Accepted Manuscript

Clustering of multiple energy balance related behaviors is associated with body fat composition indicators in adolescents: Results from the HELENA and ELANA studies

Naiara Ferraz Moreira, Gloria Valeria da Veiga, Alba María Santaliestra-Pasías, Odysseas Androutsos, Magdalena Cuenca-García, Alessandra Silva Dias de Oliveira, Rosangela Alves Pereira, Anelise Bezerra de Vasconcelos de Moraes, Karen Van den Bussche, Laura Censi, Marcela González-Gross, David Cañada, Frederic Gottrand, Anthony Kafatos, Ascensión Marcos, Kurt Widhalm, Dénes Mólnar, Luis Alberto Moreno

PII: S0195-6663(17)31472-1

DOI: 10.1016/j.appet.2017.10.008

Reference: APPET 3640

To appear in: *Appetite*

Received Date: 14 September 2016

Revised Date: 5 October 2017

Accepted Date: 6 October 2017

Title page

Article title:

Clustering of multiple energy balance related behaviors is associated with body fat composition indicators in adolescents: results from the HELENA and ELANA studies

Running title: Clustering of multiple EBRB in adolescents

Authors:

Naiara Ferraz Moreira, Ph.D.[1]; Gloria Valeria da Veiga, Ph.D.[2]; Alba María Santaliestra-Pasías, Ph.D.[3,4]; Odysseas Androutsos, Ph.D.[5]; Magdalena Cuenca-García, Ph.D.[6,7]; Alessandra Silva Dias de Oliveira, Ph.D.[8]; Rosangela Alves Pereira, Ph.D.[2]; Anelise Bezerra de Vasconcelos de Moraes, Ph.D.[2]; Karen Van den Bussche, MSc [9]; Laura Censi, MSc.[10]; Marcela González-Gross, Ph.D.[4,11]; David Cañada[11]; Frederic Gottrand, Ph.D.[12]; Anthony Kafatos, Ph.D.[13]; Ascensión Marcos, Ph.D.[14]; Kurt Widhalm, Ph.D.[15]; Dénes Mólnar, Ph.D.[16]; Luis Alberto Moreno, Ph.D.[3,4].

[1] Faculty of Health Sciences, Federal University of Grande Dourados, Dourados, Brazil.

[2] Department of Social and Applied Nutrition, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil.

[3]GENUD (Growth, Exercise, Nutrition and Development) Research Group, Faculty of Health Sciences, Universidad de Zaragoza, Instituto Agroalimentario de Aragón (IA2), Instituto de Investigación Sanitaria Aragón (IIS Aragón), Zaragoza, Spain.

[4]Centro de Investigación Biomédica en Red de Fisiopatología de la Obesidad y Nutrición (CIBERObn).

[5]Department of Nutrition and Dietetics, School of Health Science & Education, Harokopio University, Athens, Greece.

[6]Department of Physiology, School of Medicine, University of Granada, Granada, Spain.

[7]Department of Physical Education, School of Education, University of Cadiz, Puerto Real, Spain.

[8]Department of Social Nutrition, State University of Rio de Janeiro, Rio de Janeiro, Brazil.

[9]Department of Public Health, Ghent University, Ghent, Belgium.

[10] Council for Agricultural Research and Economics (CREA) - Research Center for Food and Nutrition, Rome, Italy.

[11]ImFINE Research Group, Department of Health and Human Performance, Facultad de Ciencias de la Actividad Física y del Deporte (INEF), Universidad Politécnica de Madrid, Madrid, Spain.

[12]8 Univ. Lille2, CHU Lille, LIRIC-UMR995, Lille, France.

[13] Preventive Medicine and Nutrition Clinic, University of Crete, Heraklion, Greece.

[14]Immunonutrition Research Group, Department of Metabolism and Nutrition, Institute of Food Science, Technology and Nutrition (ICTAN), Spanish National Research Council (CSIC), Madrid, Spain.

[15]Department of Pediatrics, Private Medical University, Salzburg, Austria.

[16] Department of Pediatrics, Medical Faculty, University of Pécs, Pecs, Hungary.

Corresponding author:

Naiara Ferraz Moreira (e-mail: naiaraferraz@ymail.com). Address: Rodovia Dourados / Itahum, Km 12 - Unidade II | Caixa Postal: 364 | Cep: 79.804-970. Telephone number: 55 (67) 3410-232. Dourados – Mato Grosso do Sul – Brasil.

ABSTRACT

The objective of this study was to identify clustering patterns of four energy balance-related behaviors (EBRB): television (TV) watching, moderate and vigorous physical activity (MVPA), consumption of fruits and vegetables (F&V), and consumption of sugar-sweetened beverages (SSB), among European and Brazilian adolescents. EBRB associations with different body fat composition indicators were then evaluated. Participants included adolescents from eight European countries in the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescents) study (n=2,057, 53.8% female; age: 12.5-17.5 years) and from the metropolitan region of Rio de Janeiro/Brazil in the ELANA study (the Adolescent Nutritional Assessment Longitudinal Study) (n=968, 53.2% female; age: 13.5-19 years). EBRB data allowed for sex- and study-specific clusters. Associations were estimated by ANOVA and odds ratios. Five clustering patterns were identified. Four similar clusters were identified for each sex and study. Among boys, different cluster identified was characterized by high F&V consumption in the HELENA study and high TV watching and high MVPA time in the ELANA study. Among girls, the different clusters identified was characterized by high F&V consumption in both studies and, additionally, high SSB consumption in the ELANA study. Regression analysis showed that clusters characterized by high SSB consumption in European boys; high TV watching, and high TV watching plus high MVPA in Brazilian boys; and high MVPA, and high SSB and F&V consumption in Brazilian girls, were positively associated with different body fat composition indicators. Common clusters were observed in adolescents from Europe and Brazil, however, no cluster was identified as being completely healthy or unhealthy. Each cluster seems to impact on body composition indicators, depending on the group. Public health actions should aim to promote adequate practices of EBRB.

BACKGROUND

Although recent findings have shown a stabilization in the prevalence of overweight and obesity among young persons in high-income countries (Rokholm, Baker, & Sorensen, 2010), in low- and middle-income countries (LMIC) the scenario is diverse. In Brazil, the most recent national surveys have shown that, between 2002/2003 and 2008/2009, the prevalence of overweight increased from 16.7% to 21.7% in boys, and from 15.1% to 19.4% in girls (Instituto Brasileiro de Geografia e Estatistica, 2010). Nevertheless, worldwide, obesity prevalence is still unacceptably high (Ogden, Carroll, Kit, & Flegal, 2014; Wolfgang, Moreno, & Pigeot, 2011).

At the individual level, the most important determinant of obesity development is genetic susceptibility. At the population level, energy balance-related behaviors (EBRB) are among the main determinants of the high prevalence of overweight and obesity in children and adolescents (Moreno, Pignot, & Wolfgang, 2011). Among EBRB, there is increased evidence that the following play a key role: increased sedentary behavior, low level of physical activity, low consumption of fruits and vegetables, and high consumption of sugar-sweetened beverages (Malik, Willett, & Hu, 2013; Moreno, et al., 2011). All of these are highly prevalent among adolescents (Diethelm, et al., 2012; Duffey, et al., 2012; Instituto Brasileiro de Geografia e Estatísitica, 2013; Rey-Lopez, et al., 2010; Ruiz, et al., 2011).

Several studies have observed associations between EBRB and obesity in adolescents (Enes & Slater, 2010; Malik, Pan, Willett, & Hu, 2013; Rey-Lopez, Vicente-Rodriguez, Biosca, & Moreno, 2008; Tremblay, et al., 2011) and a number of studies have evaluated the effect of multiple EBRB clustering on body composition, with inconsistent results in children and adolescents (Leech, McNaughton, & Timperio, 2014; Santaliestra-Pasias, et al., 2015). The association between EBRB and body composition could be related to socioeconomic status (SES), demographic, and cultural contexts (Leech, et al., 2014). To the authors' knowledge, there are no studies addressing this relationship using cluster analysis among adolescents in LMIC. Moreover, studies comparing high income countries and LMIC are not found in the majority of commonly used scientific databases. The present study aims to fill this gap by analyzing this association among participants of two studies that collected a similar set of information on EBRB and body composition: the Healthy Lifestyle in Europe by Nutrition in Adolescents (HELENA study), conducted in Europe, and the Adolescent Nutritional Assessment Longitudinal Study (ELANA), conducted in Brazil.

Therefore, the primary aim of this study was to identify the clustering of four EBRB among European and Brazilian adolescents: television (TV) watching, as a sedentary behavior; moderate and vigorous physical activity (MVPA); and consumption of fruits and vegetables (F&V) and of sugar-sweetened beverages (SSB), as dietary behaviors. The secondary aim was to ascertain whether the identified clusters were associated with different body fat composition indicators: body mass index (BMI), body fat percentage (%BF), and waist circumference (WC).

METHODS

Studies design

Data were obtained from two studies, the HELENA study (Europe) and the ELANA (Brazil). The HELENA study is a cross-sectional multicenter study conducted in 2006 and 2007 and involving adolescents between 12.5 and 17.7 years of age from 10 European cities, in nine countries (Austria, Belgium, France, Greece, Germany, Hungary, Italy, Spain, and Sweden). The primary aim of the HELENA study was to obtain data concerning nutritional and lifestyle status of adolescents at a European level (Moreno, Gonzalez-Gross, et al., 2008). Detailed description of the study design and implementation has been published elsewhere (Moreno, De Henauw, et al., 2008). There were 3,865 eligible adolescents for the HELENA study. The final study sample included 3,528 participants (Beghin, et al., 2012). Of these, only participants with complete information regarding TV watching, MVPA, and F&V and SSB consumption were included in the current analysis. A total of 2.057 adolescents that were included in this study as adolescents in some HELENA regions, specifically Pecs in Hungary and Heraklion in Crete, did not complete the 24-hour recall (24HR) due to logistic reasons. Therefore, their dietary intake data was incomplete and these subjects were excluded from the current analysis (Santaliestra-Pasias, et al., 2012). An increased prevalence of overweight was observed among boys included in this study compared to those excluded (data not shown). No differences were observed between girls included and girls excluded from the study (data not shown).

The ELANA is a longitudinal study following up adolescents from two cohorts, the *Middle school cohort* and the *High school cohort*, between 2010 and 2012. Participants attended two public and four private schools in the metropolitan region of Rio de Janeiro, Brazil. This study included data (baseline information) only for the High school cohort, collected in 2010, when adolescents were aged between 13.5 and 19 years. The main aim of the ELANA study was to examine changes in anthropometric indicators of nutritional status, body composition, and its associated factors, in adolescents. Of the 1,131 adolescents meeting the eligibility criteria, 1,039 were included in the ELANA study (Moreira, Sichieri, Reichenheim, Oliveira, & Veiga, 2015). Only participants with complete information on TV watching, MVPA, and F&V and SSB consumption (n=968) were included in the present study. No differences were observed between included and excluded subjects (data not shown).

These studies were conducted according to the guidelines set out in the Declaration of Helsinki and all procedures involving human subjects were approved, before clinical examination was performed, by the appropriate local ethics committees in each of the HELENA study survey centers (Beghin, et al., 2008) and by the Ethics Committee in Research of the Institute of Social Medicine of the State University of Rio de Janeiro. Written informed consent was obtained from the legal guardians of the adolescents involved.

Energy balance-related behaviors

TV watching was used as the most common sedentary behavior showing the strongest association with obesity in adolescents (Rey-Lopez, et al., 2008; Tremblay, et al., 2011). In the HELENA study, TV watching time was obtained by a self-administered questionnaire, asking the following question *"How many hours do you usually spend watching TV?"*. Weekdays and weekends were analyzed separately. Questionnaire answers were categorized according to a seven-point scale and time was expressed in minutes: (i) 0 min; (ii)1–30 min; (iii) 31–60 min, (iv) 61–120 min, (v) 121–180 min, (vi) 181–240 min and (vii) >240 min. The intervals were converted into minutes per day as follows: category 1 = 0 min, 2 = 15 min, 3 = 45 min, 4 = 90 min, 5 = 150 min, 6 = 210 min and 7 = 241 min, respectively. Average daily time spent watching TV, in minutes, was calculated from the daily time during weekdays and weekends, applying the following formula: [(weekdays*5) + (weekend*2)]/7. The reliability of the evaluation of TV watching among European adolescents was good for weekdays (k=0.71) and weekend days (k=0.68) (Rey-Lopez, et al., 2012).

In the ELANA study, TV watching time was also obtained by a self-administered questionnaire, asking two questions. The first question was *"How many days do you watch TV per week?"* Questionnaire answers were categorized according to a five-point scale: (1) almost never or never, (2) 1 to 2 times per week, (3) 3 to 4 times per week, (4) 5 to 6 times per week, and (5) every day. The intervals were converted into days per week as follows: category 1 = 0 days (almost never or never), 2 = 1.5 days, 3 = 3.5 days, 4 = 5.5 days, 5 = 7 days. The second question was *"In general, how many hours do you usually spend watching TV per day?"* Average daily time in minutes was calculated by multiplying "hours per day" by "days per week" according the following formula: [(days per week)*(hours per day)]*60/7.

In both studies, physical activity (PA) was assessed by the self-administered International Physical Activity Questionnaire (IPAQ), taking into account PA over the preceding 7 days. In the HELENA study, IPAQ-A, a validated version for European adolescents, was used, replacing the questions regarding PA at work with questions regarding PA at school (Hagstromer, et al., 2008). In the ELANA study, a short version of the IPAQ questionnaire, previously validated in Brazilian adolescents (2005), was used. In both studies, MVPA was calculated in minutes/day, by the sum of moderate (e.g., bicycling at a regular pace, carrying light loads that spend 4 Metabolic Equivalents - METs) and vigorous (e.g., aerobics, fast bicycling and heavy lifting that spend 8 METs) PA, based on the IPAQ guidelines for data processing and analysis (Patersson, 2005).

In the HELENA study, a validated (Vereecken, et al., 2008) computerized self-administered 24-hours dietary recall, HELENA-DIAT (Dietary Assessment Tool), was applied over two non-consecutive days. The consumption registered with the 24-hours dietary recall was obtained from Sunday to Thursday, which offers the opportunity to include both week and weekend days. The two 24 hour dietary recall included the six meal occasion, *i.e.* the three main meals as breakfast, lunch and dinner, and also three snack moment (mid-morning snack, mid-afternoon snack and after-dinner snack). The adolescents completed the program autonomously in the computer classroom during school time (therefore no data could be collected regarding dietary intake on Fridays and Saturdays), in the presence of fieldworkers to provide assistance, if necessary. In order to calculate energy and nutrient intake, HELENA-DIAT data were linked to the German Food Code and Nutrient Database (Dehne, Klemm, Henseler, & Hermann-Kunz, 1999) (BLS (Bundeslebensmittelschlussel) version II.3.1, 2005). Culture-specific composite dishes were disaggregated into their basic food components, all of which were available in the German database. Usual food and nutrient intakes were estimated by using the Multiple Source Method (MSM) (https://nugo.dife.de/msm/). This calculates food intake for individuals and then generates the population distribution. This method allows for correction of intra-personal and inter-personal variability of dietary data (Ottevaere, Huybrechts, Beghin, et al., 2011). The F&V and SSB consumption in grams per day was obtained, respectively, by the sum of each F&V (excluding potatoes) and SSB (carbonated, soft and isotonic drinks, including non-alcoholic wine and non-alcoholic beer) consumed.

In the ELANA study, a qualitative self-administered food frequency questionnaire (FFQ) with 72 food items was conducted. It was adapted from a validated questionnaire for Brazilian adolescents (Araujo, Yokoo, & Pereira, 2010). Food frequency consumption was evaluated according to an eight-point scale: "(1) less than once a month or never, (2) 1 to 3 times per month, (3) once a week, (4) 2 to 4 times per week, (5) 5 to 6 times per week, (6) once a day, (7) 2 to 3 times per day and (8) 4 or more times a day". These frequencies were converted into times per day, ranging from 0 (never) to 4 times per day, accordingly: 0 (no consumption reported), 0.07, 0.14, 0.43, 0.79, once a day, 2.5, and 4.0 times/day. The portion sizes for F&V and SSB consumption were those used in the FFQ validated by Araujo et al. (2010). Consumption frequencies expressed in times per day were multiplied by the corresponding portion sizes for each item of the groups of

F&V and SSB (carbonated and soft drinks, ready-to-drink (processed) tea, and guarana refreshment (a typical Brazilian beverage). Subsequently, these results were added together to obtain, respectively, the total consumption of F&V and of SSB in grams per day.

Body composition

Height and weight were measured using the same protocol in both studies (Lohman & Martorell, 1988). The adolescents were barefoot and wearing light clothes. Weight was measured using an electronic scale to the nearest 0.1 kg (SECA® 861 in the HELENA study and Kratos® in the ELANA study). The height was measured with a portable stadiometer, to the nearest 0.1 cm (SECA® 225 in the HELENA study and Alturexata® in the ELANA study) with the subject standing fully erect with feet together, head in the Frankfort plane, and arms hanging freely. The BMI was computed using the following formula: weight (kg)/height (m)^2.

For the purposes of the analysis, sex- and age-specific BMI z-scores were computed using WHO reference standards (de Onis, et al., 2007). To classify adolescents as having overweight (including obesity) the international standard definitions (≥1 SD) were used.

The WC, as an indicator of central body fat, was measured using an anthropometric non-elastic tape (SECA® in both studies) to the nearest 0.1 cm. In the HELENA study, WC was measured at the midpoint between the lowest rib and the iliac crest (World Health Organization, 2000) and in the ELANA study it was measured at the narrowest WC (Callaway, Chumlea, Bouchard, Himes, & Lohman, 1988).

To assess body composition, a tetra-polar bioelectrical impedance (BIA) device was used in both studies (101 AKERN SRL® in the HELENA study and RJL System® in the ELANA study). Two current-injector electrodes were positioned on the metacarpal-phalangeal joint of the dorsal surface of the right hand, and on the distal metacarpal-phalangeal joint of the right foot. The fat-free mass (FFM) was estimated from resistance values using validated sex-specific equations (Sun, et al., 2003). The %BF was estimated from the FFM. For this analysis, in both sexes, WC and %BF were transformed into z-scores (standardized residuals) by regression analysis, with age as an independent variable. WC and %BF values were considered high when z-scores were above 1 SD (Verloigne, et al., 2012).

Socioeconomic variables

In the HELENA study, SES was assessed using a modified version of the Family Affluence Scale (FAS) (Currie, et al., 2008). It is an indicator of the material affluence of the adolescents derived from the following questions: whether the adolescent has his/her own room, the number of cars and computers present at home, and internet availability at home. This scale, based on the sum of the aforementioned items, was used in earlier HELENA papers (Ottevaere, Huybrechts, Benser, et al., 2011; Santaliestra-Pasias, et al., 2012) to classify SES as low, medium or high.

In the ELANA study, the type of school (public or private) was used as a proxy for SES. In Brazil, adolescents studying in private schools generally belong to middle and upper SES. The type of school appeared superior to the Brazilian SES classification for the purpose of discriminating between socio-economic levels (Moreira, et al., 2015).

Data analyses

EBRB variables included in the clusters were transformed into sex-specific z-scores. Outliers (> or < 3 SDs) were removed before cluster analysis (Bel-Serrat, et al., 2013; Fernandez-Alvira, et al., 2013; Santaliestra-Pasias, et al., 2015).

A combination of hierarchical and non-hierarchical clustering methods was performed according to sex, as used by our research group in previous studies (Collings, et al., 2014; Cuenca-Garcia, et al., 2013; Fernandez-Alvira, et al., 2013; Ogden, et al., 2014; Ottevaere, Huybrechts, Benser, et al., 2011). The hierarchical procedure was performed using Ward's method, based on the Euclidian distances that identify several possibilities of cluster solutions. The non-hierarchical procedure, a K-means procedure, was performed to better fit the preliminary hierarchical solution. Finally, the stability of the final cluster solution was analyzed by randomly splitting the total sample into two subsamples and applying the full two step procedures to both subsamples. A Cohen's kappa was performed to check for agreement among the clusters in these subsamples and the original. In both studies, agreement was considered excellent because the kappa coefficient was always >0.910.

The ANOVA test and the *post hoc* Bonferroni test were used to investigate differences between age, BMI and EBRB, according to the identified clusters. The Chi-square test was performed to investigate differences in SES among clusters. Logistic regression with an estimation of odds ratios (OR) and a 95% confidence interval (95% CI) was performed to evaluate the associations between the identified clusters and, respectively, overweight, high WC and high %BF, adjusted for the following: total energy intake in both studies, SES in the HELENA study, and type of school in the ELANA study (Moreira, et al., 2015). We chose the odds ratio to measure associations based on the arguments of Pearce (2004).

Statistical analyses were performed using the Predictive Analytic Software (PASW) for Windows (SPSS version 19.0 SPSS Inc., Chicago, IL, USA).

RESULTS

Table 1 presents descriptive information of the adolescents participating in the HELENA and ELANA studies. About 54% of the adolescents in both studies were female, 68.9% of HELENA adolescents and 48.7% ELANA adolescents were under 15.5 years of age. The majority of the adolescents in the HELENA study were of medium (42.8%) and high (34.2%) SES and in the ELANA study, 50.6% of adolescents studied in private schools. In both studies, approximately 18% of adolescents were overweight. Obesity prevalence was 7.1% in the HELENA study and 8.2% in the ELANA study.

Cluster analysis resulted in a five-cluster solution as the most appropriate for the identification of EBRB among the four groups (European boys, Brazilian boys, European girls and Brazilian girls) (Figure 1). Among boys, clusters 1 to 3, and 5, were similar in both studies whereas cluster 4 showed different behaviors in Europe and Brazil (Figure 1.a and Table 2). Cluster 1 (C1) was characterized by high TV watching time and low MVPA time; cluster 2 (C2) was characterized by high SSB consumption; and cluster 3 (C3) was characterized by high MVPA time and low TV watching time. Cluster 4 (C4) was characterized by healthy diet pattern (the highest F&V and the lowest SSB consumption) and low TV watching time and low MVPA time in the HELENA study. However, in the ELANA study, C4 was characterized by the highest TV watching time, and the highest MVPA time. In both studies, cluster 5 (C5) was characterized by low TV watching time, low MVPA time, and low F&V and SSB consumption.

Among girls, clusters also showed similarities in both studies (Figure 1.b and Table 3). C1 was largely characterized by high TV watching time and low MVPA time; C2 was characterized by the highest SSB consumption and low MVPA time; C3 was characterized by high MVPA time; and C4 was characterized by high F&V consumption, whereas in Brazilian girls this cluster presented high SSB consumption; and C5 was characterized by low TV watching time, MVPA time, F&V and SSB consumption.

Tables 2 and 3 also showed some SES and demographic characteristics for each cluster. Among boys, in the HELENA study, adolescents in C3 had the lowest mean age and significant difference in SES percentage (among the five clusters). In the ELANA study, boys in C2 had the lowest BMI mean values (Table 2). Among girls in the HELENA study, a significant difference in age mean (the lowest value was observed in C3) and SES percentage (among the five clusters) was found. In the ELANA study, girls in C4 had a higher mean age than girls in other clusters and 76.7% studied in public schools (Table 3).

Associations among the identified clusters and body fat composition indicators (overweight, WC, and %BF z-scores >1) are shown in Table 4. C5 is regarded as the reference category, because this cluster was present in all groups. Among European boys, C2 was associated with a high WC

(OR: 2.32; 95%CI: 1.22-4.43) and high %BF (OR: 2.07; 95%CI: 1.09-3.93). Among Brazilian boys, C1 was associated with a high WC (OR: 2.16; 95%CI: 1.03-4.52) and a high %BF (OR: 2.21; 95%CI: 1.14-4.30) while C4 was associated with a high WC (OR: 3.64; 95% CI: 1.25-10.62). Brazilian girls in C3 and C4 showed a positive association with a higher BMI (OR: 2.19 and 2.89, respectively).

DISCUSSION

In European and Brazilian adolescents, five EBRB clusters were identified according to sex, and by combining four behaviors (TV watching time, MVPA time, F&V consumption, and SSB consumption). Clusters C1, C2, C3, and C5 were very similar in boys from both studies. However, C4 was characterized by a high F&V consumption in European boys and high TV watching time and high MVPA time in Brazilian boys. All clusters showed similar characteristics in girls from both studies, except for C4, that in Brazilian girls, besides being characterized by high F&V consumption, as well as in European girls, was also characterized by high SSB consumption.

The main finding of our study is that all clusters were associated with body fat composition indicators. However, this association depends on the location of the study and on the sex of participants. A cluster characterized by high TV watching time and low MVPA time (C1) was positively associated with higher WC and %BF z-scores in Brazilian boys. A cluster characterized by high SSB consumption (C2) was positively associated with a higher WC z-score in European boys. C3, characterized by high MVPA time, presented a positive association with BMI in Brazilian girls. In boys, C4 was characterized by high TV watching time, high MVPA time, and low F&V consumption while in girls, it was characterized by high F&V and SSB consumption. Of note, C4 was positively associated with body composition only in Brazilian adolescents and specifically, increased WC in boys and increased BMI in girls.

Some studies have evaluated the effect of clustering of multiple EBRB on BMI and weight status in adolescents. These identified three to seven clusters (Fernandez-Alvira, et al., 2013; Leech, et al., 2014). In our study, we identified five clusters, among boys and girls, as the most appropriate to characterize the clustering of EBRB. To the best of our knowledge, this is the first study identifying clusters of EBRB in two different populations of adolescents, and assessing their relationship with body fat composition indicators.

In a review, Leech et al.(2014) performed cluster analysis with the same behaviors analyzed in this study and found out that sedentary behavior and PA contribute to the characterization of clusters more strongly than food consumption. However, in our study, both dietary and PA variables contributed to the characterization of the identified clusters with the exception of F&V

consumption in Brazilian boys, characterized by low values among all identified clusters (Figure 1.a).

The estimated EBRB mean values per cluster revealed that Brazilian adolescents spent more time watching TV, less time doing MVPA, and consumed more SSB than European adolescents. This is particularly relevant for MVPA. For example, on average, European boys from C3, characterized by higher MVPA practices, performed, on average, 251.2 min/day of MVPA while boys from Brazil, performed on average MVPA of 151.7 min/day. Among girls, time spent performing MVPA was 205.6 min/day in Europe and 114.8 min/day in Brazil.

A common characteristic of European and Brazilian adolescents was that no cluster was characterized by a healthy score across all EBRB. These results corroborate those of comparable studies (Fernandez-Alvira, et al., 2013; Leech, et al., 2014). Therefore, it seems that exhibiting one specific healthy behavior does not always involve healthy behavior across all categories. For instance, high MVPA levels and high TV watching time characterized Brazilian boys from C4. This was also observed in studies where high levels of PA coexisted with high levels of sedentary behavior (Santaliestra-Pasias, et al., 2015; Seghers & Rutten, 2010; Turner, Dwyer, Edwards, & Allison, 2011) or a poorer diet (Cuenca-Garcia, et al., 2013). These findings highlight the complex relationship between the different EBRB.

The most important goal of this study was to examine whether the identified clusters were associated with body fat composition indicators. One potential confounding factor is the SES level. Some studies found associations between SES and clusters of some lifestyle behaviors, showing that unhealthy clusters were more likely to occur in low SES individuals (Leech, et al., 2014). This has been previously shown in the HELENA study (Ottevaere, Huybrechts, Benser, et al., 2011). In European adolescents, we observed a significant association between SES and the five identified clusters for both sexes and, in the ELANA study, school type (public or private), a proxy of SES, was associated with EBRB clusters in girls. In general, the association between prevalence of obesity and SES is inverse in high income countries and direct in LMIC (Wang & Lim, 2012) as is the case for Brazil. However, recent studies have shown changes in these patterns in LMIC (Dinsa, Goryakin, Fumagalli, & Suhrcke, 2012; Popkin, Adair, & Ng, 2012). In view of the association between obesity and, respectively, SES and EBRB, we assessed the association between EBRB clusters and body fat composition indicators, adjusting by SES.

C1, mainly characterized by high TV watching time, was positively associated with high WC and high %BF in Brazilian boys. This supports the majority of studies assessing the association between TV watching and obesity in adolescents (Tremblay, et al., 2011), as well as those studies evaluating EBRB clusters characterized by high sedentary time (Leech, et al., 2014). Despite the significant associations observed in our study, it is surprising not to find more associations with the other body composition indicators in the others adolescent group. However, some multiple EBRB clustering studies, including sedentary behavior, have also observed no association with overweight and obesity (Leech, et al., 2014).

C2, characterized by high SSB consumption, was associated with a high WC and a high %BF in European boys. SSB consumption is considered a risk factor for obesity, particularly for children and other adolescents groups (Hu, 2013). Our results require corroboration by future studies, as three of the subgroups studied (both Brazilian adolescents and European girls) did not show significant associations. The lack of significant associations in these subgroups could be explained by the fact that the association between food intake and overweight was linked to F&V and SSB consumption, as well as to the consumption of other food groups and to other lifestyle characteristics, which were not evaluated in this study.

C3, characterized by high levels of MVPA, was positively related to overweight in Brazilian girls. This result was unexpected, as the majority of studies find an inverse association between MVPA and overweight (Malik, Willett, et al., 2013; Rauner, Mess, & Woll, 2013). In general, studies only consider BMI to assess body composition. If this applied to our study, we could explain the findings in terms of the high FFM levels. Nevertheless, we were also able to measure other indicators of total and abdominal obesity. In our study, we only considered four EBRB supposedly associated with obesity. Nevertheless, adolescents could be exposed to other behaviors (e.g. internet/computer and studying/homework time) not considered in our study, as this information was not available from the two studies. Additionally, sedentary behavior is not a key characteristic of C3, however, among Brazilian girls from C3, the mean TV watching time was 147.4 min/day, whereas for those classified as C5 (reference group), it was 77.7 min/day. This difference could explain, at least in part, our results, as excess TV watching could counter balance the protective effect of PA (Ghavamzadeh, Khalkhali, & Alizadeh, 2013). In addition, Leech et al.(2014), have also reported that some studies found an unexpected inverse association between BMI and unhealthy clusters, confirming the complexity of these associations.

C4, characterized by high TV watching and high MVPA time in Brazilian boys and by high F&V and SSB consumption in Brazilian girls, was positively associated with body composition indicators. Brazilian boys from C4 presented an increased mean TV watching time (240 min/day), compared to that observed in C1 (232.1 min/day). Among Brazilian girls in C4, mean values for F&V and SSB consumption were greater than those in the remaining three groups, showing an elevated consumption of food, irrespective of whether the food consumed was healthy or unhealthy.

This study has some limitations. The cross-sectional design provides evidence for some associations, but causality could not always be established. As we observed more significant results among Brazilian adolescents, and the ELANA is a longitudinal study, in future we could add more information on this issue. In our study, the only sedentary behavior taken into account was TV watching. This could underestimate the effect of sedentary behavior, as other types of behavior, such as video game use, reading and homework, and computer/internet use, were not considered in order to compare both studies. However, the time spent in front of the TV was the dominant sedentary behavior during leisure time in youth, specially at the moment that both studies were developed (HELENA 2007, ELANA 2010) (Kaiser Family Foundation, 2010; Rey-Lopez, et al., 2010) and has been shown as the behavior with the strongest association with overweight (Ghavamzadeh, et al., 2013; Tremblay, et al., 2011). Furthermore, we did not use an objective method, such as accelerometers or pedometers, to capture MVPA and these could potentially obtain more accurate MVPA results. However, the questionnaires used in both studies were previously validated. The HELENA and ELANA studies were not designed to use the same methods. The methods to assess sedentary behavior, PA, and body composition were very similar. Even the variables included in the cluster analysis were the same in the HELENA and the ELANA studies, we cannot exclude the results may be different because of differences in the dietary assessment methods and in the beverage components of the “SSB” group. A consensus on the definition of SSB is required in order to be comparable between studies. A further important point to be noted is that only participants with complete information on EBRB were included in the current analysis. Even though the variables differences were evaluated between subjects with and without EBRB information and only European boys presented differences in BMI we cannot exclude the possibility that the results could be influenced by this difference. Additionally, in ELANA study the sexual maturation was not investigated. Therefore, the biological age was taking into account to adjust the analysis in order to compare the results between the two studies.

A strength of the present study was the identification of the clusters and of the association with total and central body fat indicators in adolescents living in different geographical areas and exposed to different lifestyle behaviors. Furthermore, cluster analysis is a convenient method for the identification of groups with similar behavior patterns. This could be helpful to develop tailored strategies for obesity prevention.

CONCLUSION

According to our results, no cluster was identified as being entirely healthy or unhealthy, showing the complexity of the relationship among EBRB in adolescents. All clusters evaluated in this study seem to have an impact on body composition indicators, depending on the group. The unexpected positive association with anthropometric indicators in the cluster characterized by high MVPA could be explained by the concomitant high levels of TV watching in the same cluster. Although these results contribute to better understanding of the EBRB among adolescents, further studies are necessary, taking gender differences into account, to develop health promotion programs.

Sources of funding and acknowledgements of support and assistance:

Sources of funding: The HELENA study was funded by the European Community Sixth RTD Framework Programmed (Contract FOOD-CT: 2005-007034), partially supported by the Spanish Ministry of Health, Maternal, Child Health and Development Network (number RD08/0072) (AMS-P, LAM). The content of this paper reflects only the authors' views and the remaining HELENA study members and the European Community are not liable for any use that may be made of the information contained therein. The ELANA study was funded by the National Council for Scientific and Technological Development (CNPq, grant 47667/2011-9), the Research Support Foundation of the State of Rio de Janeiro (FAPERJ, grants E26/110.847/2009, E-26/110.626/2011, and E-26/110.774/2013), and Coordination for the Improvement of Higher Education Personnel (CAPES, grant 23038.007702/2011-5).

Competing Interests: The authors have declared that no competing interests exist.

Contribution of each author to the manuscript: Conceived and designed the HELENA study: Luis Alberto Moreno, Marcela González Gross, Frederic Gottrand, Antonios Kafatos, Ascencion Marcos, Kurt Widhalm, and Denes Molnar. Conceived and designed the ELANA study: Gloria Valeria da Veiga and Rosangela Alves Pereira. Article concept, design/analysis, and interpretation of data/drafting of the manuscript: Naiara Ferraz Moreira, Alba María Santaliestra-Pasías, Gloria Valeria da Veiga and Luis Alberto Moreno. Critical revision of the manuscript for important intellectual content: Gloria Valeria da Veiga, Odysseas Androutsos, Magdalena Cuenca-García, Alessandra Silva Dias de Oliveira, Rosangela Alves Pereira, Anelise Bezerra de Vasconcelos de Moraes, Karen Van den Bussche, Laura Censi, David Cañada, Marcela González Gross, Frederic Gottrand, Antonios Kafatos, Ascencion Marcos, Kurt Widhalm, Denes Molnar, Luis Alberto Moreno. Statistical analysis: Naiara Ferraz Moreira, Alba María Santaliestra-Pasías.

Ethical information*:* The HELENA study was approved by the Ethical Committee of each city involved. The ELANA study was approved by the Ethics Committee in Research of the Institute of

Social Medicine of the State University of Rio de Janeiro (certificate number 0020.0.259.000-09). A signed informed consent was obtained from the parents of the adolescents in both studies. For further information regarding ethical issues in the HELENA study (Béghin L, Castera M, Manios Y, et al.; HELENA Study Group. Quality assurance of ethical issues and regulatory aspects relating to good clinical practices in the HELENA Cross-Sectional Study. Int J Obes (Lond) 2008;32:S12–18).

The authors thank all the adolescents who took part in the HELENA and ELANA studies.

REFERENCES

Araujo, M. C., Yokoo, E. M., & Pereira, R. A. (2010). Validation and calibration of a semiquantitative food frequency questionnaire designed for adolescents. *J Am Diet Assoc, 110*, 1170-1177.

Beghin, L., Castera, M., Manios, Y., Gilbert, C. C., Kersting, M., De Henauw, S., Kafatos, A., Gottrand, F., Molnar, D., Sjostrom, M., Leclercq, C., Widhalm, K., Mesana, M. I., Moreno, L. A., & Libersa, C. (2008). Quality assurance of ethical issues and regulatory aspects relating to good clinical practices in the HELENA Cross-Sectional Study. *Int J Obes (Lond), 32 Suppl 5*, S12-18.

Beghin, L., Huybrechts, I., Vicente-Rodriguez, G., De Henauw, S., Gottrand, F., Gonzales-Gross, M., Dallongeville, J., Sjostrom, M., Leclercq, C., Dietrich, S., Castillo, M., Plada, M., Molnar, D., Kersting, M., Gilbert, C. C., & Moreno, L. A. (2012). Main characteristics and participation rate of European adolescents included in the HELENA study. *Arch Public Health, 70*, 14.

Bel-Serrat, S., Mouratidou, T., Santaliestra-Pasias, A. M., Iacoviello, L., Kourides, Y. A., Marild, S., Molnar, D., Reisch, L., Siani, A., Stomfai, S., Vanaelst, B., Veidebaum, T., Pigeot, I., Ahrens, W., Krogh, V., & Moreno, L. A. (2013). Clustering of multiple lifestyle behaviours and its association to cardiovascular risk factors in children: the IDEFICS study. *Eur J Clin Nutr, 67*, 848-854.

Callaway, C. W., Chumlea, W. C., Bouchard, C., Himes, J. H., & Lohman, T. G. (1988). *Circumferences.*: Champaign: Human Kinetics Book.

Collings, P. J., Wijndaele, K., Corder, K., Westgate, K., Ridgway, C. L., Dunn, V., Goodyer, I., Ekelund, U., & Brage, S. (2014). Levels and patterns of objectively-measured physical activity volume and intensity distribution in UK adolescents: the ROOTS study. *Int J Behav Nutr Phys Act, 11*, 23.

Cuenca-Garcia, M., Huybrechts, I., Ruiz, J. R., Ortega, F. B., Ottevaere, C., Gonzalez-Gross, M., Moreno, L. A., Vicente-Rodriguez, G., Molnar, D., Polito, A., Manios, Y., Plada, M., Vanhelst, J., Widhalm, K., Sjostrom, M., Kersting, M., & Castillo, M. J. (2013). Clustering of multiple lifestyle behaviors and health-related fitness in European adolescents. *J Nutr Educ Behav, 45*, 549-557.

Currie, C., Molcho, M., Boyce, W., Holstein, B., Torsheim, T., & Richter, M. (2008). Researching health inequalities in adolescents: the development of the Health Behaviour in School-Aged Children (HBSC) family affluence scale. *Soc Sci Med, 66*, 1429-1436.

de Onis, M., Onyango, A. W., Borghi, E., Siyam, A., Nishida, C., & Siekmann, J. (2007). Development of a WHO growth reference for school-aged children and adolescents. *Bull World Health Organ, 85*, 660-667.

Dehne, L. I., Klemm, C., Henseler, G., & Hermann-Kunz, E. (1999). The German Food Code and Nutrient Data Base (BLS II.2). *Eur J Epidemiol, 15*, 355-359.

Diethelm, K., Jankovic, N., Moreno, L. A., Huybrechts, I., De Henauw, S., De Vriendt, T., Gonzalez-Gross, M., Leclercq, C., Gottrand, F., Gilbert, C. C., Dallongeville, J., Cuenca-Garcia, M., Manios, Y., Kafatos, A., Plada, M., & Kersting, M. (2012). Food intake of European adolescents in the light of different food-based dietary guidelines: results of the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) Study. *Public Health Nutr*, *15*, 386-398.

Dinsa, G. D., Goryakin, Y., Fumagalli, E., & Suhrcke, M. (2012). Obesity and socioeconomic status in developing countries: a systematic review. *Obes Rev*, *13*, 1067-1079.

Duffey, K. J., Huybrechts, I., Mouratidou, T., Libuda, L., Kersting, M., De Vriendt, T., Gottrand, F., Widhalm, K., Dallongeville, J., Hallstrom, L., Gonzalez-Gross, M., De Henauw, S., Moreno, L. A., & Popkin, B. M. (2012). Beverage consumption among European adolescents in the HELENA study. *Eur J Clin Nutr*, *66*, 244-252.

Enes, C. C., & Slater, B. (2010). [Obesity in adolescence and its main determinants]. *Rev Bras Epidemiol*, *13*, 163-171.

Fernandez-Alvira, J. M., De Bourdeaudhuij, I., Singh, A. S., Vik, F. N., Manios, Y., Kovacs, E., Jan, N., Brug, J., & Moreno, L. A. (2013). Clustering of energy balance-related behaviors and parental education in European children: the ENERGY-project. *Int J Behav Nutr Phys Act*, *10*, 5.

Ghavamzadeh, S., Khalkhali, H. R., & Alizadeh, M. (2013). TV viewing, independent of physical activity and obesogenic foods, increases overweight and obesity in adolescents. *J Health Popul Nutr*, *31*, 334-342.

Guedes, D. P., Lopes, C. C., & Guedes, J. E. R. P. (2005). Reprodutibilidade e validade do questionário internacional de atividade física em adolescentes. *Rev Bras Med Esporte*, *11*, 151-158.

Hagstromer, M., Bergman, P., De Bourdeaudhuij, I., Ortega, F. B., Ruiz, J. R., Manios, Y., Rey-Lopez, J. P., Phillipp, K., von Berlepsch, J., & Sjostrom, M. (2008). Concurrent validity of a modified version of the International Physical Activity Questionnaire (IPAQ-A) in European adolescents: The HELENA Study. *Int J Obes (Lond)*, *32 Suppl 5*, S42-48.

Hu, F. B. (2013). Resolved: there is sufficient scientific evidence that decreasing sugar-sweetened beverage consumption will reduce the prevalence of obesity and obesity-related diseases. *Obes Rev*, *14*, 606-619.

Instituto Brasileiro de Geografia e Estatísitica. (2013). National Adolescent School-based Health Survey (2012). In. Rio de Janeiro: Instituto Brasileiro de Geografia e Estatística.

Instituto Brasileiro de Geografia e Estatistica. (2010). National Household Budget Survey: 2008/2009. Anthropometry and nutritional status of children, adolescents and adults in Brazil. In. Rio de Janeiro: Instituto Brasileiro de Geografia e Estatistica.

Kaiser Family Foundation. (2010). Generation M: media in the lives of 8-18-year-olds. The Henry J. Kaser Family Foundation. Available from: http://kff.org/entmedia/mh012010pkg.cfm.

Leech, R. M., McNaughton, S. A., & Timperio, A. (2014). The clustering of diet, physical activity and sedentary behavior in children and adolescents: a review. *Int J Behav Nutr Phys Act*, *11*, 4.

Lohman, T. G. R. A., & Martorell, R. (1988). *Anthropometric Standardization Reference Manual*. Champaign, Illinois.

Malik, V. S., Pan, A., Willett, W. C., & Hu, F. B. (2013). Sugar-sweetened beverages and weight gain in children and adults: a systematic review and meta-analysis. *Am J Clin Nutr*, *98*, 1084-1102.

Malik, V. S., Willett, W. C., & Hu, F. B. (2013). Global obesity: trends, risk factors and policy implications. *Nat Rev Endocrinol*, *9*, 13-27.

Moreira, N. F., Sichieri, R., Reichenheim, M. E., Oliveira, A. S., & Veiga, G. V. (2015). The associations of BMI trajectory and excessive weight gain with demographic and socioeconomic factors: the Adolescent Nutritional Assessment Longitudinal Study cohort. *Br J Nutr, 114*, 2032-2038.

Moreno, L. A., De Henauw, S., Gonzalez-Gross, M., Kersting, M., Molnar, D., Gottrand, F., Barrios, L., Sjostrom, M., Manios, Y., Gilbert, C. C., Leclercq, C., Widhalm, K., Kafatos, A., & Marcos, A. (2008). Design and implementation of the Healthy Lifestyle in Europe by Nutrition in Adolescence Cross-Sectional Study. *Int J Obes (Lond), 32 Suppl 5*, S4-11.

Moreno, L. A., Gonzalez-Gross, M., Kersting, M., Molnar, D., de Henauw, S., Beghin, L., Sjostrom, M., Hagstromer, M., Manios, Y., Gilbert, C. C., Ortega, F. B., Dallongeville, J., Arcella, D., Warnberg, J., Hallberg, M., Fredriksson, H., Maes, L., Widhalm, K., Kafatos, A. G., & Marcos, A. (2008). Assessing, understanding and modifying nutritional status, eating habits and physical activity in European adolescents: the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) Study. *Public Health Nutr, 11*, 288-299.

Moreno, L. A., Pignot, I., & Wolfgang, A. (2011). Chidhood Obesity: Etiology - Synthesis Part II. In P. I. Moreno LA, Ahrens W, eds. (Ed.), *Epidemiology of Obesity in Children and Adolescents: Prevalence and Etiology*. New York, NY: Springer Science.

Ogden, C. L., Carroll, M. D., Kit, B. K., & Flegal, K. M. (2014). Prevalence of childhood and adult obesity in the United States, 2011-2012. *JAMA, 311*, 806-814.

Ottevaere, C., Huybrechts, I., Beghin, L., Cuenca-Garcia, M., De Bourdeaudhuij, I., Gottrand, F., Hagstromer, M., Kafatos, A., Le Donne, C., Moreno, L. A., Sjostrom, M., Widhalm, K., & De Henauw, S. (2011). Relationship between self-reported dietary intake and physical activity levels among adolescents: the HELENA study. *Int J Behav Nutr Phys Act, 8*, 8.

Ottevaere, C., Huybrechts, I., Benser, J., De Bourdeaudhuij, I., Cuenca-Garcia, M., Dallongeville, J., Zaccaria, M., Gottrand, F., Kersting, M., Rey-Lopez, J. P., Manios, Y., Molnar, D., Moreno, L. A., Smpokos, E., Widhalm, K., & De Henauw, S. (2011). Clustering patterns of physical activity, sedentary and dietary behavior among European adolescents: The HELENA study. *BMC Public Health, 11*, 328.

Patterson E. (2005). Guidelines for data processing and analysis of the international physical activity questionnaire – IPAQ (GDPA-IPAQ). Available at: http:// www.ipaq.ki.se/scoring.pdf Accessed Nov 9 2014.

Pearce N. (2004). Effect measures in prevalence studies. *Environ Health Perspect, 112*, 1047-50.

Popkin, B. M., Adair, L. S., & Ng, S. W. (2012). Global nutrition transition and the pandemic of obesity in developing countries. *Nutr Rev, 70*, 3-21.

Rauner, A., Mess, F., & Woll, A. (2013). The relationship between physical activity, physical fitness and overweight in adolescents: a systematic review of studies published in or after 2000. *BMC Pediatr, 13*, 19.

Rey-Lopez, J. P., Ruiz, J. R., Ortega, F. B., Verloigne, M., Vicente-Rodriguez, G., Gracia-Marco, L., Gottrand, F., Molnar, D., Widhalm, K., Zaccaria, M., Cuenca-Garcia, M., Sjostrom, M., De Bourdeaudhuij, I., & Moreno, L. A. (2012). Reliability and validity of a screen time-based sedentary behaviour questionnaire for adolescents: The HELENA study. *Eur J Public Health, 22*, 373-377.

Rey-Lopez, J. P., Vicente-Rodriguez, G., Biosca, M., & Moreno, L. A. (2008). Sedentary behaviour and obesity development in children and adolescents. *Nutr Metab Cardiovasc Dis, 18*, 242-251.

Rey-Lopez, J. P., Vicente-Rodriguez, G., Ortega, F. B., Ruiz, J. R., Martinez-Gomez, D., De Henauw, S., Manios, Y., Molnar, D., Polito, A., Verloigne, M., Castillo, M. J., Sjostrom, M., De Bourdeaudhuij, I., & Moreno, L. A. (2010). Sedentary patterns and media availability in European adolescents: The HELENA study. *Prev Med, 51*, 50-55.

Rokholm, B., Baker, J. L., & Sorensen, T. I. (2010). The levelling off of the obesity epidemic since the year 1999--a review of evidence and perspectives. *Obes Rev, 11*, 835-846.

Ruiz, J. R., Ortega, F. B., Martinez-Gomez, D., Labayen, I., Moreno, L. A., De Bourdeaudhuij, I., Manios, Y., Gonzalez-Gross, M., Mauro, B., Molnar, D., Widhalm, K., Marcos, A., Beghin, L., Castillo, M. J., & Sjostrom, M. (2011). Objectively measured physical activity and sedentary time in European adolescents: the HELENA study. *Am J Epidemiol, 174*, 173-184.

Santaliestra-Pasias, A. M., Mouratidou, T., Reisch, L., Pigeot, I., Ahrens, W., Marild, S., Molnar, D., Siani, A., Sieri, S., Tornatiris, M., Veidebaum, T., Verbestel, V., De Bourdeaudhuij, I., & Moreno, L. A. (2015). Clustering of lifestyle behaviours and relation to body composition in European children. The IDEFICS study. *Eur J Clin Nutr*, *69*, 811-816.

Santaliestra-Pasias, A. M., Mouratidou, T., Verbestel, V., Huybrechts, I., Gottrand, F., Le Donne, C., Cuenca-Garcia, M., Diaz, L. E., Kafatos, A., Manios, Y., Molnar, D., Sjostrom, M., Widhalm, K., De Bourdeaudhuij, I., & Moreno, L. A. (2012). Food consumption and screen-based sedentary behaviors in European adolescents: the HELENA study. *Arch Pediatr Adolesc Med, 166*, 1010-1020.

Seghers, J., & Rutten, C. (2010). Clustering of multiple lifestyle behaviours and its relationship with weight status and cardiorespiratory fitness in a sample of Flemish 11- to 12-year-olds. *Public Health Nutr, 13*, 1838-1846.

Sun, S. S., Chumlea, W. C., Heymsfield, S. B., Lukaski, H. C., Schoeller, D., Friedl, K., Kuczmarski, R. J., Flegal, K. M., Johnson, C. L., & Hubbard, V. S. (2003). Development of bioelectrical impedance analysis prediction equations for body composition with the use of a multicomponent model for use in epidemiologic surveys. *Am J Clin Nutr, 77*, 331-340.

Tremblay, M. S., LeBlanc, A. G., Kho, M. E., Saunders, T. J., Larouche, R., Colley, R. C., Goldfield, G., & Connor Gorber, S. (2011). Systematic review of sedentary behaviour and health indicators in school-aged children and youth. *Int J Behav Nutr Phys Act, 8*, 98.

Turner, K., Dwyer, J. J., Edwards, A. M., & Allison, K. R. (2011). Clustering of specific health-related behaviours among Toronto adolescents. *Can J Diet Pract Res, 72*, e155-160.

Vereecken, C. A., Covents, M., Sichert-Hellert, W., Alvira, J. M., Le Donne, C., De Henauw, S., De Vriendt, T., Phillipp, M. K., Beghin, L., Manios, Y., Hallstrom, L., Poortvliet, E., Matthys, C., Plada, M., Nagy, E., & Moreno, L. A. (2008). Development and evaluation of a self-administered computerized 24-h dietary recall method for adolescents in Europe. *Int J Obes (Lond), 32 Suppl 5*, S26-34.

Verloigne, M., Van Lippevelde, W., Maes, L., Yildirim, M., Chinapaw, M., Manios, Y., Androutsos, O., Kovacs, E., Bringolf-Isler, B., Brug, J., & De Bourdeaudhuij, I. (2012). Levels of physical activity and sedentary time among 10- to 12-year-old boys and girls across 5 European countries using accelerometers: an observational study within the ENERGY-project. *Int J Behav Nutr Phys Act, 9*, 34.

Wang, Y., & Lim, H. (2012). The global childhood obesity epidemic and the association between socio-economic status and childhood obesity. *Int Rev Psychiatry, 24*, 176-188.

Wolfgang, A., Moreno, L. A., & Pigeot, I. (2011). Childhood Obesity: Prevalence Worldwide - Synthesis Part I. In P. I. Moreno LA, Ahrens W, eds. (Ed.), *Epidemiology of Obesity in Children and Adolescents: Prevalence and Etiology*. New York, NY: Springer Science.

World Health Organization. (2000). Obesity: preventing and managing the global epidemic. Report of a WHO Consultation In. Geneva.

Table 1. Characteristics of adolescents' participants in HELENA and ELANA studies.

	HELENA (N=2.057)		ELANA (N=968)	
	% (n)	**IC95**	**% (n)**	**IC95**
Sex				
Male	46.2 (950)	44.0 – 48.3	46.8 (453)	43.6 – 49.9
Female	53.8 (1107)	51.6 – 55.9	53.2 (515)	50.6 – 56.3
Age				
Younger (<15.5 years)	68.8 (1415)	66.8 – 70.8	48.7 (471)	45.5 – 51.8
Older (≥15.5 years)	31.2 (642)	29.2 – 33.2	51.3 (497)	48.1 – 54.4
SES*				
Low	23.0 (472)	21.1 – 24.8	–	–
Medium	42.8 (881)	40.6 – 44.9	–	–
High	34.2 (703)	32.1 – 36.2	–	–
Type of school attended**				
Public	–	–	49.4 (478)	46.2 – 52.5
Private	–	–	50.6 (490)	47.4 – 53.7
Weight Status***				
Underweight	1.2 (25)	0.7 – 1.6	1.5 (14)	0.7 – 2.2
Normal weight	73.3 (1508)	71.3 – 75.2	71.9 (681)	69.0 – 74.7
Overweight	18.3 (377)	16.6 – 19.9	18.4 (174)	15.9 – 20.8
Obesity	7.1 (147)	5.9 – 8.2	8.2 (78)	6.4 – 9.9

* Missing for 1 adolescents in HELENA; **Proxy of SES classification used in Brazilian adolescents; ***Missing for 21 adolescents in ELANA

Table 2 Main characteristics of boys participating in the HELENA and ELANA studies, according to the identified clusters

HELENA study – (n=950)	**Cluster 1** (n=178; 18.7%)	**Cluster 2** (n=110; 11.6%)	**Cluster 3** (n=189; 19.6%)	**Cluster 4** (n=168; 17.7%)	**Cluster 5** (n=308; 32.4%)	**P-value**
Age X (±SD)	14.8 (1.3)[ac]	15.1 (1.1)[a]	14.4 (1.1)[b]	14.8 (1.2)[ac]	14.6 (1.2)[bc]	<0.05
Television watching (min/day) X (±SD)	208.4 (42.6)[a]	132.6 (57.5)[b]	97.4 (53.0)[c]	74.6 (41.8)[d]	75.8 (34.7)[d]	<0.05
Moderate and vigorous physical activity (min/day) X (±SD)	76.7 (58.6)[ad]	93.4 (64.9)[ac]	251.2 (57.2)[b]	94.1 (52.9)[c]	72.8 (44.7)[d]	<0.05
Fruits and vegetables consumption (g/day) X (±SD)	173.9 (91.7)[a]	154.4 (83.4)[ad]	219.8 (111.1)[b]	373.1 (85.3)[c]	143.3 (59.6)[d]	<0.05
Sugar sweetened beverages consumption (g/day) X (±SD)	325.0 (224.6)[a]	944.4 (327.7)[b]	328.9 (265.1)[a]	222.9 (207.1)[c]	245,1 (184.6)[c]	<0.05
BMI (kg/m^2) X (±SD)	21.7 (4.2)	21.5 (4.7)	21.2 (3.6)	20.8 (3.5)	21.1 (3.5)	0.17
SES (Low/medium/high) (%)	32.8/41.2/26.0	20.9/36.4/42.7	21.0/39.8/39.2	10.7/56.5/32.7	21.4/42.2/36.4	<0.05

ELANA – (n=453)	**Cluster 1** (n=160; 35.3%)	**Cluster 2** (n=78; 16.2%)	**Cluster 3** (n=56; 12.4%)	**Cluster 4** (n=33; 7.3%)	**Cluster 5** (n=126; 26.1%)	**P-value**
Age X (±SD)	15.6 (0.9)	15.9 (1.0)	15.9 (0.8)	15.7 (0.7)	15.7 (0.8)	0.12
Television watching (min/day) X (±SD)	232.1 (41.1)[a]	162.6 (91.1)[b]	77.9 (53.0)[c]	240.0 (49.7)[d]	71.3 (42.2)[e]	<0.05
Moderate and vigorous physical activity (min/day) X (±SD)	41.8 (35.6)[a]	62.6 (49.5)[b]	151.7 (41.3)[c]	218.9 (49.4)[d]	38.1 (30.0)[e]	<0.05
Fruits and vegetables consumption (g/day) X (±SD)	243.5 (227.8)[ac]	495.5 (479.4)[b]	294.3 (271.6)[ad]	348.7 (511.0)[ab]	173.5 (195.1)[cd]	<0.05
Sugar sweetened beverages consumption (g/day) X (±SD)	272.6 (191.9)[a]	1081.4 (271.1)[b]	214.8 (198.3)[a]	495.6 (346.7)[c]	208.7 (176.1)[a]	<0.05
BMI (kg/m2) X (±SD)	22.2 (4.3)[ab]	20.7 (2.7)[b]	23.2 (4.8)[a]	23.2 (5.1)[a]	21.9 (3.6)[ab]	<0.05
Type of school (public/private) (%)	39.4/60.6	56.4/43.6	44.6/55.4	60.6/39.4	46.8/53.4	0.06

SES, Socioeconomic status.

[a,b,c,d,e] Significant differences. Mean values is significantly different from one cluster to the other if they have **different capitals.**

Table 3 Main characteristics of girls participating in the HELENA and ELANA studies, according to the identified clusters

HELENA study (n=1107)	**Cluster 1** (n=242; 21.9%)	**Cluster 2** (n=150; 13.6%)	**Cluster 3** (n=172; 15.5%)	**Cluster 4** (n=209; 18.9%)	**Cluster 5** (n=334; 30.2%)	**P-value**
Age X (±SD)	14.6 (1.1)[ab]	14.8 (1.3)[a]	14.3 (1.1)[b]	14.8 (1.1)[a]	14.8 (1.2) [a]	<0.05
Television watching (min/day) X (±SD)	203.8 (40.5)[a]	101.3 (51.0)[b]	84.8 (52.1)[c]	83.9 (46.2)[c]	73.7 (35.1)[c]	<0.05
Moderate and vigorous physical activity (min/day) X (±SD)	74.8 (60.1)[a]	76.0 (57.0)[a]	205.6 (44.9)[b]	70.6 (47.0)[a]	53.2 (35.5)[c]	<0.05
Fruits and vegetables consumption (g/day) X (±SD)	169.3 (72.6)[ad]	188.0 (85.1)[a]	214.8 (88.0)[b]	365.4 (72.8)[c]	165.6 (61.1)[d]	<0.05
Sugar sweetened beverages consumption (g/day) X (±SD)	201.1 (167.3)[a]	549.4 (149.5)[b]	142.3 (120.1)[c]	139.6 (141.7)[c]	103.5 (89.6)[d]	<0.05
BMI (kg/m2) X (±SD)	21.3 (3.7)	20.9 (3.1)	20.7 (3.0)	20.9 (3.0)	21.4 (3.8)	0.13
SES (Low/medium/high) (%)	33.9/43.8/22.3	18.7/47.3/34	25.6/36/38.4	19.6/43.5/36.8	21.9/41.6/36.5	<0.05

ELANA (n=515)	**Cluster 1** (n=179; 34.8%)	**Cluster 2** (n=61; 11.8%)	**Cluster 3** (n=63; 12.2%)	**Cluster 4** (n=30; 5.8%)	**Cluster 5** (n=182; 35.3%)	**P-value**
Age X (±SD)	15.5 (0.9)[a]	15.9 (0.9)[ab]	15.5 (0.7)[a]	16.4 (1.1)[b]	15.6 (0.8)[a]	<0.05
Television watching (min/day) X (±SD)	242.5 (36.5)[a]	158.7 (92.5)[b]	147.4 (87.9)[b]	84.7 (76.5)[c]	77.7 (41.2)[c]	<0.05
Moderate and vigorous physical activity (min/day) X (±SD)	19.2 (18.8)[ad]	28.4 (28.8)[a]	114.8 (28.3)[b]	50.2 (34.9)[c]	18.3 (18.8)[d]	<0.05
Fruits and vegetables consumption (g/day) X (±SD)	222.6 (229.9)[a]	332.9 (279.1)[b]	243.2 (264.2)[ab]	1378.6 (295.1)[c]	189.0 (182.4)[a]	<0.05
Sugar sweetened beverages consumption (g/day) X (±SD)	253.9 (197.7)[a]	1139.0 (284.6)[b]	322.9 (295.7)[a]	651.3 (525.4)[c]	225.3 (196.8)[a]	<0.05
BMI (kg/m2) X (±SD)	21.6 (4.0)	21.3 (4.0)	22.9 (4.6)	22.9 (3.9)	21.6 (3.1)	0.06
Type of school (public/private) (%)	54.2/45.8	55.7/44.3	52.4/47.6	76.7/23.3	44.0/56.0	<0.05

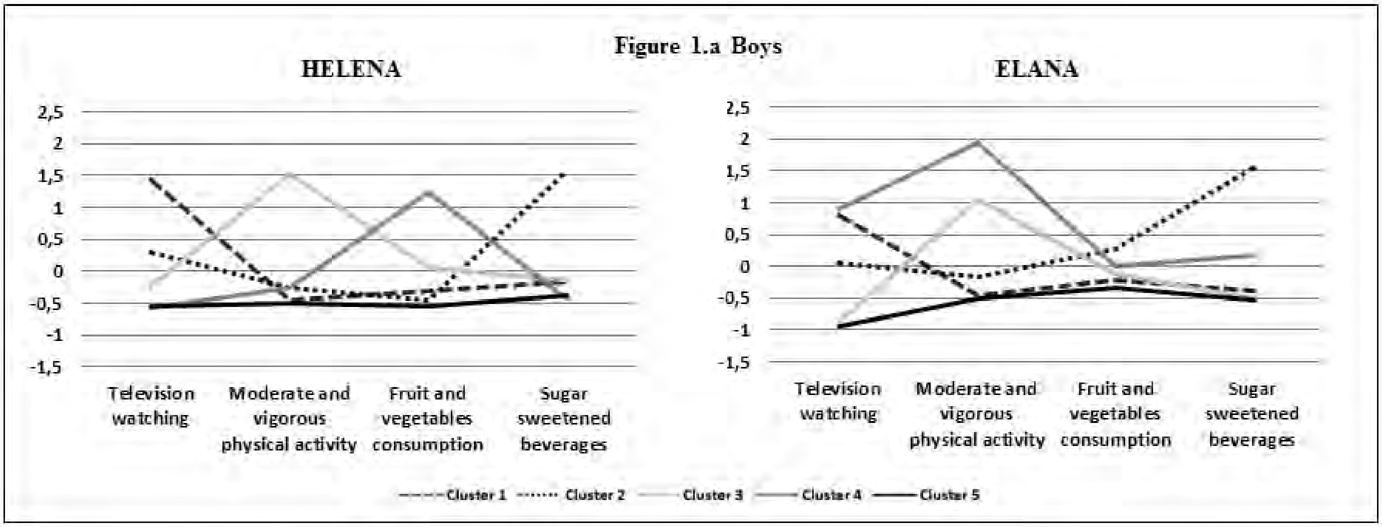
SES, Socioeconomic status

[a,b,c,d,e] Significant differences. EBRBs mean values is significantly different from one cluster to the other if they have **different capitals**.

Table 4 Logistic regression analysis between clusters of EBRBs and body fat composition indicators. **HELENA and ELANA studies**

Clusters	**BMI z-score** (> 1 SD)		**Waist circumference z-score** (> 1 SD)		**Body fat percentage z-score** (> 1 SD)	
	OR*	**95%IC**	**OR***	**95%IC**	**OR***	**95%IC**
HELENA'S BOYS						
Cluster 1	1.20	0.79, 1.82	1.68	0.98, 2.90	1.44	0.85, 2.44
Cluster 2	1.30	0.77, 2.19	**2.32**	**1.22, 4.43**	**2.07**	**1.09, 3.93**
Cluster 3	1.08	0.72, 1.63	1.48	0.87, 2.54	1.59	0.96, 2.64
Cluster 4	0.93	0.59, 1.46	1.23	0.67, 2.27	1.59	0.91, 2.77
Cluster 5	1.00		1.00		1.00	
ELANA'S BOYS						
Cluster 1	1.19	0.70, 2.02	**2.16**	**1.03, 4.52**	**2.21**	**1.14, 4.30**
Cluster 2	0.85	0.39, 1.89	1.69	0.54, 5.25	0.43	0.09, 2.06
Cluster 3	1.44	0.72, 2.86	1.67	0.63, 4.41	1.61	0.67, 3.89
Cluster 4	1.84	0.79, 4.27	**3.64**	**1.25, 10.62**	2.76	0.98, 7.78
Cluster 5	1.00		1.00		1.00	
HELENA'S GIRLS						
Cluster 1	1.25	0.85, 1.85	0.77	0.47, 1.26	1.17	0.75, 1.82
Cluster 2	1.11	0.68, 1.79	1.00	0.56, 1.78	0.72	0.39, 1.36
Cluster 3	0.95	0.61, 1.48	0.74	0.43, 1.29	0.58	0.32, 1.02
Cluster 4	0.85	0.55, 1.33	1.05	0.64, 1.72	0.67	0.34, 1.06
Cluster 5	1.00		1.00		1.00	
ELANA'S GIRLS						
Cluster 1	1.42	0.86, 2.35	1.61	0.82, 3.17	1.50	0.83, 2.70
Cluster 2	1.60	0.72, 3.55	1.93	0.70, 5.26	2.03	0.81, 5.08
Cluster 3	**2.19**	**1.14, 4.19**	2.29	0.99, 5.28	1.77	0.81, 3.86
Cluster 4	**2.89**	**1.09, 7.62**	2.81	0.84, 9.36	2.65	0.87, 7.99
Cluster 5	1.00		1.00		1.00	

OR, Odds ratio; CI, Confidence Interval.
*OR and 95 % CI are from logistic regression with BMI z-score, waist circumference z-score and body fat percentage z-score as the dichotomous outcome and clusters for each study and sex (cluster 5 as a reference because this cluster was present in all groups). Models were fitted for socioeconomic status and total energy intake in HELENA study and for type of school and total energy intake in ELANA.



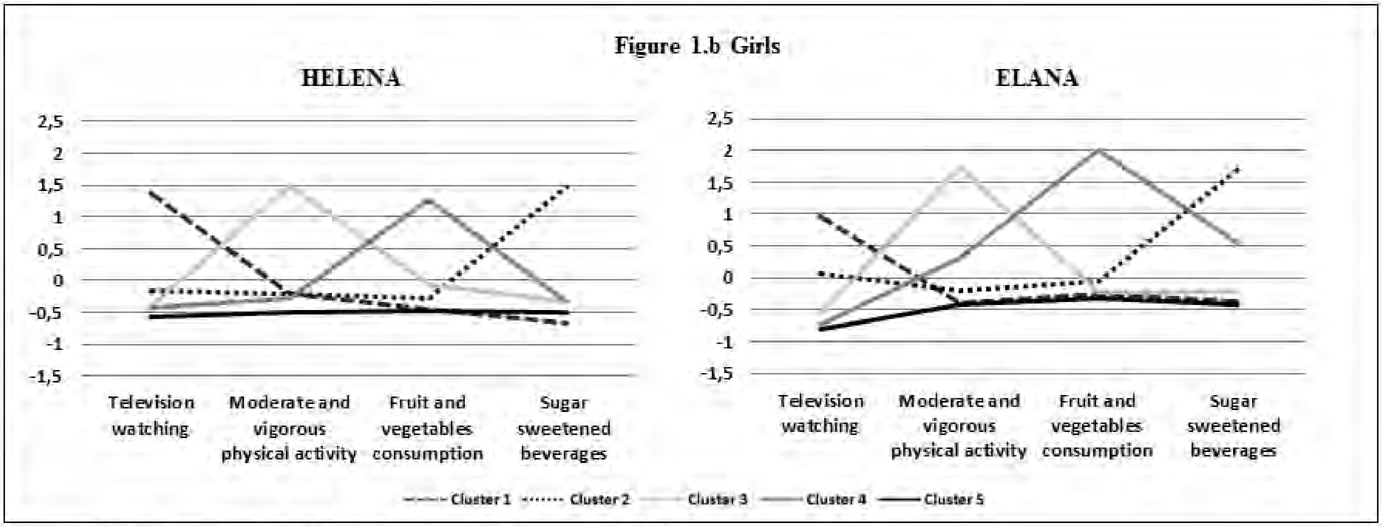


Figure. 1 Cluster solutions and mean z-scores of obesity risk behavior