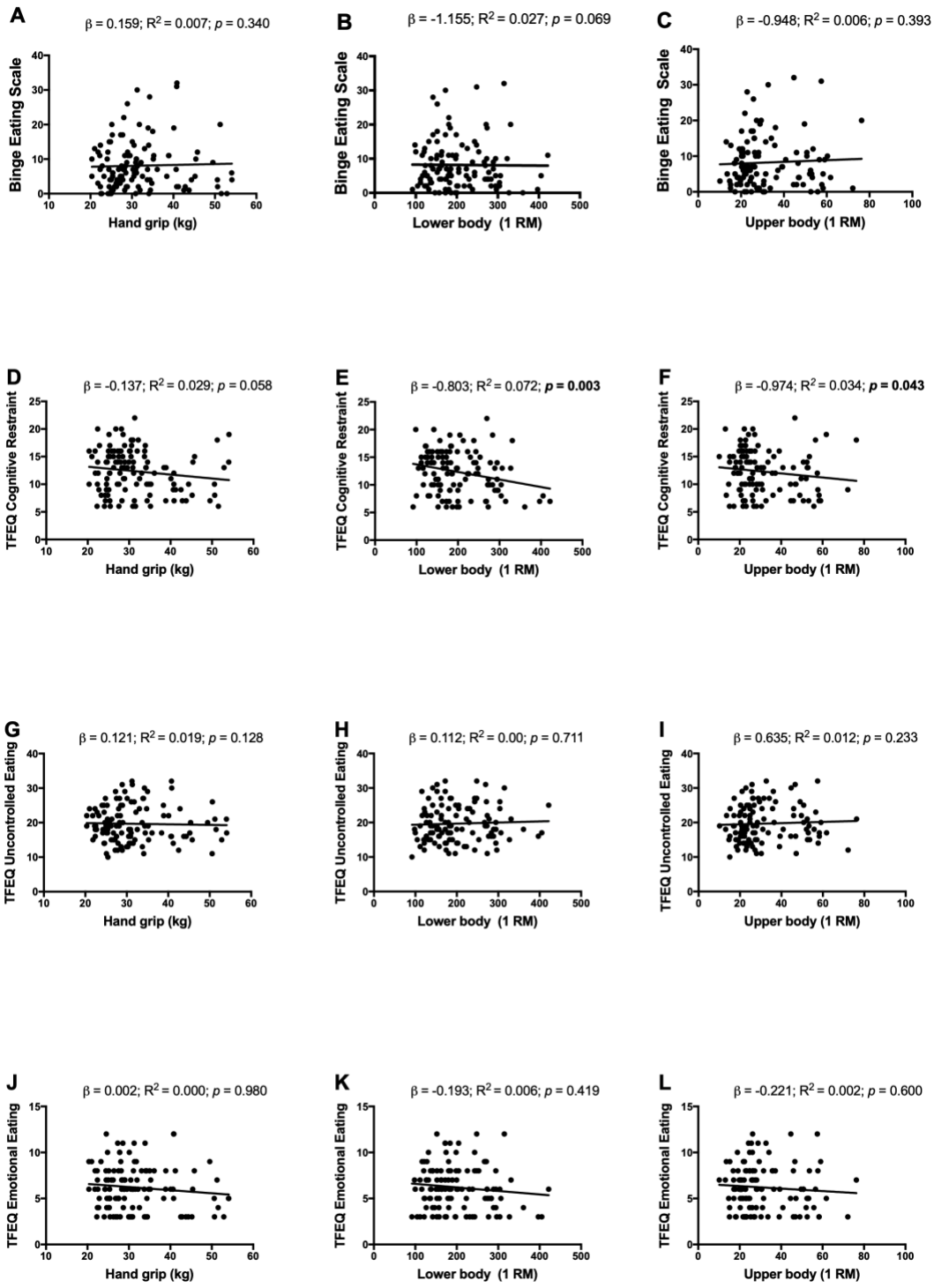

Figure 1. Associations between muscular strength outcomes and eating behavior. Hand grip n = 136. Upper and lower body n = 126 β: unstandardized coefficient; R^2: explained variance; TFEQ: Three-Factor Eating questionnaire; RM: repetition maximum.

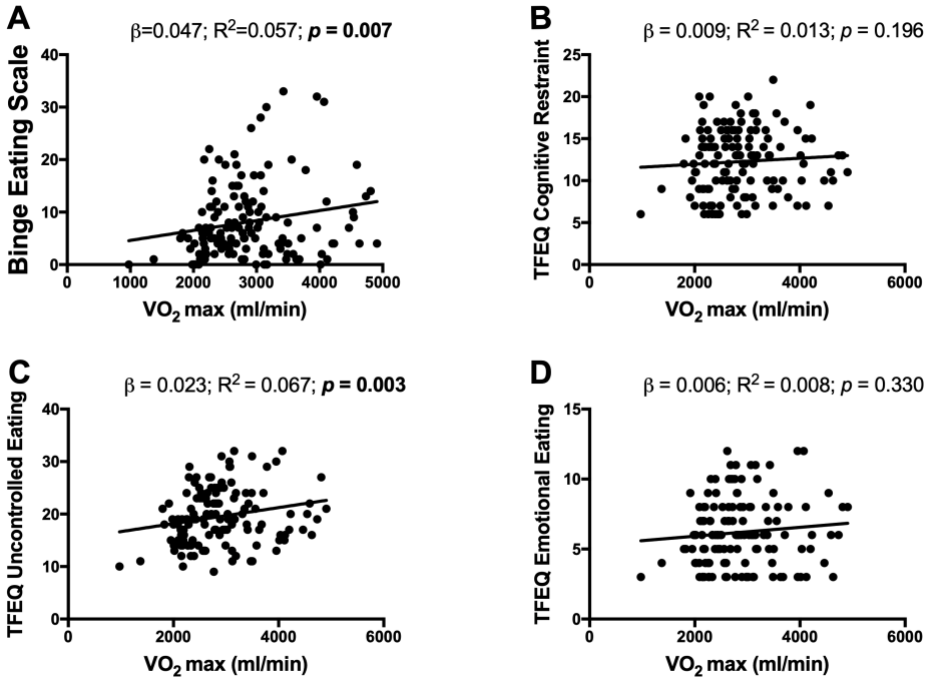

Figure 2. Associations between cardiorespiratory fitness and eating behavior. *n* = 135. β: unstandardized coefficient; R^2: explained variance; TFEQ: Three-Factor Eating questionnaire.

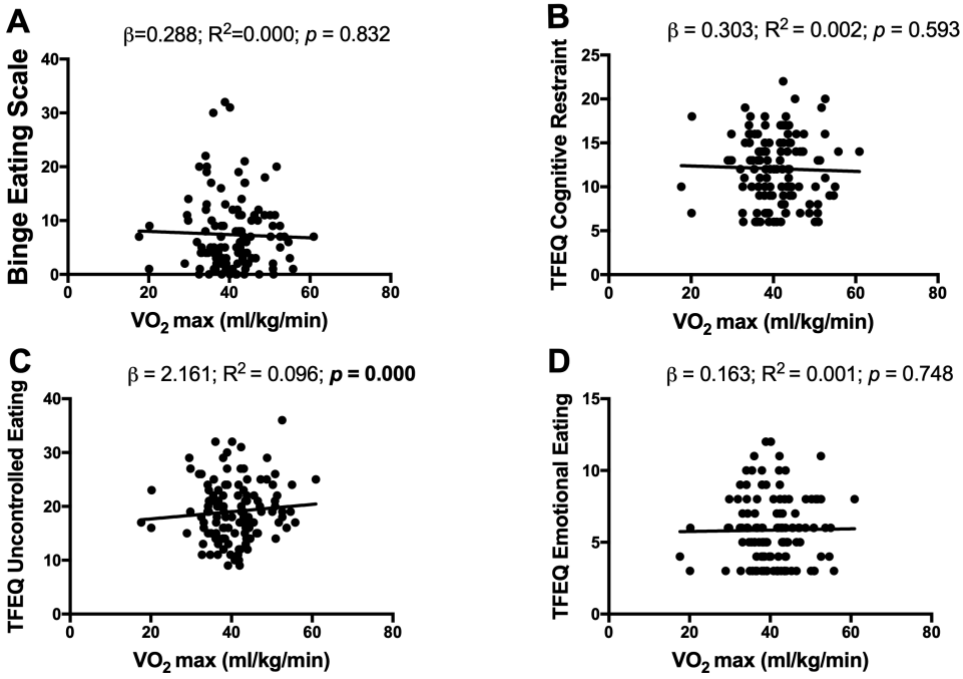

Figure 3. Associations between cardiorespiratory fitness in relative terms of body weight and eating behavior. *n* = 135. β: unstandardized coefficient; R^2: explained variance; TFEQ: Three-Factor Eating questionnaire.

Table 2. Associations between physical fitness parameters and eating behavior traits

		TFEQ											
		Binge Eating Scale			Cognitive Restraint			Uncontrolled eating			Emotional eating		
		β	R^2	*p*	β	R^2	*p*	β	R^2	*p*	β	R^2	*p*
Model 0	Hand grip	0.159	0.007	0.340	-0.137	0.029	0.058	0.121	0.019	0.128	0.002	0.000	0.980
	Lower body (1RM)	-1.155	0.027	0.069	-0.803	0.072	**0.003**	0.112	0.001	0.711	-0.193	0.006	0.419
	Upper body (1RM)	-0.948	0.006	0.393	-0.974	0.034	**0.043**	0.635	0.012	0.233	-0.221	0.002	0.600
	VO_2 max (ml/min)	0.047	0.057	**0.007**	0.009	0.013	0.196	0.023	0.067	**0.003**	0.006	0.008	0.330
	VO_2 max (ml/kg/min)	0.288	0.000	0.832	0.303	0.002	0.593	2.161	0.096	**0.000**	0.163	0.001	0.748
Model 1	Hand grip	0.590	0.038	**0.033**	-0.071	0.033	0.557	0.273	0.036	**0.039**	0.230	0.059	**0.029**
	Lower body (1RM)	-1.613	0.037	**0.034**	-0.759	0.073	**0.018**	0.051	0.002	0.887	-0.075	0.010	0.791
	Upper body (1RM)	-1.841	0.011	0.253	-0.726	0.036	0.292	0.943	0.015	0.219	0.215	0.011	0.722
	VO_2 max (ml/min)	0.085	0.102	**0.001**	0.023	0.045	**0.020**	0.033	0.082	**0.002**	0.022	0.065	**0.011**
	VO_2 max (ml/kg/min)	0.200	0.001	0.890	0.459	0.009	0.440	2.164	0.096	**0.001**	0.367	0.014	0.492
Model 2	Hand grip	0.271	0.077	0.467	-0.143	0.035	0.400	0.248	0.038	0.170	0.190	0.069	0.179
	Lower body (1RM)	-1.557	0.105	0.053	-0.888	0.086	**0.012**	-0.127	0.021	0.739	-0.250	0.059	0.404
	Upper body (1RM)	-1.509	0.079	0.384	-0.712	0.036	0.361	0.603	0.025	0.468	0.155	0.053	0.812
	VO_2 max (ml/min)	0.057	0.114	**0.048**	0.025	0.047	**0.049**	0.038	0.079	**0.006**	0.018	0.055	0.102
	VO_2 max (ml/kg/min)	1.254	0.088	0.398	0.669	0.022	0.301	2.245	0.105	**0.001**	0.726	0.047	0.194

Model 0: unadjusted. Model 1 adjusted for sex; Model 2: adjusted for sex and FFM. TFEQ: Three Factor Eating Questionnaire; RM: repetition maximum, VO_2 max: maximal oxygen consumption; β: unstandardized coefficient; R^2: Explained variance.

4. DISCUSSION

The main findings of this study indicate that there is an association between physical fitness and eating traits in young healthy adults. We observed that muscular strength (i.e., lower and upper body 1 RM) was negatively associated with cognitive restraint, whereas cardiorespiratory fitness was positively associated with binge eating and uncontrolled eating. Although several studies exploring the impact of eating habits on health have focused on the effect of dietary patterns on weight and body composition (20), there is a need for multidisciplinary behavioral interventions aiming on improve healthy eating practices and physical fitness.

To our knowledge, this is the first study to assess the relationship between physical fitness measured by muscular strength and cardiorespiratory fitness with eating traits in young healthy adults. Our results indicate that poorer muscular strength, both lower and upper body, is associated with higher cognitive restraint score. This could be explained by the fact that individuals with low perception of physical fitness could tend to consciously maintain a restrictive eating behavior to control body weight, which concurs with other

studies. Jauregui-Lobera et al. (8) showed that poor self-perception physical fitness is associated with higher cognitive restraint in adults.

Physical fitness is a powerful marker of health and a strong predictor of all-cause mortality (21). A previous study (22) reported that men and women with higher fitness levels consume healthier diets compared to their lower fit peers. In our study, a greater score in self-reported eating behaviors reflecting a tendency to eat more than usual due to loss of control over intake (i.e., uncontrolled eating) and binge eating were positively associated with cardiorespiratory fitness. These findings concur with those reported by Martin-Garcia et al. who found greater cardiorespiratory fitness to be associated with greater uncontrolled eating, although in a younger population (23). A possible explanation to our findings could be that individuals with greater physical fitness would tend to have compensatory eating behavior that promotes excessive consumption as indulgent behavior. For instance, a previous research in inactive people conducted by Sim (24) concluded that restrained eaters exhibited a disinhibited eating behavior when placed in a situation as exercise or dietary restriction. Another plausible explanation would be that individuals who are more likely to consciously self-report unregulated eating behavior, would have future compensatory healthy behaviors (25) such as higher levels of physical activity and that would explain the association with greater physical condition.

This study presents several limitations. The cross-sectional design does not allow to stablish causality in the relationship between physical fitness measured by muscular strength and cardiorespiratory fitness and eating traits. A non-previously validated Spanish version of the BES was used. The correlation coefficients are weak. While their persist upon the different statistically models.

5. CONCLUSION

In summary, results indicates that physical fitness levels are associated with eating traits in young healthy adults. Specifically, poorer lower and upper body muscular strength is associated with greater cognitive restraint and greater cardiorespiratory fitness is associated with binge eating and uncontrolled eating. Further longitudinal studies are needed to elucidate if greater physical condition could influence eating behavior.

6. SUPPLEMENTARY MATERIAL

TABLE S1: Bivariate correlations between physical fitness parameters and eating behavior.

	BES	TFEQ CR	TFEQ UE	TFEQ EE
Hand grip mean (kg)	0.086	-0.171	0.138	0.002
Lower body (1RM)	-0.166	-0.269**	0.034	-0.074
Upper body (1RM)	-0.078	-0.185*	0.110	-0.048
VO_2 max (ml/min)	0.059**	0.134	0.282**	0.105
VO_2 max (ml/kg/min)	0.019	0.048	0.309***	0.748

Values are Pearson correlation coefficients (*r*); * p < 0.05; ** p < 0.005; *** p < 0.001. BES: Binge Eating Scale; TFEQ: Three-Factor Eating Questionnaire; CR: Cognitive Restraint; UE: Uncontrolled Eating; EE: Emotional Eating; RM: repetition maximum; VO_2 max: Maximal oxygen consumption.

TABLE S2: Partial correlations between physical fitness parameters and eating behavior

	BES	TFEQ CR	TFEQ UE	TFEQ EE
Hand grip mean (kg)	0.187*	-0.057	0.185*	0.202*
Lower body (1RM)	-0.196*	-0.217*	0.013	-0.025
Upper body (1RM)	-0.114	-0.097	0.114	0.033
VO_2 max (ml/min)	0.334***	0.221**	0.299**	0.239**
VO_2 max (ml/kg/min)	0.008	0.070	0.297**	0.062

Values are Pearson correlation coefficients (*r)*; * p < 0.05; ** p < 0.005; *** p < 0.001. Adjusted for sex. BES: Binge Eating Scale; TFEQ: Three-Factor Eating Questionnaire; CR: Cognitive Restraint; UE: Uncontrolled Eating; EE: Emotional Eating; RM: repetition maximum; VO_2 max: Maximal oxygen consumption.

TABLE S3: Partial correlations between physical fitness parameters and eating behavior

	BES	TFEQ CR	TFEQ UE	TFEQ EE
Hand grip mean (kg)	0.004	-0.133	0.108	0.059
Lower body (1RM)	-0.254*	-0.286**	-0.045	-0.161
Upper body (1RM)	-0.193*	-0.168	0.036	-0.106
VO_2 max (ml/min)	0.191*	0.196*	0.280**	0.157
VO_2 max (ml/kg/min)	0.009	0.051	0.278**	0.049

Values are Pearson correlation coefficients (*r*); * p < 0.05; ** p < 0.005; *** p < 0.001. Adjusted for FFM BES: Binge Eating Scale; TFEQ: Three-Factor Eating Questionnaire; CR: Cognitive Restraint; UE: Uncontrolled Eating; EE: Emotional Eating; RM: repetition maximum; VO_2 max: Maximal oxygen consumption.

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4.3 STUDY III

CULTURAL ADAPTATION AND VALIDATION OF THE SPANISH VERSION OF THE LEEDS FOOD PREFERENCE QUESTIONNAIRE (LFPQ-SP)

STUDY III

Cultural adaptation and validation of the Spanish version of the Leeds Food Preference Questionnaire (LFPQ-SP)

1.INTRODUCTION

The multifactorial etiology of obesity and its development from complex interactions between environmental, genetic and marked individual differences accounts for the use of personalized interventions to prevent and treat this health problem (1). Besides, there is evidence that an interaction exists among biological/physiological with behavioral factors in the control of food intake (2). Some intrinsic food properties and food palatability are known to influence appetite and food intake (3) constituting risk factors for overconsumption and weight gain (4) . For example, energy density and macronutrient composition could influence energy intake. Although, dietary fibres also influence on satiation and satiety (3). Nevertheless, overeating that is produced by an imbalance of satiation and satiety hormonal signaling, it also occurs due to an excessive or weakened response to the hedonic aspects of food (5).

Eating patterns are controlled by brain mechanisms of food reward, although some mechanisms operate in a normal or abnormal way (6) due to individual differences in the hedonic aspects of food intake that are linked to genetic, physiologic, metabolic and psychological factors (7). The quantitative aspect of eating behavior directs how much to eat and is mainly driven by signals of fullness and satiety (8). On the other hand, the qualitative aspect of eating behavior (what to eat) depends largely on food preference. The latter is driven by motivation and the pleasure of the experience obtained by food (wanting and liking for food) (8).

These psychological components of food reward operate at implicit or subconscious, automatic level and also at explicit or conscious, introspective level (7). In this context, liking is understood as the perceived or expected given pleasure value of food. Also, it is thought to be more important in determining the range of food eaten (8). On the other side, wanting refers to the attraction triggered by the perception of a food or a food cue in the environment (8). These two processes would be interrelated, and it is possible to

know under which circumstances they may differ by degree or become dissociated through its measurement (8).

The Leeds Food Preference Questionnaire (LFPQ) is a computer-based task platform that allows measure explicit liking and wanting for relative food preference, and implicit wanting for food categories consisting in typical consumed foods (9). The LFPQ task presents to the participants a previously validated array of food pictures common in the diet divided in four categories depending on nutritional aspects (8). Responses are collected and used to calculate mean scores for high or low fat and sweet or savoury food types (8). The LFPQ have been used for several years and seems to be a good predictor of actual food choice and food intake in laboratory settings (8). Furthermore, it is well known cultural issues play a major role in food choice, selection and consumption (10). Therefore, a translated and cultural adapted version would be appropriate to improve sensitivity and comparability of this measure in Spanish population.

This study aims to create and validate a Spanish version of the LFPQ (LFPQ-SP) following the proposed method for cultural adaptation and best practice recommendations propositioned by Oustric et al. (9) in order to assure better quality and sensitivity in the examination of these constructs of eating behavior.

2. METHODS

Spanish version of Leeds Food Preference Questionnaire (LFPQ-SP)

With the purpose of create the Spanish version of the LFPQ task, a culturally appropriate array of food images was created and validated.

2.1 Creation of food database

For the achievement of the first step of the cultural adaptation and considering that at least 16 food pictures are needed for each category, a list of 80 food options were selected by a group of Dietitians. These food items were chosen accordingly to match categories: i) High-fat savoury (HFSA), ii) Low-fat savoury (LFSA); iii) High-fat sweet (HFSW) and iv) Low-fat sweet (LFSW). Likewise, food items were chosen to match proposed criteria as ready-to-eat characteristics, easily recognized and well accepted by the Spanish population.

Once a final list of selected food items was created, food pictures were taken following a standardized process (i.e., photographs of each food item were taken on the same plate and with a semiprofessional photographic camera). The food pictures are enlisted in **Figure 1**.

Figure 1. Panel **A** shows High-Fat Savoury (HFSA) foods; Panel **B** shows Low-Fat Savoury (LFSA) foods: Panel **C** shows High-Fat Sweet (HFSW) foods; Panel **D** shows Low-Fat Sweet (LFSW) foods.

2.2 Food database online validation

An online validation of food pictures was needed to select the best pictures that are well recognized, frequently eaten, adequately liked, correctly identified as savoury/sweet, low or high-fat and suitable for the intended time of the day. This procedure was done through an online questionnaire performed on LimeSurvey platform. It consisted of a questionnaire where 32 images of food were presented. It was distributed nationally via email and social media. A sequence of the main questions performed regarding food items validation is enlisted in **Table 1**.

Table 1. Criteria and questions implemented in the online validation

Criteria	Question	Cut-off points
Recognition	Por favor, escriba el nombre de la comida de la imagen.	>80% correctly recognized
Frequency	¿Con qué frecuencia consume usted esta comoda? •( ) Nunca •( ) Una vez al año •( ) De 2 a 6 veces al año •( ) De 1 a 3 veces al mes •( ) Una vez a la semana •( ) De 2 a 4 veces a la semana •( ) Diario	Food eaten more twice per year
Liking	¿Cómo de agradable es el sabor de esta comida?	VAS response >60 as Unpleasant (0) vs Extremely pleasant (100)
Taste	¿Esta comida es más dulce o más salada?	VAS response <40 as Sweet (0) vs >60 as Savoury (100)
Fat perception	¿Esta comida es baja o alta en grasa	VAS response <40 as Low-fat (0) vs >60 as High-fat (100)
Appropriateness for time of the day	Cuando consume este alimento, ¿cómo de habitual es que lo haga… …En el desayuno/por la mañana? …En el almuerzo/al medio día? …En la merienda/a media tarde? …En la cena/por la noche?	VAS response as >60 as usually eaten in the time of the day: Nothing usual (0) vs Extremely usual (100)
Healthiness	¿Cómo de saludable es esta comida?	VAS response >60 as Non-healthy (0) vs Healthy (100)

VAS: visual analogue scale.

2.3 Participants in the online validation

To avoid bias, only native Spanish people living in the country were permitted for participation. Then, the questionnaire was answered anonymously and only the responses from people over 18 years of age were selected.

2.4 Food images

A total of 32 images were presented through an online questionnaire. Food images were previously selected by the nutritionist staff and a pilot testing were done within the research group to assure that food items were adequate in a typical Spanish diet. Food pictures were randomly presented. **Table 2** shows food categories.

Table 2. Food categories and food items.

Food categorie	Food item
High-Fat Savoury >60% fat content	Olivier salad / Ensaladilla rusa
	Potato chips / Patatas Chips
	Potato omelette / Tortilla de patatas
	Iberic Ham / Jamón serrano
	Olives /Acetiunas
	Cheese / Queso
	Cold meat / Fuet
	Fried potatoes with sauces / Patatas bravas
Low-Fat Savoury <20% fat content	Bread sticks / Picos-colines
	Chicken breast, grilled / Pechuga de pollo, asada
	Bread / Pan
	Rice w/veggetables / Arroz con vegetales
	Cherry tomato / Tomate
	Veggetable stew / Menestra de verduras
	Carrots / Zanahorias
	Salad / Ensalada
High-Fat Sweet >60% fat content	Cookies / Galletas con chispas de chocolate
	Puff pastry cookies / Palmeritas
	Doughnut / Donus
	Chocolate-filled pie / Napolitana de chocolate
	Apple pastry / Tarta de manzana
	Muffins / Magdalenas
	Waffle / Gofre
	Majorcan sweet bun / Ensaimada
Low-Fat Sweet <20% fat content	Cereal bar / Barrita de muesli
	Apple / Manzana
	Jelly / Gelatina
	Orange / Naranja
	Banana / Plátano
	Vainila custard / Flan de Vainilla
	Kiwi
	Gummies / Gominolas

2.5 Statistical Analyses

Processing of the responses obtained

For the processing of the responses, only the complete responses were considered. Also, responses from repeated IP addresses were removed from analyses.

Data are presented as means and standard deviation for both descriptive and main analyses for the validation of food images accordingly to Oustric et al. (9). These

calculations were performed using the Statistical Package for Social Sciences (SPSS v. 22.0, IBM SPSS Statistics, IBM Corporation).

3. RESULTS

3.1 Participants

A total of 96 participants (60.4 % women) were included in the analyses from anonymously recorded responses. Most of the participants responded to be in the range of 18 to 30 years of age, have a university degree and reside in the city of Granada. Likewise, one of the important aspects was to question the type of diet they carried, to which 78 participants responded that they did not carry out any type of diet or special eating pattern; 8 of them answered as vegetarian or vegan diet; 3 of them answered to be performing fasting, and 7 participants answered as other (not specified). **Table 3.** shows descriptive data from the participants in the online validation.

3.2 Results of the food images for each criterion proposed

All food pictures were considered valid if they matched the proposed criteria by Oustric et al. (9). Although, the category of food perception of healthiness, initially was not proposed by Oustric, it has been analyzed with the same cut-off point. That is, a food was considered as healthy if the scored was >60 on the VAS response. Following this, in the recognition criterion six foods were not recognized by more than 80 percent of the responses. These foods were cold meat (*fuet)* (HFSA), breadsticks and rice with vegetables (LFSA), puff pastry apple pie and Majorcan sweet bun (*ensaimada)* (HFSW) and the cereal bar (LFSW).

Within the criterion of frequency of consumption (i.e., to consume the food item more than twice per year), the foods that did not meet the cut-off point were fried potatoes with sauces (*patatas bravas*) (HFSA), all in the HFSW group except from the cookies, and cereal bar, jelly, vanilla custard, kiwi and gummies (LFSW). All food item in LFSA matched the criterion for frequency.

The liking criterion for each food was matched if it was correctly scored as a liked food (> 60). Therefore, most food items were accepted at this cut-off point except puff pastry apple pie (HFSW), cereal bar and jelly (LFSW). The taste criterion for each food were

matched if it was correctly scored as sweet (<40) or as savoury (> 60). Therefore, all food items were accepted at this cut-off point except for carrots.

Regarding the recognition of the fat content of each food, items were accepted within the cut-off point if they were valued as low-fat (<40) or as high-fat (> 60). Therefore, the foods were not correctly recognized as low or high in fat except for the cereal bar, vanilla custard, and gummies. All included in the LFSW category. It should be noted that for the criterion of time adequacy for the intended time of the day, all the foods have been adequately valued. In addition, the results on the last evaluation criterion for the perception of food healthiness show a relatively low value for foods within the high-fat category and relatively high, or healthy for the low-fat category of foods. **Table 4** shows the percentage of participants responses correctly answered for each criterion and **Table 5** shows the mean and standard deviation for the VAS responses for criterion liking, taste, fat content, appropriateness for time of the day and perception of healthiness.

Table 3. Descriptive characteristics of the participants from the online survey (n=96).

Variables	n=96	%
Age		
18 - 30	55	(57.3)
31 - 40	10	(10.4)
41 - 50	15	(15.6)
51 - 60	14	(14.6)
+60	2	(2.08)
Gender		
Male	38	(39.6%)
Female	58	(60.4%)
Schooling		
No schooling/elementary	0	(0)
Middle school	2	(2.1)
High School	16	(16.7)
Formative Course	4	(4.2)
University Degree	34	(35.4)
Master's Degree	18	(18.8)
Doctorate	22	(22.9)
Professional activity		
Worker	52	(54.2)
Retired	2	(2.1)
Unemployed	9	(9.4)
Student	31	(32.3)
Domestic work	1	(1.0)
Not answer	1	(1.0)
Type of diet		
None	78	(81.3)
Vegetarian/vegan	8	(8.3)
Fasting	3	(3.1)
Other	7	(7.3)
Province		
Granada	33	(34.4)
Palmas, Las	10	(10.4)
Cádiz	7	(7.3)
Gipuzkoa	5	(5.2)
Málaga	5	(5.2)
Madrid	3	(3.1)
Other	33	(34.0)

Table 4. Results of the validation of food images for each category.

	Food item	Recognition	Frequency	Liking	Taste	Fat	Morning/ Breakfast	Afternoon /Lunch	Mid-afternoon/ Snack	Evening/ Dinner	Healthy
HFSA	Olivier salad	95.80	85.20	79.2	98.9	92.8	0.0	80.0	4.2	46.3	20.0
	Potato chips	100.00	94.80	87.5	100.0	100.0	0.0	44.8	36.5	60.4	2.1
	Potato omelette	100.00	96.90	96.9	98.9	80.8	9.4	75.0	9.4	62.5	46.8
	Iberic Ham	100.00	88.50	91.5	100.0	91.5	38.7	33.7	24.7	64.5	53.3
	Olives	100.00	86.50	79.2	97.8	76.3	1.1	57.9	17.9	42.1	57.9
	Cheese	100.00	93.80	88.3	100.0	97.8	21.3	40.4	28.7	68.1	44.1
	Cold meat	65.50*	72.90	73.4	100.0	96.7	10.8	35.5	26.3	47.3	5.3
	Fried potatos w/sauces	89.60	60.40*	78.3	98.8	97.8	0.0	50.0	10.9	46.7	4.3
LFSA	Bread sticks	60.40*	81.30	64.5	88.9	68.2	7.3	44.1	18.8	52.6	14.1
	Chicken breast, grilled	86.50	90.60	75.3	97.6	92.9	1.1	75.8	1.0	62.1	85.3
	Bread	99.00	95.80	85.3	91.4	65.7	61.2	58.5	23.2	48.9	26.6
	Rice w/veggetables	59.40*	88.50	78.9	97.8	91.7	0.0	78.9	0.0	41.1	84.2
	Cherry tomato	100.00	85.40	77.9	69.9	98.9	25.3	72.6	9.6	68.4	95.8
	Veggetable stew	95.80	90.6	68.1	95.0	100.0	0.0	73.4	1.1	1.1	98.9
	Carrots	97.90	90.6	76.6	44.6*	98.9	3.2	67.0	17.0	97.9	97.9
	Salad	99.00	89.60	75.8	97.6	97.8	9.0	77.9	3.2	72.6	96.8
HFSW	Cookies	100.00	83.30	91.7	99.0	95.5	43.8	4.2	68.4	11.5	0.0
	Puff pastry cookies	97.90	47.90*	84.2	99.0	97.2	31.6	6.3	53.2	7.4	0.0
	Doughnut	100.00	46.90*	83.9	100.0	100.0	34.1	2.2	53.8	3.3	1.1
	Chocolate-filled pie	85.60	53.10*	81.7	100.0	98.9	30.8	2.2	50.5	0.0	1.1
	Apple pastry	67.70*	24.0*	53.9*	98.9	97.6	13.5	11.2	31.5	3.4	3.3
	Muffins	97.90	45.8*	74.7	100.0	97.7	34.4	1.1	48.9	5.6	1.1
	Waffle	94.80	22.9*	71.9	98.9	95.5	9.0	2.2	51.7	4.5	1.1
	Majorcan sweet bun	77.10*	20.8*	65.9	100.00	98.8	25.3	2.3	28.7	1.1	1.1
LFSW	Cereal bar	67.70*	40.60*	50.5*	97.8	46.5*	30.5	4.2	45.3	0.0	18.9
	Apple	100.00	94.80	82.3	98.7	100.0	45.7	52.6	58.9	33.7	97.9
	Jelly	93.80	21.90*	44.4*	98.9	75.3	2.2	0.0	18.7	14.3	24.2
	Orange	96.90	90.60	86.2	96.5	100.0	60.6	43.6	44.7	36.2	96.8
	Banana	100.00	95.80	88.5	100.0	91.6	51.0	42.7	53.1	17.7	97.9
	Vanilla custard	100.00	44.80*	69.2	100.0	10.5*	1.1	42.2	11.2	26.7	7.6
	Kiwi	100.00	74.0*	73.1	96.4	97.8	42.4	38.0	22.8	34.8	100
	Gummies	100.00	44.80*	69.6	100.0	19.0	0.0	3.3	48.4	12.1	1.1

Data are presented as the percentage of participants responses correctly answered (i.e. *Recognition*: food item correctly named "Please, write the name of the food from the picture"; *Frequency:* percentage of participants that scored the food item as eaten more than 2 times per year "How often do you eat this food?"; *Liking*: percentage of participants that scored on the VAS response the food item >60 as Unpleasant (0) vs Extremely pleasant (100) "How pleasant is the taste of this food?; *Taste*: percentage of participants that correctly scored on the VAS response the food item <40 as Sweet (0) vs >60 as Savoury (100) "Is this food sweeter of more savoury?"; *Fat*: percentage of participants that correctly scored on the VAS response the food item <40 as Low-fat (0) vs >60 as High-fat (100) "Is this food low-fat or high-fat?"; *Morning/Breakfast:* percentage of participants that scored on the VAS response the food item as >60 usually eaten in the morning/breakfast "When you eat this food, how usual is it for breakfast/morning?" Nothing usual (0) vs >60 as Extremely usual (100); *Afternoon/Lunch*: percentage of participants that scored on the VAS response the food item >60 as usually eaten in the afternoon/lunch "When you eat this food, how usual is it for afternoon/lunch?" Nothing usual (0) vs >60 as Extremely usual (100); *Mid-afternoon/Snack*: percentage of participants that scored on the VAS response the food item as >60 as usually eaten in the mid-afternoon/snack "When you eat this food, how usual is it for mid-afternoon/snack?" Nothing usual (0) vs Extremely usual (100); *Evening/Dinner*: percentage of participants that scored on the VAS response the food item >60 as usually eaten in the evening/dinner "When you eat this food, how usual is it for the evening/dinner?" Nothing usual (0) vs Extremely usual (100); *Healthy*: percentage of participants that scored on the VAS response

the food item >60 as Non-healthy (0) vs Healthy (100) “How healthy is this food?”). * indicate food items that do not meet criteria. VAS: visual analogue scale.

Table 5. Results of the validation of the food images of each food category from the VAS responses.

Food item		Liking		Taste		Fat		Morning/ breakfast		Afternoon/ Lunch		Mid-afternoon/Snack		
		Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mea*
HFSA	Olivier salad	73.74	(26.20)	83.56	(16.02)	71.61	(18.04)	3.21	(6.02)	74.25	(29.95)	6.44	-15,76	46.4
	Potato chips	81.25	(18.30)	94.41	(7.90)	88.84	(12.48)	2.89	(3.55)	45.32	(36.71)	35.86	(37.13)	57.9
	Potato omelette	89.31	(13.37)	85.76	(14.09)	64.75	(20.39)	13.99	(25.41)	71.03	(29.51)	13.06	(25.67)	64.2
	Iberic Ham	86.60	(22.65)	93.81	(8.10)	68.78	(19.76)	40.52	(39.10)	38.18	(36.06)	28.62	(33.60)	59.9
	Olives	72.93	(29.54)	88.12	(15.26)	63.51	(26.78)	3.67	(8.63)	60.05	(35.53)	19.73	(31.27)	46.1
	Cheese	83.15	(22.09)	87.48	(13.20)	79.40	(15.57)	23.96	(32.43)	47.18	(33.74)	30.48	(35.02)	64.4
	Cold meat	72.73	(29.61)	88.95	(12.54)	83.85	(16.57)	12.89	(23.74)	38.38	(37.07)	26.82	(34.77)	48.0
	Fried potatos w/sauces	74.34	(27.29)	85.85	(17.30)	83.00	(14.78)	2.84	(23.73)	53.24	(38.53)	11.45	(23.11)	45.0
	mean	**79.32**	**(14.69)**	**88.48**	**(9.57)**	**75.34**	**(10.39)**	**13.08**	**(11.93)**	**53.84**	**(21.66)**	**21.85**	**(19.91)**	**54**
LFSA	Bread sticks	63.43	(21.50)	73.02	(21.90)	39.68	(22.27)	12.70	(22.91)	46.66	(32.9)	23.53	(30.65)	53.3
	Chicken breast, grilled	68.89	(21.35)	80.15	(16.74)	25.86	(19.14)	4.28	(11.01)	69.11	(33.12)	5.93	(11.99)	61.4
	Bread	77.79	(17.42)	71.87	(21.07)	41.90	(22.65)	62.23	(39.28)	58.46	(35.01)	31.16	(33.44)	50.0
	Rice w/veggetables	76.27	(21.38)	79.77	(15.96)	23.00	(19.52)	2.85	(3.65)	76.13	(28.29)	3.32	(5.52)	45.1
	Cherry tomato	72.20	(26.96)	62.50	(27.13)	9.08	(11.03)	29.14	(34.67)	65.97	(32.60)	13.51	(25.65)	64.8
	Veggetable stew	64.16	(27.90)	75.27	(18.14)	8.34	(9.64)	2.88	(5.79)	71.71	(29.48)	3.81	(9.41)	65.1
	Carrots	71.10	(24.20)	52.15	(29.08)	7.01	(11.56)	5.19	(14.42)	63.12	(32.61)	18.86	(31.46)	64.0
	Salad	71.76	(25.70)	77.73	(19.22)	9.12	(13.07)	2.87	(3.65)	72.88	(31.64)	5.14	(14.72)	69.0
	mean	**70.57**	**(13.10)**	**71.47**	**(14.32)**	**20.58**	**(8.85)**	**15.29**	**(10.05)**	**65.52**	**(16.90)**	**13.29**	**(11.62)**	**59**
HFSW	Cookies	82.66	(21.12)	6.68	(11.56)	79.53	(18.08)	43.16	(37.80)	8.18	(17.07)	61.36	(34.65)	15.9
	Puff pastry cookies	78.67	(23.11)	6.53	(9.86)	82.01	(16.90)	34.49	(37.68)	9.84	(20.80)	50.81	(36.53)	11.3
	Doughnut	81.10	(24.60)	3.82	(5.07)	91.63	(10.06)	34.77	(38.86)	6.01	(13.46)	51.77	(38.88)	8.9
	Chocolate-filled pie	78.40	(30.63)	3.72	(4.43)	89.03	(15.11)	32.24	(37.48)	4.67	(11.92)	50.81	(39.18)	5.1
	Apple pastry	56.48	(36.93)	6.51	(12.34)	82.39	(15.83)	18.09	(30.96)	12.33	(26.34)	31.92	(36.86)	8.1
	Muffins	76.29	(25.50)	4.95	(5.74)	82.05	(15.00)	40.18	(35.58)	5.62	(11.93)	49.30	(36.66)	9.6
	Waffle	72.12	(33.00)	6.30	(6.30)	85.21	(18.29)	12.18	(25.46)	4.10	(11.94)	48.30	(42.37)	7.2

	Majorcan sweet bun	64.97	(33.45)	5.65	(8.96)	86.23	(15.12)	28.80	(37.75)	5.14	(13.55)	31.60	(36.76)	5.0
	mean	**74.36**	**(20.69)**	**5.58**	**(5.07)**	**84.37**	**(11.57)**	**31.31**	**(26.29)**	**7.67**	**(11.96)**	**47.56**	**(27.32)**	**9**
LFSW	Cereal bar	54.82	(28.97)	14.67	(15.10)	52.09	(25.60)	31.33	(36.46)	6.96	(15.00)	46.36	(40.29)	3.6
	Apple	74.21	(22.85)	21.00	(18.02)	6.50	(8.36)	47.46	(37.20)	50.94	(37.20)	59.23	(33.94)	36.8
	Jelly	49.49	(33.98)	11.40	(13.81)	32.19	(30.75)	6.44	(14.82)	23.26	(35.65)	23.41	(32.34)	16.2
	Orange	80.26	(24.03)	19.18	(17.80)	8.65	(12.07)	58.37	(39.26)	47.23	(38.85)	44.84	(38.10)	38.1
	Banana	81.15	(23.51)	12.69	(13.21)	21.47	(21.53)	53.08	(39.94)	47.44	(38.35)	53.46	(37.40)	23.9
	Vanilla custard	66.02	(33.44)	5.92	(6.92)	70.72	(20.80)	4.61	(12.46)	45.40	(39.99)	14.75	(26.57)	27.2
	Kiwi	67.81	(30.08)	19.82	(17.80)	9.46	(12.55)	41.52	(39.84)	38.23	(38.22)	27.97	(33.76)	32.6
	Gummies	67.90	(32.04)	4.72	(6.76)	70.20	(30.22)	2.52	(4.23)	6.20	(15.88)	49.64	(38.72)	16.5
	mean	**67.87**	**(16.28)**	**13.70**	**(9.25)**	**33.28**	**(11.87)**	**31.45**	**(18.19)**	**33.45**	**(19.02)**	**40.79**	**(20.87)**	**24**

Data are presented as the mean and standard deviation scores of participants responses (i.e. *Liking*: "How pleasant is the taste of this food pleasant (100); *Taste*: Sweet (0) vs Savoury (100) "Is this food sweeter of more savoury?"; *Fat*: "Is this food low-fat or high-fat?" I *Morning/Breakfast:* "When you eat this food, how usual is it for breakfast/morning?" Nothing usual (0) vs Extremely usual (100); *Afterno* food, how usual is it for afternoon/lunch?" Nothing usual (0) vs Extremely usual (100); *Mid-afternoon/Snack*: "When you eat this f afternoon/snack?" Nothing usual (0) vs Extremely usual (100); *Evening/Dinner*: "When you eat this food, how usual is it for the evening Extremely usual (100); *Healthy*: "How healthy is this food?" Non-healthy (0) vs Healthy (100).

4. DISCUSION

4.1 First online validation

This first online procedure was carried out following the process proposed by Oustric et al. (9). Other research groups have also done this procedure to validate different versions of the LFPQ in Brazilian (10) and Arab (11) populations. This procedure has allowed determine a set of foods images accepted and recognized by the Spanish population to be included in the LFPQ-SP, an instrument of measurement of food reward.

4.2 Experimental procedure (food reward in fasted and fed states)

Although this first procedure yielded valid and useful food images to be included in the LFPQ-SP, it is appropriate to carry out an experimental phase to evaluate the reliability of the task. This would consist of carrying out the measurement under fasted and fed state. Consequently, determining magnitude of the agreement between measurements and analyze their consistency would be powerful.

5. CONCLUSION

This online validation questionnaire permitted to determine well-accepted and recognized frequently eaten food items by the Spanish population that could be included in the experimental phase of cultural adaptation and validation of the LFPQ-SP. Nevertheless, there are still food items that can provide greater quality and validity to this instrument. The experimental phase should be performed to complete the cultural adaption and provide a well validated instrument to examiner dimensions of eating behavior and food reward as liking and wanting and food choice.

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5. GENERAL DISCUSSION

GENERAL DISCUSSION

The present Doctoral Thesis provided insights of the role of sedentary behavior, physical activity and fitness, and exercise training on eating behavior in young healthy adults. Also, it provides a new cultural adapted to Spanish population tool to assess dimensions of eating behavior such as food reward and food preference in adults in future studies.

Section 1. Sedentary behavior, physical activity, fitness, and exercise training on eating behavior traits

Several self-reported measures of eating behavior have been developed to quantify the extent to which and individual is appealed to food in the environment and find food consumption rewarding (1). Although, food intake in regulated by numerous homeostatic and non-homeostatic mechanisms controlling appetite, there is evidence to support the view that energy intake varies along the spectrum of physical activity levels in a J-shape (**Figure 1**) (2). On the one hand, individuals with low levels of physical activity being in a non-regulated zone of appetite, meanwhile those with higher levels of physical activity would operate in a regulated zone with more sensitive appetite control (2). Also, it has been documented that individuals with severe binge eating problems have poorer physical fitness (3).

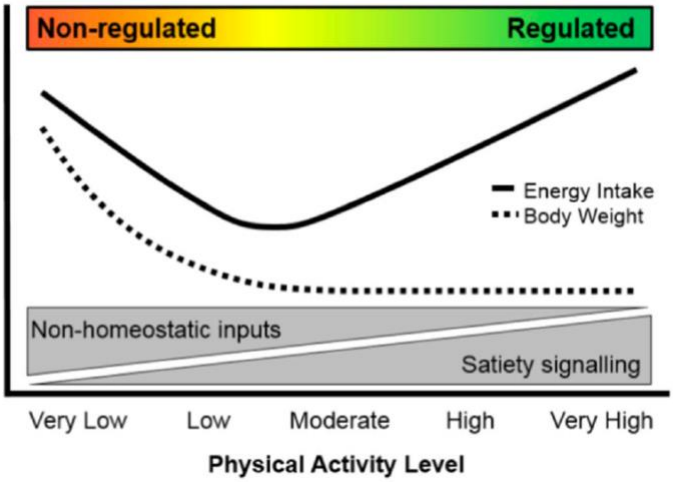

Figure 1. An updated perspective of appetite control along the spectrum of physical activity levels from Beaulieu et al (2).

In **study I**, self-reported eating traits such as binge eating, uncontrolled eating and emotional eating are inversely associated with time spent in sedentary behavior, and directly associated with time spent in PA, especially MVPA and overall PA in young,

healthy adults. However, these eating behavior traits were not altered by a six-month exercise training intervention (combining aerobic and resistance training at different intensities), which even significantly increased emotional eating in those following the vigorous-intensity exercise program. The lack of exercise-induced effects on binge and uncontrolled eating suggests that PA did not influence these psychological markers, maybe due to their lasting nature.

1.1 Association of Eating Behavior Traits with Time Spent in Sedentary Behavior and Physical Activity

In **study I**, sedentary behavior was inversely associated with reports of binge eating and uncontrolled eating. **Study I** also shows that young healthy adults who are more physically active, are more likely to consciously self-report a tendency to binge eat and eat uncontrollably—perhaps because they understand PA as deserving of reward (4). According to a study done by Sim et al. (5), inactive overweight restrained eaters appear to adjust their eating behavior depending on the perceived healthiness of activities like exercising. It follows the Compensatory Health Beliefs model by Rabiau et al. which states that the negative effects of an unhealthy behavior can be compensated for another healthy behavior (6). Our findings disagree however with those by Shook et al. (7) who reported low-level PA to be associated with higher levels of appetite-related disinhibition, and that less active individuals show significantly more intense cravings for savoury foods (e.g., chips, burgers and pizza). The relationship between physical activity and appetite control may vary from culture to culture and between geographical regions and needs further research. The present results show body composition to be associated with binge eating. This is similar to that reported by Myers et al. (8), who concluded that a relationship exists between adiposity and uncontrolled and binge eating.

1.2 Effect of the Exercise Intervention on Eating Behavior Traits

The only eating behavior trait modified by the exercise intervention was emotional eating (assessed by the self-reported TFEQ), which increased in the vigorous-intensity exercise group. It suggests that exercise might have negatively affected the ability to resist emotional cues or eating as a response to different negative emotions. This might be explained by the effect of training on emotional state and mood. Hormonal changes that occur during exercise can affect mood positively and reduce stress indicators (9). Although

the response may differ between individuals. Emotional eating has been associated with individuals with lower self-esteem and poorer perception of their physical fitness (10). Emotional eating can manifest as either increased food intake or food avoidance (11). In the present work, the subjects of the moderate-intensity exercise group showed a trend towards reduced craving control, suggesting overeating may be more likely than food avoidance (12).

We did not find any other effect of this intervention in this population of young healthy adults. This suggests that the numerous associations between eating behavior traits and physical activity levels observed at baseline are not reflecting a cause–effect relationship and are likely spurious or explained by other confounders. It is also relevant to consider that the eating behavior traits represent more lasting and resilient influences on the tendency to eat or on food selection, and are not modified on a daily basis, and they influence food consumption in different ways and through different processes (13).

1.3 Fitness and eating behavior traits

Findings in **study II** revealed that there is an association between physical fitness and self-reported eating traits in young healthy adults. We observed that muscular strength assessed by leg and bench press 1 RM, was negatively associated with cognitive restraint. On the other hand, cardiorespiratory fitness was positively associated with binge eating and uncontrolled eating. Nevertheless, these cross-sectional findings do not allow to stablish causality and more interventional studies focused on improved physical fitness should be performed to better understand if a greater physical fitness improves eating behavior.

The results in **study II** indicate that poorer muscular strength, both lower and upper body, is associated with higher cognitive restraint score. This could be explained by the fact that individuals with low perception of physical fitness could tend to consciously maintain a restrictive eating behavior to control body weight. This had been previously demonstrated by Jauregui-Lobera et al. (10) whose results showed that poor self-perception physical fitness is associated with higher cognitive restraint in adults.

Physical fitness is a powerful marker of health and a strong predictor of all-cause mortality (14). In a study conducted by Brodney S. et al (15) had been determined that men and women with higher fitness levels consume healthier diets compared to their lower fit peers. In **study II**, a greater score in self-reported behaviors reflecting a tendency to eat more than

usual due to loss of control over intake (i.e., Uncontrolled eating) and binge eating were positively associated with maximal oxygen consumption (VO_2 max) and binge eating and uncontrolled eating. These findings concurs with those reported by Martin-Garcia et al. who found greater cardiorespiratory fitness to be associated with greater uncontrolled eating, although in a younger population (16). A possible explanation to our findings could be that individuals with greater physical fitness would tend to have compensatory eating behavior that promotes excessive consumption as indulgent behavior. For instance, a previous research in inactive people conducted by Sim (5) concluded that restrained eaters exhibited a disinhibited eating behavior when placed in a situation as exercise or dietary restriction. Another plausible explanation would be that individuals who are more likely to consciously self-report unregulated eating behavior, would have future compensatory healthy behaviors (17) such as higher levels of physical activity (as seen in **Study I**) and that would explain the association with greater physical condition.

Notably, there is consistency in the results of **Study I** and **Study II** that show that self-reported eating behaviors that indicate overconsumption are associated with greater physical activity and greater physical condition. Although, a training program did not modify these self-reported traits.

Section 2. Cultural adaptation and validation of the Spanish LFPQ

The homeostatic and hedonic systems of appetite control operate in conjunction to promote or inhibit food intake (18). The behavioral quantification of food hedonics in laboratory settings helps to elucidate their role in susceptibility to overeating and could help in weight management treatment. The original Leeds Food Preference Questionnaire is a computer-based task that measures with a single instrument, separate aspects of food reward and food preferences for food categories consisting in common food in the diet (19). After following a stablished protocol (19), which other international groups have used before (20,21), we performed the first phase of the cultural adaptation and validation of the LFPQ to Spanish population. Therefore, we have acquired a set of valid food images ready to use (**study III**). This set of pictures will allow to assess psychobiological constructs of food hedonics by measures of food reward and food preference as implicit liking, explicit liking and explicit wanting (22).

MAIN LIMITATIONS

The results of the present Doctoral Thesis should be interpreted with caution. Several limitations could be highlighted:

i) We used a not previously validated Spanish versions of the BES and CoEQ questionnaires (**study I** and **study II**).

ii) We collect responses from the CoEQ questionnaire during an interview face-to-face between participant and a staff nutritionist (**study I**) which could introduce certain bias.

iii) **Studies I** and **II** were carried out in a group of young adults and mostly healthy. Consequently, our finding may not apply to older or less healthy populations.

iv) Responses collected in the online validation (**study III**) could be not representative of the Spanish population since they were mainly answered from people living in Granada city. Similarly, they could come from people who congregate in the field of physical activity and sports.

STRENGTHS

Meanwhile in other studies have used self-reported questionnaire of physical activity and self-perception of physical fitness, we objectively assessed sedentary time as well as time spent in physical activity of different intensities and physical fitness through muscular strength and cardiorespiratory fitness through a maximal effort test.

The 6-months exercise intervention training was performed and supervised by graduates in sports sciences with a Personal Training Master's degree. Performing physical exercise training without supervision can suppose avoidable harms.

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6. CONCLUDING REMARKS AND FUTURE PERSPECTIVES

CONCLUSIONS

The main conclusions of the present Doctoral Thesis are:

Section 1. Physical activity, fitness, and exercise training on eating behavior traits

Study I

- Regular physical activity and time spent in sedentary behavior is associated with self-reported eating behavior traits that suggest unregulated food intakes such as binge eating and uncontrolled eating, emotional eating in young healthy adults.
- In contrast, a concurrent training program did not show changes in the scores for these self-reported traits in this population.

Study II

- Physical fitness levels are associated with self-reported eating traits. Specifically, poorer lower and upper body muscular strength is associated with greater cognitive restraint.
- Greater cardiorespiratory fitness is associated with binge eating and uncontrolled eating.

Section 2. Cultural adaptation and validation of the Spanish LFPQ

Study III

- Following the protocol for the cross-cultural application of the LFPQ in Spanish population, a validated food database has been acquired to be integrated in this instrument and thus, assure better quality and reliability of this instrument to assess food reward and food preference in different contexts.

FUTURE PERSPECTIVES

- A validation process of version of BES and CoEQ questionnaire to Spanish population should be performed.
- Further studies are needed to better understand the role of physical activity and other types of exercises training and the enduring nature of eating traits.
- Further longitudinal studies are needed to elucidate if poorer physical condition could influence eating behavior.

- The experimental phase of the cultural adaptation of Spanish version of the LFPQ should be performed to complete the adaption and provide a well validated instrument to examiner dimensions of eating behavior and food reward as liking and wanting and food choice.

7. ANNEXES

PAPERS DERIVED FROM THE THESIS

- **Martinez-Avila, WD,** Sanchez-Delgado G, Acosta FM, Jurado-Fasoli, L, Oustric P, Labayen I, Blundell, JE; Ruiz, JR. Eating Behavior, Physical Activity and Exercise Training: A Randomized Controlled Trial in Young Healthy Adults. **Nutrients.** 2020, 12, 3685.

- **Martinez-Avila, WD** et al. Association of physical fitness and eating behavior in young healthy adults. *In preparation*

- **Martinez-Avila, WD** et al. Cultural adaptation and validation of the Leeds Food Preference Questionnaire in Spanish population (LFPQ-SP). *In preparation*

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MARTÍNEZ ÁVILA

Short CV

1. Información Personal

Nombre: Wendy Daniela Martínez Ávila
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Perfiles académicos

- ORCID: 0000-0002-2650-2784
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- Google Scholar: https://scholar.google.es/citations?user=g9wOG5wAAAAJ&hl=es

2. Afiliacion actual

Departamento de Educación Física y Deportiva
Facultad de Ciencias del Deporte
Universidad de Granada
Carretera de Alfacar s/n, Granada, 18071, España

3. Educación científica y clínica

2016 – 2021: Estudiante del Programa de Doctorado de Biomedicina, Universidad de Granada.
2014 – 2015: Máster en Nutrición Humana, Facultad de Farmacia. Universidad de Granada
2008 – 2013: Licenciatura en Nutrición, Facultad de Enfermería. Universidad Autonoma de San Luis Potosí.

4. Experiencia investigadora

11-2014 - a la fecha: Estudiante predoctoral del Grupo de investigación CTS-977 Promoting Fitness and Health through physical activity (PROFITH) de la Universidad de Granada

Principales proyectos:

- **2014 – 2017 ACTIBATE Project** Activating Brown Adipose Tissue through Exercise. Effects of an exercise intervention on activity and quantity of Brown adipose tissue: A Randomized Controlled Trial
  Principal Investigador: Jonatan Ruiz Ruiz
  Financiamiento: ≈600000€ Ministerio de Economía y Competitividad, España, entre otros.

- **2014 – 2016 ActiveBrains Project**: An exercise-based randomized controlled trial on brain, cognition, physical health and mental health in overweight/obese children
  Principal Investigador: Francisco B. Ortega Porcel
  Financiación: 120,000 €. Ministerio de Economía y Competitividad, España,

• **2015 Sporteus Project:** Effects of the intake of a protein enriched smoothie on recovery of muscular function and muscle damage after an acute bout of high intensity exercise.
Principal Investigador: Jonatan Ruiz Ruiz.
Financiamiento: 190000€. Lactalis-Puleva S.L.

5. Experiencia profesional y divulgadora

03/2020 - 12/2020: Colaborador científico en The Voice of Science, S.L. (@TvoiceOfScience)
10-2019 – a la fecha: Gestión de la cuenta de Twitter del Grupo de investigación PROFITH (@profithugr)
10/2013 – 04/2014: Coordinadora de Comunicación en Aprende Educación en Nutrición (San Luis Potosí, México)
08-2013 – 04/2014: Responsable de Servicio de alimentación en Estancia Infantil Aventuritas, San Luis Potosi, México.

6. Cursos más relevantes

03/2021	Curso "Ruta emprendedora de los investigadores en formación 2021" UGR Emprendedora 30 horas
03/2021	Curso "Divulgación Científica" Escuela Internacional de Posgrado UGR 20 horas
10/2020 – 01/2021	Curso "Photoshop para la Arquitectura y el Diseño" AIIC – UGR 50 horas
09/2020 – 10/2020	Curso "Metodología de Cuestionarios online: Introducción a Limesurvey" Centro de Estudios Andaluces 20 horas
09/2020	Curso "Técnicas de Divulgación" Centro de Estudios Andaluces 20 horas
09/2020	Curso "Neurociencia del comportamiento: del laboratorio a la vida real" Centro Mediterráneo UGR 20 horas
05/2017	Curso "Early Early Programming: factores que condicionan la salud posnatal. Introducción metodológica e implicaciones clínicas" Escuela Internacional de Posgrado UGR 10 horas

7. Becas y ayudas

- 2016 –2021 Beca para estudios en el extranjero del Consejo Nacional de Ciencia y Tecnología (CONACYT) de México. Beca 440575.

- 2019 – Beca del Plan Propio para estancias de movilidad en el extranjero para el curso 2019-2020 de la Universidad de Granada

8. Publicaciones:

i. *Impact of an intermittent and localized cooling intervention on skin temperature, sleep quality and energy expenditure in free-living, young, healthy adults.* Xu H, Martinez-Nicolas A, **Martinez-Avila WD**, Alcantara JMA, Corral-Perez J, Jimenez-Pavon D, Acosta FM, Ruiz JR, Martinez-Tellez B. J Therm Biol. 2021 Apr; 97:102875.

- doi: 10.1016/j.jtherbio.2021.102875.
- SJR 2019: 0.68 - Q1
- IF JCR: 2.361
- Ranking: 38/93

ii. *Eating Behavior, Physical Activity and Exercise Training: A Randomized Controlled Trial in Young Healthy Adults*. **Martinez-Avila WD**, Sanchez-Delgado G, Acosta FM, Jurado-Fasoli L, Oustric P, Labayen I, Blundell JE, Ruiz JR. Nutrients. 2020 Nov 29;12(12):3685.

- doi: 10.3390/nu12123685.
- SJR 2019: 1.33 - Q1
- IF JCR: 4.546
- Ranking: 17/89

iii. *Association between dietary factors and brown adipose tissue volume/18F-FDG uptake in young adults.* Jurado-Fasoli L, Merchan-Ramirez E, Martinez-Tellez B, Acosta FM, Sanchez-Delgado G, Amaro-Gahete FJ, Muñoz Hernandez V, **Martinez-Avila WD**, Ortiz-Alvarez L, Xu H, Arias Téllez MJ, Ruiz-López MD, Llamas-Elvira JM, Gil Á, Labayen I, Ruiz JR. Clin Nutr. 2021 Apr;40(4):1997-2008

- doi: 10.1016/j.clnu.2020.09.02
- SJR 2019: 1.79 - Q1
- IF JCR: 6.360
- Ranking: 9/89

iv. *Association of Neck Circumference with Anthropometric Indicators and Body Composition Measured by DXA in Young Spanish Adults*. Arias Téllez MJ, Acosta FM, Sanchez-Delgado G, Martinez-Tellez B, Muñoz-Hernández V, **Martinez-Avila WD**, Henriksson P, Ruiz JR. Nutrients. 2020 Feb 18;12(2):514.

- doi: 10.3390/nu12020514.
- SJR 2019: 1.33 - Q1
- IF JCR: 4.546
- Ranking: 17/89

v. *Associations of dietary energy density with body composition and cardiometabolic risk in children with overweight and obesity: role of energy density calculations, under-reporting energy intake and physical activity.* Gomez-Bruton A, Arenaza L, Medrano M, Mora-Gonzalez J, Cadenas-Sanchez C, Migueles JH, Muñoz-Hernández V, Merchan-Ramirez E, **Martinez-Avila WD**,

Maldonado J, Oses M, Tobalina I, Gracia-Marco L, Vicente-Rodriguez G, Ortega FB, Labayen I. Br J Nutr. 2019 May;121(9):1057-1068.

- doi: 10.1017/S0007114519000278
- SJR 2019: 1.24 - Q1
- IF JCR: 3.334
- Ranking: 40/89

vi. *Association of Objectively Measured Physical Activity with Brown Adipose Tissue Volume and Activity in Young Adults.* Acosta FM, Martinez-Tellez B, Sanchez-Delgado G, Migueles JH, Contreras-Gomez MA, **Martinez-Avila WD**, Merchan-Ramirez E, Alcantara JMA, Amaro-Gahete FJ, Llamas-Elvira JM, Ruiz JR. J Clin Endocrinol Metab. 2019 Feb 1;104(2):223-233.

- doi: 10.1210/jc.2018-01312.
- SJR 2019 2.48 – Q1
- IF JCR: 5.39.
- Ranking: 21/143

vii. *Influence of Physical Activity on Bone Mineral Content and Density in Overweight and Obese Children with Low Adherence to the Mediterranean Dietary Pattern.* Muñoz-Hernandez V, Arenaza L, Gracia-Marco L, Medrano M, Merchan Ramirez E, **Martinez Avila WD**, Oses M, Ruiz JR, Ortega FB, Labayen I. Nutrients. 2018 Aug 12;10(8):1075.

- doi: 10.3390/nu10081075.
- SJR 2019: 1.33 - Q1
- IF JCR: 4.546
- Ranking: 17/89

viii. *Skin temperature response to a liquid meal intake is different in men than in women.* Martinez-Tellez B, Ortiz-Alvarez L, Sanchez-Delgado G, Xu H, Acosta FM, Merchan-Ramirez E, Muñoz-Hernandez V, **Martinez-Avila WD**, Contreras-Gomez MA, Gil A, Labayen I, Ruiz JR.Clin Nutr. 2019 Jun;38(3):1339-1347.

- doi: 10.1016/j.clnu.2018.05.026.
- SJR 2019: 1.79 - Q1
- IF JCR: 6.360
- Ranking: 9/89

ix. *A New Personalized Cooling Protocol to Activate Brown Adipose Tissue in Young Adults.* Martinez-Tellez B, Sanchez-Delgado G, Garcia-Rivero Y, Alcantara JMA, **Martinez-Avila WD**, Muñoz-Hernandez MV, Olza J, Boon MR, Rensen PCN, Llamas-Elvira JM, Ruiz JR. Front Physiol. 2017 Nov 2; 8:863.

- doi: 10.3389/fphys.2017.00863.
- SJR 2019: 1.21 - Q2
- IF JCR: 3.367
- Ranking: 20/81

x. *An exercise-based randomized controlled trial on brain, cognition, physical health and mental health in overweight/obese children (ActiveBrains project): Rationale, design and methods.* Cadenas-Sánchez C, Mora-González J, Migueles

JH, Martín-Matillas M, Gómez-Vida J, Escolano-Margarit MV, Maldonado J, Enriquez GM, Pastor-Villaescusa B, de Teresa C, Navarrete S, Lozano RM, de Dios Beas-Jiménez J, Estévez-López F, Mena-Molina A, Heras MJ, Chillón P, Campoy C, Muñoz-Hernández V, **Martínez-Ávila WD**, Merchan ME, Perales JC, Gil Á, Verdejo-García A, Aguilera CM, Ruiz JR, Labayen I, Catena A, Ortega FB. Contemp Clin Trials. 2016 Mar; 47:315-24.

- doi: 10.1016/j.cct.2016.02.007.
- SJR 2019: 1.05 – Q3
- IF JCR: 1.832
- Ranking: 103/139

xi. *Activating brown adipose tissue through exercise (ACTIBATE) in young adults: Rationale, design and methodology.* Sanchez-Delgado G, Martinez-Tellez B, Olza J, Aguilera CM, Labayen I, Ortega FB, Chillon P, Fernandez-Reguera C, Alcantara JMA, **Martinez-Avila WD**, Muñoz-Hernandez V, Acosta FM, Prados-Ruiz J, Amaro-Gahete FJ, Hidalgo-Garcia L, Rodriguez L, Ruiz YA, Ramirez-Navarro A, Muros-de Fuentes MA, García-Rivero Y, Sanchez-Sanchez R, de Dios Beas Jimenez J, de Teresa C, Navarrete S, Lozano R, Brea-Gomez E, Rubio-Lopez J, Ruiz MR, Cano-Nieto A, Llamas-Elvira JM, Jimenez Rios JA, Gil A, Ruiz JR.Contemp Clin Trials. 2015 Nov;45(Pt B):416-425.

- doi: 10.1016/j.cct.2015.11.004
- SJR 2019: 1.05 – Q3
- IF JCR: 1.832
- Ranking: 103/139

9. Actividades de diseminación como primer autor

-Titulo: *Asociación entre desregulación de apetito y composición corporal*
Congreso: I Congreso Nacional / III Jornadas Investigadores en Formación Fomentando la Interdisciplinariedad
Lugar de celebración: Granada, España
Fecha de celebracion: Mayo 2018
Tipo de presentación: comunicación oral
Autores: **Martínez-Ávila WD**, Acosta-Manzano FM, Sánchez-Delgado G, Muñoz-Hernández MV, Merchán Ramírez E, Ruiz JR

-Titulo: *Sugar intake and cognitive performance indicators in overweight/obese children: The ActiveBrains Project.*
Congreso: International Symposium: ActiveBrains for all: exercise, cognitition and mental health.
Lugar de celebración: Granada, España
Fecha de celebracion: Junio 2017
Tipo de presentación: Abstract, poster
Autores: **Martínez-Ávila WD**, Mora-González J, Henriksson P, Henriksson H, Muñóz-Hernández MV, Merchán-Ramírez E, Cadenas-Sánchez C, Esteban-Cornejo I, Hidalgo-Migueles J, Sánchez-Delgado G, Rodríguez-Ayllón M, Molina-García P, Arenaza-Etxeberria L, Labayen I, Ortega FB.

-Titulo: *Physical activity, sedentary time and appetite regulation in young adults: The ACTIBATE pilot study*

Congreso*:* 17º Congreso Internacional de Dietética y Nutrición
Lugar de celebración: Granada, España
Fecha de celebracion: Septiembre 2016
Tipo de presentación: Abstract, poster
Autores: **Martínez-Ávila WD**, Sanchez-Delgado G, Muñoz-Hernandez MV, Martinez-Tellez B, Alcantara JMA, Ruiz JR

-Titulo: *Asociación entre el perfil calórico de la dieta, gasto metabólico basal, respuesta termogénica a una comida y percepción de apetito en adultos jóvenes: resultados preliminares del estudio ACTIBATE*
Congreso: I Jornadas de Investigadores en Formación
Lugar de celebración: Granada, España
Fecha de celebracion: Mayo 2016
Tipo de presentación: Comunicación oral
Autores: **Martínez-Ávila WD**, Muñoz-Hernandez MV, Sanchez-Delgado G, Ruiz JR

Titulo: *Associations of adherence to Mediterranean diet with measures of adiposity and blood pressure in overweight and obese Spanish children: Results from the ActiveBrains project.*
Congreso: Early Nutrition Meeting Posgraduate School
Lugar de celebración: Granada, España
Fecha de celebracion: Mayo 2016
Tipo de presentación: Poster
Autores: **Martínez-Ávila WD**, Muñoz-Hernandez MV, Sanchez-Delgado G, Ruiz JR

10. Otos meritos

Member of the Scientific Committee of the International Symposium: Role of brown adipose tissue in human health. Granada, Spain. (2018)

CUESTIONARIOS DE CONDUCTA ALIMENTARIA

Binge Eating Scale

Instrucciones
Debajo puede encontrar una serie de declaraciones agrupadas en diferentes apartados. Lea todas las opciones correspondientes a cada apartado y seleccione el número correspondiente a la opción que mejor le describa a usted.

A.
1. No me siento consciente de mi peso y tamaño corporal cuando estoy con otros.
2. Me preocupa cómo me vean los demás, pero normalmente no me hace sentir decepcionado conmigo mismo.
3. Me preocupo por mi apariencia y mi peso, los cuales me hacen sentir decepcionado conmigo mismo.
4. Me siento muy consciente de mi peso y a menudo siento pena y asco de mí mismo. Intento evitar contactos sociales por cohibición.

B.
1. No tengo ninguna dificultad para comer despacio de manera adecuada.
2. Aunque parece que engullo los alimentos, no termino de sentirme lleno por comer mucho.
3. A veces trato de comer deprisa y después me siento incómodamente lleno.
4. Tengo el hábito de tragar mi comida sin realmente masticarla bien. Cuando esto ocurre, generalmente me siento incómodamente lleno porque he comido demasiado.

C.
1. Me siento capaz de controlar mis impulsos por la comida cuando quiero.
2. Siento que no he podido controlar mi alimentación más que una persona normal.
3. Me siento absolutamente incapacitado respecto al sentimiento de control de mis impulsos alimenticios.
4. Al sentirme tan impotente para controlar mi alimentación, estoy desesperado por intentar tomar el control.

D.
1. No tengo el hábito de comer cuando estoy aburrido.
2. Algunas veces como cuando estoy aburrido, pero a menudo soy capaz de “ocuparme” y alejar mi mente de la comida.
3. Tengo el hábito regular de comer cuando estoy aburrido, pero ocasionalmente, puedo usar alguna otra actividad para alejar mi mente de la comida.
4. Tengo el fuerte hábito de comer cuando estoy aburrido. Nada parece ayudar a romper ese hábito.

E.
1. Normalmente estoy físicamente hambriento cuando como algo.
2. En ocasiones, como por impulso, aunque realmente no tenga hambre.
3. Tengo la costumbre de comer alimentos, aunque no los disfrute de verdad, para satisfacer un sentimiento de hambre, aunque físicamente, no necesite comer.
4. Aunque no esté físicamente hambriento, me entra una sensación de hambre en la boca que sólo parece satisfacerse cuando como alimentos, como un bocadillo, que me llenan la boca. En ocasiones, cuando como los alimentos para satisfacer el hambre de mi boca, escupo los alimentos para no ganar peso.

F.
1. No siento ninguna culpa u odio a mí mismo después de comer en exceso. cuando como en exceso.
2. Después de comer en exceso, a veces siento culpa u odio a mí mismo.
3. Casi siempre tengo un gran sentimiento de culpa o u odio a mí mismo cuando como en exceso.

G.
1. No pierdo el control total de mi forma de comer cuando estoy a dieta, incluso tras períodos en que como en exceso.
2. A veces cuando como una "comida prohibida" en una dieta. por la dieta, me siento como que le eché a perder y como aún más.
3. Frecuentemente me digo a mí mismo, "la he roto ya, por qué no romperla del todo" cuando como en exceso. Cuando eso ocurre, como todavía más.
4. Tengo la costumbre de comenzar dietas estrictas por mí mismo, pero las rompo con una comida compulsiva. Mi vida está entre la "fiesta" y el "hambre".

H.
1. Raramente como tanta comida que me sienta incómodamente lleno al terminar.
2. Normalmente sobre una vez al mes, como tal cantidad de comida que termino sintiéndome muy lleno.
3. Tengo períodos regulares durante el mes en que como grandes cantidades de comida, sea a la hora de la comida o en aperitivos.
4. Como tanta comida que regularmente me siento incómodo después de comer y a veces un poco nauseabundo.

I.
1. Mi nivel de ingesta calórica no sube ni baja mucho normalmente.
2. A veces después de comer en exceso, trato de reducir mi ingesta a prácticamente nada para compensar el exceso de calorías que he comido.
3. Tengo el hábito regular de comer en exceso por la noche. Parece que mi rutina no es tener hambre por la mañana, pero comer en exceso por la noche.
4. En mis años adultos, he tenido períodos de una semana en los que prácticamente me moría de hambre. Esto sigue períodos en los que como en exceso. Parece que vivo una vida de "fiesta o hambre".

J.
1. Normalmente puedo parar de comer cuando quiero. Sé cuándo decir "basta".
2. De vez en cuando, experimento una impulsividad para comer que no parece que pueda controlar.
3. Frecuentemente experimento fuertes impulsos por comer que no parezco poder controlar, pero en otras ocasiones puedo controlar mis impulsos por comer.
4. Me siento incapaz de controlar mis impulsos por comer. Tengo miedo de no ser capaz de parar de comer voluntariamente.

K.
1. No tengo ningún problema en parar de comer cuando me siento lleno.
2. Normalmente puedo para de comer cuando me siento lleno, pero ocasionalmente como en exceso y me siento incómodamente lleno.
3. Tengo un problema para parar de comer una vez comienzo y habitualmente me siento incómodamente lleno después de una comida.
4. Al tener el problema de no ser capaz de comer cuando quiero, a veces me induzco el vómito para liberar aliviar mi sensación de pesadez.

L.
1. Parece que como lo mismo cuando estoy con otros (familia, relaciones sociales) que cuando estoy solo.
2. A veces, cuando estoy con otras personas, no como tanto como quiero porque estoy concienciado sobre mi forma de comer.
3. Frecuentemente, solo como una pequeña cantidad de comida cuando estoy con otros, pues me siento muy avergonzado sobre mi forma de comer.
4. Me siento tan avergonzado por comer en exceso que a ratos como en exceso cuando nadie me ve. Me siento como un "devorador".

M.
1. Como tres comidas al día y sólo ocasionalmente un aperitivo entre comidas.
2. Como 3 comidas al día, pero también normalmente un aperitivo entre comidas.
3. Cuando como muchos snacks, cojo el hábito de saltarme comidas principales.
4. Hay períodos en que parece que estoy comiendo continuamente, sin comidas planificadas.

N.
1. No pienso mucho sobre intentar controlar los impulsos alimenticios no deseados.
2. Al menos parte del tiempo, siento que mis pensamientos están preocupados tratando de controlar mis impulsos alimenticios.
3. Siento que frecuentemente gasto mucho tiempo pensando sobre cuánto comí o tratando de no comer más.
4. Me parece que la mayoría de mis horas despierto están preocupadas con pensamientos sobre comer o no comer. Siento como si estuviera constantemente luchando para no comer.

O.
1. No pienso mucho sobre comida como un gran asunto
2. Tengo grandes antojos sobre comida, pero duran sólo breves períodos de tiempo.
3. Tengo días en que parece que no pienso en otra cosa que comer.
4. La mayoría de mis días parecen estar predeterminados con pensamientos sobre comida. Siento que vivo para comer.

P.
1. Normalmente sé si estoy o no físicamente hambriento. Tomo la porción apropiada de alimentos para satisfacerme.
2. Ocasionalmente me siento inseguro sobre saber o no si estoy físicamente hambriento.
3. Aunque puede que sepa cuántas calorías debo comer, no tengo ni idea sobre cuál es la cantidad normal de comida para mí.

Spanish Version of the Three-Factor Eating Questionnaire-R18 (TFEQ-SP)

1. Cuando huelo una comida deliciosa me resulta muy difícil no probarla, incluso si acabo de terminar mi comida.
1=Totalmente cierto; 2=Mayormente cierto; 3=Mayormente falso; 4=Totalmente falso

2. Deliberadamente tomo pequeñas cantidades de comida como medio para controlar mi peso.
1=Totalmente cierto; 2=Mayormente cierto; 3=Mayormente falso; 4=Totalmente falso

3. Cuando me siento ansioso/a (nervioso/a) sin darme cuenta me encuentro comiendo.
1=Totalmente cierto; 2=Mayormente cierto; 3=Mayormente falso; 4=Totalmente falso

4. A veces cuando empiezo a comer parece que no puedo parar.
1=Totalmente cierto; 2=Mayormente cierto; 3=Mayormente falso; 4=Totalmente falso

5. Estar con alguien mientras come me hace sentir hambre como para ponerme a comer también.
1=Totalmente cierto; 2=Mayormente cierto; 3=Mayormente falso; 4=Totalmente falso

6. Cuando me siento mal (depresivo, infeliz) suelo comer demasiado.
1=Totalmente cierto; 2=Mayormente cierto; 3=Mayormente falso; 4=Totalmente falso

7. Cuando veo algo muy exquisito me entra tanta hambre que tengo que comerlo en ese mismo momento.
1=Totalmente cierto; 2=Mayormente cierto; 3=Mayormente falso; 4=Totalmente falso

8. Me siento tan hambriento/a que mi estómago a menudo parece un pozo sin fondo.
1=Totalmente cierto; 2=Mayormente cierto; 3=Mayormente falso; 4=Totalmente falso

9. Siempre tengo hambre, de modo que para mí es difícil parar de comer hasta que acabo la comida del plato.
1=Totalmente cierto; 2=Mayormente cierto; 3=Mayormente falso; 4=Totalmente falso

10. Cuando me siento solo/a me consuelo comiendo.
1=Totalmente cierto; 2=Mayormente cierto; 3=Mayormente falso; 4=Totalmente falso

11. Me controlo conscientemente en las comidas para no ganar peso.
1=Totalmente cierto; 2=Mayormente cierto; 3=Mayormente falso; 4=Totalmente falso

12. No suelo comer algunos alimentos porque me hacen engordar.
1=Totalmente cierto; 2=Mayormente cierto; 3=Mayormente falso; 4=Totalmente falso

13. Siempre siento tanta hambre como para poder comer en cualquier momento.
1=Totalmente cierto; 2=Mayormente cierto; 3=Mayormente falso; 4=Totalmente falso

14. ¿Con qué frecuencia te sientes hambriento/a?
1=Tan solo a la hora de las comidas; 2=Algunas veces entre comidas; 3=A menudo entre comidas; 4=Casi siempre

15. ¿Con qué frecuencia evitas almacenar alimentos muy tentadores/apetecibles?

1=Casi nunca; 2=Raramente; 3=Habitualmente; 4=Casi siempre

16. ¿Con qué probabilidad comes conscientemente menos de lo que quieres?
1=Improbable; 2=Ligeramente improbable; 3=Moderadamente probable; 4=Muy probable

17. ¿Continúas comiendo excesivamente aunque no tengas hambre?
1=Nunca; 2=Raramente; 3=Algunas veces; 4=Al menos una vez a la semana

18. En una escala de 1 a 8, donde 1 significa no restringir la ingesta y 8 significa restricción total, ¿con qué número te valorarías a ti mismo/a?
No restringir ingesta (1) (2) (3) (4) (5) (6) (7) (8) Restricción total

Control of Eating Questionnaire (CoEQ)

Por favor, lea cuidadosamente cada pregunta y señale con una línea el punto que mejor representa su experiencia. Responda todas las preguntas en el contexto de los últimos 7 días.

1. ¿Cómo de hambriento se ha sentido?

Nada hambriento _____ Extremadamente hambriento

2. ¿Cómo de lleno se ha sentido?

Nada lleno _____ Extremadamente lleno

3. ¿Cómo de fuerte ha sido su deseo por comer alimentos dulces?

Nada fuerte _____ Extremadamente fuerte

4. ¿Cómo de fuerte ha sido su deseo por comer alimentos salados?

Nada fuerte _____ Extremadamente fuerte

5. ¿Cómo de feliz se ha sentido?

Nada feliz _____ Extremadamente feliz

6. ¿Cómo de ansioso se ha sentido?

Nada ansioso _____ Extremadamente ansioso

7. ¿Cómo de alerta se ha sentido?

Nada alerta _____ Extremadamente alerta

8. ¿Cómo de satisfecho se ha sentido?

Nada satisfecho _____ Extremadamente satisfecho

Un antojo por la comida es un fuerte impulso de comer un alimento o bebida en particular

9. Durante los últimos 7 días, ¿con qué frecuencia ha tenido antojos por la comida?

Nada en absoluto _____ Muy a menudo

10. ¿Cómo de fuerte ha sido cualquier antojo por la comida?

Nada fuerte ——— Extremadamente fuerte

11. ¿Cómo de difícil ha sido resistir los antojos?

Nada difícil ——— Extremadamente difícil

12. ¿Con qué frecuencia ha comido en respuesta a antojos?

Nada ——— Tras cada antojo

¿Con qué frecuencia ha tenido antojos de comida por los siguientes alimentos/bebidas?

13. Chocolate o comidas con sabor a chocolate

Nada ——— Extremadamente a menudo

14. Otros alimentos dulces (tartas, pasteles, galletas, etc.)

Nada ——— Extremadamente a menudo

15. Fruta o zumos de fruta

Nada ——— Extremadamente a menudo

16. Productos lácteos (queso, yogurts, leche, etc.)

Nada ——— Extremadamente a menudo

17. Cereales (pan, arroz, pasta, etc.)

Nada ——— Extremadamente a menudo

18. Alimentos salados (patatas fritas, hamburguesa, pizza, etc.)

Nada ——— Extremadamente a menudo

19. En general, ¿cómo de difícil le ha sido controlar la comida?

Nada difícil ——— Extremadamente difícil

20. ¿Qué alimento es el que más difícil le resulta controlar su ingesta?

.....

21. ¿Cómo de difícil le ha resultado controlar este alimento durante los últimos 7 días?

Nada difícil ——— Extremadamente difícil

DIARIOS DE ACELEROMETRIA

_____

DÍA 1 de de 2015

Hora a la que me despierto: ___horas___ minutos *(Ej.: 8 horas y 10 minutos)*
Hora en la que me quito el acelerómetro:
- Periodo 1: desde___h___min, hasta___h___min. (*Ej.: desde 19 h 23 min, hasta 19 h 49 min)*
- Periodo 2: desde___h___min, hasta___h___min.
- Periodo 3: desde___h___min, hasta___h___min.
- Periodo 4: desde___h___min, hasta___h___min.
- Periodo 5: desde___h___min, hasta___h___min.

Hora a la que me acuesto: ____horas___ minutos *(Ej.: 20 horas y 30 minutos)*
Observaciones:

DÍA 2 de de 2015

Hora a la que me despierto: ___horas___ minutos *(Ej.: 8 horas y 10 minutos)*
Hora en la que me quito el acelerómetro:
- Periodo 1: desde___h___min, hasta___h___min. (*Ej.: desde 19 h 23 min, hasta 19 h 49 min)*
- Periodo 2: desde___h___min, hasta___h___min.
- Periodo 3: desde___h___min, hasta___h___min.
- Periodo 4: desde___h___min, hasta___h___min.
- Periodo 5: desde___h___min, hasta___h___min.

Hora a la que me acuesto: ____horas___ minutos *(Ej.: 20 horas y 30 minutos)*
Observaciones:

DÍA 3 de de 2015

Hora a la que me despierto: ___horas___ minutos *(Ej.: 8 horas y 10 minutos)*
Hora en la que me quito el acelerómetro:
- Periodo 1: desde___h___min, hasta___h___min. (*Ej.: desde 19 h 23 min, hasta 19 h 49 min)*
- Periodo 2: desde___h___min, hasta___h___min.
- Periodo 3: desde___h___min, hasta___h___min.
- Periodo 4: desde___h___min, hasta___h___min.
- Periodo 5: desde___h___min, hasta___h___min.

Hora a la que me acuesto: ____horas___ minutos *(Ej.: 20 horas y 30 minutos)*
Observaciones:

DÍA 4 de de 2015

Hora a la que me despierto: ___horas___ minutos *(Ej.: 8 horas y 10 minutos)*
Hora en la que me quito el acelerómetro:
- Periodo 1: desde___h___min, hasta___h___min. (*Ej.: desde 19 h 23 min, hasta 19 h 49 min)*
- Periodo 2: desde___h___min, hasta___h___min.
- Periodo 3: desde___h___min, hasta___h___min.
- Periodo 4: desde___h___min, hasta___h___min.
- Periodo 5: desde___h___min, hasta___h___min.

Hora a la que me acuesto: ____horas___ minutos *(Ej.: 20 horas y 30 minutos)*
Observaciones:

DÍA 5 de de 2015

Hora a la que me despierto: ___horas___ minutos *(Ej.: 8 horas y 10 minutos)*
Hora en la que me quito el acelerómetro:
- Periodo 1: desde___h___min, hasta___h___min. (*Ej.: desde 19 h 23 min, hasta 19 h 49 min)*
- Periodo 2: desde___h___min, hasta___h___min.
- Periodo 3: desde___h___min, hasta___h___min.
- Periodo 4: desde___h___min, hasta___h___min.
- Periodo 5: desde___h___min, hasta___h___min.

Hora a la que me acuesto: ____horas___ minutos *(Ej.: 20 horas y 30 minutos)*
Observaciones:

DÍA 6 de de 2015

Hora a la que me despierto: ___horas___ minutos *(Ej.: 8 horas y 10 minutos)*
Hora en la que me quito el acelerómetro:
- Periodo 1: desde___h___min, hasta___h___min. (*Ej.: desde 19 h 23 min, hasta 19 h 49 min)*
- Periodo 2: desde___h___min, hasta___h___min.
- Periodo 3: desde___h___min, hasta___h___min.
- Periodo 4: desde___h___min, hasta___h___min.
- Periodo 5: desde___h___min, hasta___h___min.

Hora a la que me acuesto: ____horas___ minutos *(Ej.: 20 horas y 30 minutos)*
Observaciones:

DÍA 7 de de 2015

Hora a la que me despierto: ___horas___ minutos *(Ej.: 8 horas y 10 minutos)*
Hora en la que me quito el acelerómetro:
- Periodo 1: desde___h___min, hasta___h___min. (*Ej.: desde 19 h 23 min, hasta 19 h 49 min)*
- Periodo 2: desde___h___min, hasta___h___min.
- Periodo 3: desde___h___min, hasta___h___min.
- Periodo 4: desde___h___min, hasta___h___min.
- Periodo 5: desde___h___min, hasta___h___min.

Hora a la que me acuesto: ____horas___ minutos *(Ej.: 20 horas y 30 minutos)*
Observaciones:

DÍA 8 de de 2015

Hora a la que me despierto: ___horas___ minutos *(Ej.: 8 horas y 10 minutos)*
Hora en la que me quito el acelerómetro:
- Periodo 1: desde___h___min, hasta___h___min. (*Ej.: desde 19 h 23 min, hasta 19 h 49 min)*
- Periodo 2: desde___h___min, hasta___h___min.
- Periodo 3: desde___h___min, hasta___h___min.
- Periodo 4: desde___h___min, hasta___h___min.
- Periodo 5: desde___h___min, hasta___h___min.

Hora a la que me acuesto: ____horas___ minutos *(Ej.: 20 horas y 30 minutos)*
Observaciones:

IMPORTANTE: Quitar los Acelerómetros el día ___ de _____ a las 12:00

Devolución del acelerómetro: Día ____ de _____de 2015 en _____

8. AGRADECIMIENTOS