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Physical activity/physical exercise, sedentary behaviours and nutrition in children with overweight/obesity and their families. Nereu Programme

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Hábitos de actividad física/ejercicio físico, sedentarismo y alimentación en niños con sobrepeso/obesidad y sus familias. Programa Nereu

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ABBREVIATIONS

BIA: Bioelectrical Impedance Analysis

BMI: Body Mass Index

BMI z-score: Body Mass Index Standard Deviation

BSA: Body Surface Area

CEIC: Clinical Research Ethics Committee

CG: Counselling Group

CPG: Clinical Practice Guidelines

DBP: Diastolic Blood Pressure

EE: Energy Expenditure

FM: Fat Mass

FFM: Free Fat Mass

HPU: Healthcare Paediatric Unit

HR: Heart Rate

HRQOL: Health Related Quality of Life

H/W: Hours per week

IDIAP: Primary Care Research Institute – Jordi Gol of Lleida

METs: Metabolic Equivalent Units

MH: Moderate to High

MVPA: Moderate to Vigorous Physical Activity

NP: Nereu Programme

NW: Normal Weight

OW: Overweight

OB: Obese

OW/OB: Overweight and Obese

PA: Physical Activity

PE: Physical Exercise

PC: Physical Condition

SBP: Systolic Blood Pressure

SD: Standard Deviation

TV: Television

VO_2: Oxygen Consumption

VE: Ventilation

VE/VO_2: Ventilatory Equivalents for VO_2

VE/VCO_2: Ventilatory Equivalents for VCO_2

RER: Respiratory Exchange Ratio

WC: Waist Circumference

WHtR: Waist-to-Height Ratio

ABSTRACT

The main purpose of this thesis was to analyse the relationship between physical activity habits, physical exercise practice, sedentary behaviour and food habits in overweight / obese children.

In this regard, the children's physical activity habits, physical exercise practice, food habits and sedentary behaviours by gender and degree of obesity in a sample of Lleida were studied in papers 1.1 and 1.2. This was done in order to target and match the contents of the intervention to their real needs. On the other hand, the response to acute physical exercise in overweight and obese children when walking at different gradients has been observed with regards to their energy expenditure, cardiovascular and respiratory levels and discussed in paper 2. Also, in paper 3, an initial assessment of the Nereu programme was carried out in order to observe its strengths and weaknesses in respect of the intervention and an evaluation of the effectiveness of supervised non-competitive physical exercise in the treatment of overweight and obese children. Finally, in paper 4, with the results and knowledge learned, a proposal for the future has been put forward. This is currently in the intervention phase and it aims to assess the effectiveness of the Nereu programme as an integral tool linked to public health in the field of paediatric care in the treatment of child overweight and obesity.

The main findings in papers 1.1 and 1.2 were that practising at least 3 hours a week of physical activity was associated with a lower prevalence of OW/OB and better physical condition in children. These differences have also been observed in physical activity / physical exercise, physical condition and in participants eating in the school canteen when compared by gender, degree of obesity (non-obese vs. OW/OB). Especially, these differences were observed among the non-obese and OW/OB girl subgroup. In paper 2, regarding acute response to walking exercise testing, energy expenditure and ventilation were higher in obese children compared to their overweight peers at each treadmill gradient. In paper 3, after the Nereu programme intervention, children increased the time they spent in moderate and high intensity activities and in contrast, BMI z-scores and sedentary behaviours such as watching television and playing computer games were reduced.

RESUM

L'objectiu de la present tesi ha estat analitzar la relació entre els hàbits d'activitat física, la práctica d’exercici físic, el sedentarisme i l’alimentació en nens amb sobrepès/obesitat.

En aquest sentit, en els articles 1.1 i 1.2 s'han estudiat els hàbits d'activitat física/exercici físic, les conductes sedentàries i d'alimentació segons gènere i grau d'obesitat en una mostra de la població de Lleida, amb l'objectiu de focalitzar i individualitzar els continguts de la intervenció a les seves necessitats. D'altra banda, en l’article 2, s'ha observat la resposta a l'exercici físic agut al caminar a diferents pendents a nivell energètic, ventilatori i cardiovascular en nens/es amb sobrepès i obesitat. Així mateix a l’article 3, s'ha portat a terme una primera avaluació del programa Nereu amb l'objectiu de conèixer els punts forts i febles de la intervenció i avaluar l'efectivitat de la pràctica d'exercici físic supervisat i no competitiu en el tractament del sobrepès i l’obesitat infantil. Finalment al 4 article, els resultats i coneixements adquirits s'han unit, amb la finalitat de plantejar una proposta de futur, on es pretén avaluar l'efectivitat del programa Nereu, com a eina integral vinculada a la salut pública en l'àmbit de l'atenció pediàtrica per al tractament del sobrepès i l'obesitat infantil.

Els principals resultats obtinguts en els articles 1.1 i 1.2 indiquen que practicar almenys 3 hores a la setmana d’exercici físic es va associar a una menor prevalença de sobrepès/obesitat i a una millor condició física en nens/as. Aquestes diferències també es van observar a nivell d'hàbits d’activitat física i exercici físic com de condició física o en el àpats al menjador escolar segons el gènere, grau d'obesitat (no-obesos vs. sobrepès/obesitat). Especialment estes diferencies s’han trobat en el subgrup de noies no-obeses i amb sobrepès/obesitat. En l’article 2, en relació a la resposta aguda a l'exercici físic, destacar que en la prova d'esforç es va observar que els valors de cost energètic i ventilació a les mateixes intensitats de treball eren superiors en els grups de nens/es amb obesitat en relació als seus iguals amb sobrepès. A l’article 3, una vegada acabada la intervenció del programa Nereu, va augmentar el temps dedicat a activitats de moderada i alta intensitat i per contra es va reduir l'IMC z-score i les conductes sedentàries, com mirar la televisió i jugar a l'ordinador.

RESUMEN

El objetivo de la presente tesis ha sido analizar la relación entre los hábitos de actividad física, la práctica de ejercicio físico, el sedentarismo y la alimentación en niños con sobrepeso/obesidad.

En este sentido, en los artículos 1.1 y 1.2 se han estudiado los hábitos de actividad física/ejercicio físico, las conductas sedentarias y de alimentación según género y grado de obesidad en una muestra de la población de Lleida, con el objetivo de focalizar e individualizar los contenidos de la intervención a sus necesidades reales. En el artículo 2, se ha observado la respuesta al ejercicio físico agudo al caminar a diferentes pendientes a nivel energético, ventilatorio y cardiovascular entre niños/as con sobrepeso y obesidad. Así mismo, en el artículo 3, se ha realizado una primera evaluación del programa Nereu para conocer los puntos fuertes y débiles de la intervención y evaluar la efectividad de la práctica de ejercicio físico supervisado y no competitivo en el tratamiento del sobrepeso/obesidad infantil. Por último, en el 4 artículo, los resultados y conocimientos adquiridos se han unido, con el fin de plantear una propuesta de futuro, que actualmente está en fase de intervención, para evaluar la efectividad del programa Nereu, como herramienta integral vinculada a la salud pública en el ámbito de la atención pediátrica para el tratamiento del sobrepeso y la obesidad infantil.

Los principales resultados obtenidos en los artículos 1.1 y 1.2 indican que practicar al menos 3 horas a la semana de ejercicio físico se asoció a una menor prevalencia de sobrepeso/obesidad y a una mejor condición física en niños/as. También se observaron a nivel de hábitos de actividad física y ejercicio físico como de condición física o comer en el comedor escolar según el género, grado de obesidad (no-obesos vs. sobrepeso/obesidad). Especialmente estas diferencias se han encontrado entre el subgrupo de chicas no-obesas y con sobrepeso/obesidad. En el artículo 2, en relación a la respuesta aguda al ejercicio físico, en la prueba de esfuerzo se observó que los valores de coste energético y ventilación a las mismas intensidades de trabajo eran superiores en los grupos de niños/as con obesidad que con sobrepeso. En el artículo 3, tras la intervención del programa Nereu, aumentó el tiempo dedicado a actividades de moderada y alta intensidad y se redujo el IMC z-score y las conductas sedentarias, la televisión y jugar al ordenador.

INTRODUCTION

This thesis presents research conducted at the INEFC-Lleida and is presented as a compendium of papers related to child obesity. The manuscript has been divided into three main parts: introduction, results (the papers) and discussion/conclusions. The purpose of the introduction section is to give an overview of childhood obesity, with special focus on lifestyle management. In the results section the five papers conforming the thesis are presented. Finally, the main inferences resulting from the studies exposed in the previous section are debated in the discussion/conclusions section.

Prevalence of childhood obesity

According to the World Health Organization (WHO, 2014a), overweight and obesity are defined as abnormal or excessive fat accumulation that presents a risk to health.

Obesity stands out as one of the most important public health problems in the twenty-first century. In developed countries, it is considered the most common nutritional and metabolic disorder and the most prevalent non-contagious disease (WHO, 2014a).

The International Association for the Study of Obesity and The International Obesity Task Force (IASO / IOTF) estimate that, globally, about 1 billion adults are overweight and about 475 million are obese (IASO / IOTF, 2010a). In Europe, approximately 60% of adults are overweight or obese (IASO / IOTF, 2010a). More specifically, in Spain it is estimated that 39.5% of adults are overweight and 22.9% obese (IASO / IOTF, 2010b).

Looking at the paediatric population, it is estimated that in 2010 there were 42 million overweight children worldwide, of which about 35 million live in developed countries (WHO, 2014B). In the European Union, approximately 20% of school-age children are overweight or obese. In Spain, the last three editions (2003, 2006, 2010) of the National Health Survey (ENS) have reported that there is a continuous increase (18.2 - 18.7 to 19 2%) of overweight and obesity (8.5 - 8.9 to 9.4%) among children and youth. More recently, the Aladino Study (2011) indicated that 45.2% of children are overweight or obese. In Catalonia, 36.5% of the boys and 34.3% of the girls are overweight/obese (Departament de Salut, 2013). This is in line with others that have also reported a greater prevalence of overweight/obesity in boys than in girls (Aladino, 2011; ENS, 2011-12; Serra-Majem et al., 2006).

Health impact of childhood obesity

Overweight and obesity in childhood have a negative impact on both physical and psychological health. An excess of fat mass in childhood causes an overload on the musculoskeletal and cardio-respiratory systems, psychosocial problems and reduced motor skills and physical condition (PC) (Baker, Olsen, & Sorensen, 2007; Bibbins-Domingo, Coxson, Pletcher, Lightwood, & Goldman, 2007; Dehghan, Akhtar-Danesh, & Merchant, 2005; Waters et al., 2011; Weiss, Dziura, Burgert, & Tamborlane, 2004). The prevalence of metabolic disorders is also increasing in children, especially among obese children and adolescents (Pajuelo, Bernui, Nolberto, Peña, & Zevillanos, 2007). Childhood obesity is also associated with an increased risk of cardiovascular events in adulthood. Furthermore, mortality rates in obese people are 50% higher than those in non-obese people, whether due to obesity alone or other obesity-related diseases.

As mentioned in the previous section, childhood obesity is associated with an increased risk of chronic disease and mortality, both in childhood and later on, in adulthood. In this regard, it is essential to prevent and treat obesity in childhood.

It is also important to consider that child obesity is refractory to treatment because of its anatomic pathological features (hyperplastic) (Hernandez, 1993; Waters et al, 2011). Thus, this could explain why obese children are more likely to be obese during their adult life than non-obese children. According to Parsons, Power, Logan, & Summerbell (1999) about 70% of obese adolescents remain so in adulthood. Therefore, it is preferable to prevent children from gaining too much fat mass.

In addition, childhood is the period when children establish habits associated with lifestyle. Therefore, helping them to learn and make decisions towards healthier habits, thus favouring their acquisition and subsequent maintenance in adulthood, becomes essential. For example, it is remarkable that regular physical activity declines dramatically with age (Biddle, Atkin, Cavill, & Foster, 2012), while sedentary behaviour increases (Agarwal, 2008). Just as with physical activity and sedentarism, it is also necessary to educate in healthy eating habits in childhood. Attention to nutrition at school age should be a priority, since proper nutrition during this period can be vital to achieve optimal growth and health (Velasco, Mariscal-Arcas, Rivas, Caballero, Hernandéz-Elizondo & Olesa-Serrano, 2007). Also, if these more appropriate eating habits are not acquired at school age, modifying them at a later stage becomes more difficult (Requejo & Ortega, 2006).

Main behavioural causes for the development of childhood obesity

The etiology of obesity is complex and it is attributed to multiple interconnected factors (Davison & Birch, 2001; Dehghan et al., 2005). Multiple models that attempt to explain the relationship between these factors and the development of childhood obesity have been proposed (Davison & Birch, 2001; Harrison et al., 2011; Kumanyika, Jeffery, Morabia, Ritenbaugh, & Antipatis, 2002). In general all models consider at least three levels of detail: the individual's context (the individual themselves); the closest social context (family or parental models and some models also include the school and work contexts) and a third global community level (local, national and international) in which for example, the health system would be included. One of the most widely used models is the Ecological Systems Theory (EST) (Davison & Birch, 2001) (Figure 1).

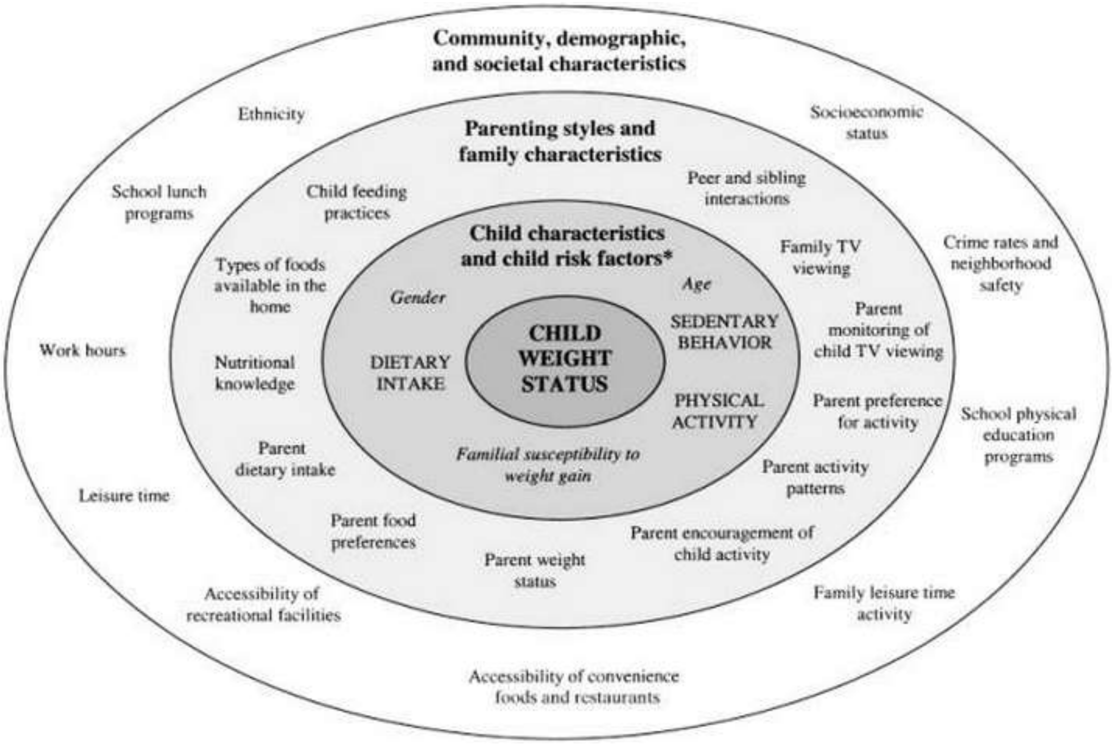

Figure 1. The Ecological Systems Theory from Davison and Birch (2001).

Apart from these three levels of detail, factors that determine or modulate obesity can also be categorised as modifiable factors and non-modifiable factors. Modifiable factors can be beyond the individual's own factors (community, demographic and social) or depend on the modifiable factors of the individual themselves (food habits, sedentary behaviours and physical activity). Non-modifiable factors include age, gender and genetic aspects:

- Modifiable factors beyond the individual themselves are those which refer mainly to the third level of specificity, where socio-community agents are involved. As before, they must be taken into account due to their influence on the prevalence or development of obesity. In this regard, it is worth mentioning those programmes that include the prevention and treatment of obesity and that are performed at the level of the community, schools and health centres.
- The individual modifiable factors refer to those that directly affect the child and their most immediate environment. These habits are mainly related to physical activity, sedentary behaviour and child and family food habits, and the interaction between them.

- The non-modifiable factors of the individual are those that cannot be altered and are a part of the individual themselves. However, they need to be taken into account as they greatly affect the development of overweight in childhood and therefore, the interpretation of the intervention results.

The research studies developed in this thesis have focused mainly on the analysis of the individual's modifiable factors which are discussed in the following sections. The role of non-modifiable factors, such as age and gender on modifiable factors, has also been taken into account.

The influence of an individual's modifiable factors on the development of childhood obesity

An individual's modifiable factors mainly refer to the individual's lifestyle related to physical activity, sedentary behaviour and food habits.

Physical Activity

According to the World Health Organization, physical activity is any bodily movement produced by skeletal muscles that require energy expenditure over 1 to 1.5 Metabolic Equivalent units (METs) (WHO, 2014c).

Physical activity is a key factor in the prevention and treatment of child obesity, since high levels of physical activity could offset the imbalance between caloric intake and energy expenditure (Davison & Birch, 2001). Global recommendations on physical activity in children and adolescents point at engaging in at least one hour of daily moderate-to-vigorous intensity physical activity (MVPA) (3 or more METs) (WHO, 2010). Although general recommendations are the same for both genders, differences in physical activity habits have been observed between genders. In general, boys are more active than girls (Chillon et al., 2011; Ruiz et al., 2011; Tercedor et al., 2007; Sallis, Prochaska, & Taylor, 2000; Troiano et al., 2008). For example, in the Helena study, 56.8% of boys and 27.5% of girls reached the recommended daily MVPA (Ruiz et al., 2011). Boys spent an average of 64 minutes daily on MVPA (25th percentile = 48 minutes/day, 75th percentile = 81 minutes/day) while girls spent an average of 49 minutes daily (25th percentile = 37 minutes/day 75th percentile = 62 minutes/day) (Ruiz et al., 2011). More specifically, MVPA time is distributed in 41.9 ± 0.5 vs. 35.7 ± 0.5 minutes/day of moderate physical activity and 23.2 ± 0.5 vs. 13.4 ± 0.4 minutes/day of vigorous activity for boys and girls respectively (Chillon et al., 2011).

Differences in physical activity have also been observed with regard to age. In general, over the years they decrease the time devoted to physical activity (Goran, Gower, Nagy, & Johnson, 1998; Strong et al. 2005; Ruiz et al. 2011; Troiano et al., 2008). For example in boys, 42% of children performed 60 minutes of MVPA per day, while only 8% of adolescents met the recommendations (Troiano et al., 2008).

On the other hand, several authors have noted that the level of physical activity, especially of MVPA, is associated with the degree of adiposity in children. It has been observed that the higher the degree of obesity, the lower the level of physical activity (Berkey et al., 2000; Ekelund et al. 2004; Ortega, Ruiz, & Sjöström, 2007b; Eisenmann, DuBose, & Donnelly, 2007; Page et al., 2005; Ruiz et al., 2011; Serra-Majem et al., 2003). For instance, Martinez-Gomez et al. (2010) showed that practising 18 minutes/day of vigorous physical activity and 55 minutes/day of MVPA allowed the discrimination of adolescents with normal weight from those with overweight/obesity. They also indicated that teens who did not reach 60 minutes/day of MVPA had a higher risk of becoming OW/OB. Lazzer et al. (2003) found that overweight/obese children spent less time on activities of moderate/light intensity throughout the day, such as walking, and more time on sedentary behaviour than their normal-weight peers. This reduction in active habits could be partly due to the decrease in the time spent playing outside or walking to school (Biddle, Atkin, Cavill, & Foster, 2011). However, Ebenegger et al. (2012) and Ortega et al. (2007a) found no differences in the time devoted to physical activity between children or adolescents according to the degree of obesity. Other authors have also mentioned that the relationship between daily physical activity habits and adiposity remains unclear, especially in preschool ages (Metallinos-

Katsaras, Freedson, Fulton, & Sherry, 2007; Trost, Sirard, Owda, Pfeiffer, & Pate, 2003). This lack of agreement may be due to the use of different methodologies to measure physical activity (self-reported registration methods vs. recording devices (Baquero, Moro, & Jimenez, 2008)); the use of different cutoff points when categorizing levels of physical activities (Ruiz et al. 2011), as well as the use of different systems for measuring the degree of adiposity (BMI, BMI z-score, bioelectrical impedance, waist circumference or skin folds) and the method used to classify the degree of obesity (Gonzalez-Casanova, 2013).

Sedentary Behaviour

Sedentary behaviour refers to those activities that do not substantially increase the individual's energy expenditure (< 1.5 METs) (Pate, O'Neill, & Lobel, 2008). These include sitting and lying, and can take place at school (in class), at home (watching TV, computer/console, reading, doing school homework, etc.) and during journeys (car, bus, etc.).

Time spent on sedentary behaviour is another factor closely related to the development of childhood overweight (Agarwal, 2008; Gortmaker et al., 1996; Ruiz et al., 2011). This impacts directly, and negatively, on the overall balance between energy expenditure and caloric intake. Also, it indirectly impairs the child's energy balance by subtracting hours from active behaviour, as suggested by the existence of a negative correlation between the amount of time spent watching TV and the time devoted to PA (Sallis et al., 2000). For instance, in Europe, it has been reported that adolescents spend 71% (9 hours/day) of their recorded daily routine on sedentary conducts (Ruiz et al., 2011). Among the most frequently observed sedentary conducts in children, we can highlight watching TV and playing computer or console games (Agarwal, 2008; Hardy, Bass, & Booth, 2007). For this reason, international guidelines advise limiting the use of these devices to no more than two hours a day (Australian Government, 2014). However, despite existing guidelines, several studies have found that a high percentage of children/adolescents exceed the suggested time limitation. For example, Salmon, Telford, Carver and Crawford (2011) reported that approximately 34% of the children exceeded the 2-hour television recommendation. In the United States, young people devote a total of 5-10 hours per day to sedentary conducts, and out of this time between 2 and 4 hours a day are dedicated exclusively to computer, television and/or console games (Troiano et al., 2008).

As for physical activity, the time spent in sedentary behaviour also shows gender differences. In The European Youth Heart Study (EYHS) conducted in four countries (Estonia, Norway, Denmark and Portugal), sedentary behaviour was measured objectively using accelerometers. The results showed that girls in Estonia were more sedentary than boys, while in other countries this difference was not appreciated (Van Sluijs, Page, Ommundsen, & Griffin, 2010). On the other hand, the Helena study, which was conducted in nine European countries and which also included the use of accelerometers, found that girls spent more time in sedentary behaviour than boys (Ruiz et al., 2011).

Regarding age, there is an overwhelming consensus that sedentary behaviour increases over the years and that this increase occurs in both genders (Agarwal, 2008; Biddle et al., 2012; Hardy et al., 2007; Kain, Albala-Brevis, García, & Andrade, 1998; Pate et al., 2008; Salmon et al., 2011; Treuth et al., 2009; Ruiz et al., 2011; Treuth et al., 2009; Van Sluijs, Page, Ommundsen, & Griffin, 2010). Thus, accelerometer records have shown that adolescents spend more time in sedentary behaviour (335 minutes/day) than children (217 minutes/day) (Van Sluijs et al., 2010) or that 6th grade children spend 51.5 minutes/day less in sedentary behaviour than 8th grade (Treuth et al., 2009). A two-and-a-half-year long longitudinal study indicates that the time spent in sedentary behaviour in association to the amount of daily recorded time grew from 45% at 12.8 years old to 63% at 14.9 years old (Hardy et al., 2007).

Generally, a higher degree of adiposity has been associated with sedentary behaviour in children and adolescents (González Jiménez et al., 2012; Marshall, Biddle, Gorely, Cameron, & Murdey, 2004, Serra-Majem et al., 2003; Tremblay et al., 2011; Ortega et al., 2007a). More specifically, a positive correlation between the time spent watching television and an increased risk of developing obesity has been observed (Jago, Baranowski, Baranowski, Thompson, & Greaves, 2005). Moreover, Lazzer et al. (2003)

found that obese children, when compared to normal-weight children, spend more time daily on sedentary conducts and less time on moderate intensity physical activity. Tirado, Barbacho, Prieto, and Moreno (2004) indicate that obese children watch television 2.7 hours/week longer than their normal-weight peers (18.8 hours/week vs. 16.1 hours/week, respectively). However, several studies have not appreciated any correlation between time spent in sedentary behaviour and parameters of adiposity in children or adolescents (Steele et al., 2009; Ekelund et al., 2004; Purslow et al., 2008). Thus, the existence of a direct correlation between the time devoted to sedentary behaviour and adiposity is unclear. As already noted above, in the "Physical Activity" section, this could be due in part to several factors such as the methodology used to measure sedentary behaviour (using electronic devices such as accelerometers or using self-reported questionnaires), who has filled in the questionnaires (children or parents), and whether confounding variables such as age, degree of maturation, gender or the country of origin of the participants have been taken into account

Food Habits

Feeding is defined as the way to provide the body with essential substances for the maintenance of life (Palacios, Montalvo, & Ribas, 2009).

Although the time devoted to physical activity and sedentary behaviour influences our energy expenditure, food directly affects our caloric intake. The interrelationship between these three factors will impact on the energy balance and, therefore, also on the weight and body composition of the individual.

Parallel to the evolution towards a more sedentary and less active lifestyle, food habits have also changed, adopting patterns that favour the growing prevalence of overweight (WHO, 2014a). Food recommendations advise eating five portions of fruit and vegetables a day, avoiding foods high in fat and salt, and encourage eating foods high in fibre, minerals and vitamins. In spite of these guidelines, there has been an increase in the use of high-energy foods rich in fat, salt and sugar and low in vitamins, minerals and other micronutrients (WHO, 2014a). Furthermore, portion sizes have also increased (Dehghan, Akhtar-Danesh, & Merchant, 2005).

As in physical activity and sedentary behaviour, there are also gender similarities and differences with regards to food habits. In a longitudinal 5-year study, Wardle et al. (2003) analysed the habits of children aged 11 and 12 years by means of a questionnaire. The study reported no differences in the daily intake of the recommended five portions of fruit and vegetables between genders. However, boys reported a higher fat intake than girls. Maier, Özel, Wagnerberger, Bischoff, and Bergheim (2013) also indicate that the total amount of carbohydrates, protein and fat is higher in boys. However, boys often have greater energy expenditure than girls (Maier et al., 2013, Velasco et al., 2007). For this reason, some authors recommend that the daily energy intake for boys should be higher than for girls (Moreiras, Carbajal, Cabrera, & Square, 2007).

In relation to food habits and children's weight status, Anta et al. (1996) already highlighted the existence of differences in the diet of overweight adolescents compared to their normal-weight peers. Where overweight adolescents followed a diet richer in fats and poorer in carbohydrates than their normal-weight peers and yet did not differ in total caloric or energy intake. More recently, Maier et al. (2013) did not record differences either in the total energy and macronutrients intake in 5-8-year-old normal-weight and overweight children. In contrast, Gillis, Kennedy, Gillis and Bar-Or (2002) found that the total caloric intake was significantly higher in obese subjects. Moreover, they also observed that the total energy consumed was the factor that showed a strongest relationship / association with the body fat percentage of children. Furthermore, and in accordance with Anta et al. (1996), obese subjects also consumed more saturated fatty acids (in grams), and a higher percentage of fat. These discrepancies could be largely due to the disparity in the methods used in collecting the data and their validity, as well as to who reports the data (the children themselves or their parents). To this problem we must add the fact that children's energy needs differ according to the growth of the child, their gender and physical activity, all of which are difficult to account for.

Consequently, the intervention pillars for the prevention and treatment of childhood obesity must be based on increasing physical activity, reducing sedentary behaviour and promoting healthy eating. However, knowing the habits of the study population before designing an intervention for the management of child obesity is considered necessary due to the lack of consensus among studies regarding the influence of habits on the degree of obesity in children. Therefore, we have analysed the patterns of physical activity, sedentary behaviour and eating habits of the children in the city of Lleida and their characteristics by gender and degree of obesity in articles 1.1 and 1.2.

Family Influence

In the development of childhood obesity, in addition to the individual factors, social influence, particularly that of parents, is a relevant factor. Parents influence children decisively when it comes to acquiring physical activity, sedentary behaviour and nutrition habits. Grube et al. (2013) state that biological factor, family interactions and the parents' behaviour patterns influence the development of obesity in children.

Physical activity in children is positively correlated with social support, especially by families, to physical activity in general (Crawford et al., 2010; McMinn et al., 2011; Wilson, Lawman, Segal, & Chappell, 2011). The family conditions act as a modifier in general habits and the physical activity of children (Davison & Birch, 2001; Maitland et al., 2013). As early as 1991, Moore et al. (1991) showed that children whose parents were more active, both mother and father, were 5.8 times more active than the children of not very active parents.

As in physical activity, the attitude of parents towards sedentary behaviour influences their children (Jago et al., 2011; Salmon et al., 2005; Troiano et al., 2008). Jago et al. (2011) found that the amount of time spent watching television by children is closely related to specific parenting styles. Adolescents whose parents limit the amount of time they can spend in sedentary behaviour activities are less likely to watch TV so long. However, children whose parents follow more permissive parenting styles tend to show higher levels in the time spent watching TV. It has also been noticed that playing video games with parents is associated with lower levels of physical activity (Salmon et al., 2005). The mothers' adiposity and amount of time they spent in sedentary behaviour were also identified as risk factors for the development of overweight in children (Maier et al., 2013).

The family context plays a key role in the acquisition of food habits in children (Bell & Rolls, 2003). In childhood, from the family unit, the mother is the one who primarily transmits the dietary patterns to their children (Requejo & Ortega, 2000). By analysing the eating habits of children, adolescents and their parents, Van der Horst et al. (2007) reported a correlation between the parents' calory intake and the fat percentage of their children and also between the parents' and the siblings' calory intake and OW/OB children's energy intake and fat.

Therefore, it seems evident that the family behaviour may influence the development of their children's obesity.

In short, in developed countries the individual's modifiable factors have evolved to favour the development of childhood obesity. The time devoted to physical activity has decreased, while the time spent on sedentary behaviour such as watching television or playing video games has increased and this trend worsens with age. Also, eating habits have also evolved towards an increase in caloric intake, mainly due to the intake of a higher proportion of rich-in-fat high-calorie foods (WHO, 2014a), which makes it very difficult to maintain proper energy balance. As a result, all these changes favour weight gain.

Prevention and treatment of childhood obesity

The Clinical Practice Guidelines for the Prevention and Treatment of Child and Adolescent Obesity (CPG) differentiates between actions at the prevention and treatment level (Grupo de trabajo de la Guía, 2009). With regards to treatment, it focuses on actions that include a change of lifestyle, and pharmacological, surgical and alternative treatments. However, most strategies focus on lifestyle interventions, except for children who exceed the 99th percentile or present comorbidity (Grupo de trabajo de la Guía 2009).

The main areas of action for the prevention and treatment (P/T) of child obesity are the school, the community and the health centres (Grupo de trabajo de la Guía, 2009). Some of the many P/T initiatives in child obesity contemplated at a Spanish national level in each of the above mentioned areas are the following:

- At a school level, schools have a fundamental role in establishing environments that enable students to stay active and eat healthily. This could be achieved through practices and policies that support regular exercise and healthy eating. In addition, schools can encourage students to learn to make decisions and adopt habits towards healthier life styles (CDC, 2014). It is worth noting P/T programmes of obesity in schools, especially the MOVI and MOVI-2 programmes. These programmes offer supervised physical activity programmes in the schools during leisure time (Martínez-Vizcaíno et al. 2012). Another programme, the Perseo programme is developed in the schools and aims to promote health and physical exercise for the prevention of childhood obesity (Programa Perseo, 2010).

- At the community level, it is worth mentioning the actions taken by local town halls or public entities that can help to promote healthier habits, offering activities and creating suitable and safe physical activity community spaces. Among these, there is the THAO programme implemented in towns, which by promoting healthy lifestyles in the population seeks to prevent childhood obesity (Estevez, Martinez & Beltran, 2010).

- The healthcare sector has an important role to play. Health centres are a key place for the treatment of childhood obesity since it is here where the problem is first diagnosed and where many families are predisposed to deal with this problem (McCallum, 2005). Among the existing interventions, it is worth highlighting the *Nens en Moviment* (*Kids in Motion*) programme, which addresses child overweight and obesity comprehensively and includes sessions promoting healthy habits and psychological aspects in the family (Gussinyé, 2005). In the Lleida province, the "Nereu Programme: physical exercise and healthy eating" is part of the set of community measures for children's health within the Physical Activity and Healthy Eating Program (Programa d'Activitat Física i Alimentació Saludable (PAAS) in the Lleida Heathcare Region (Generalitat de Catalunya, 2008). The Nereu Programme is a pioneer health intervention programme for the treatment of obesity in children in this healthcare region. Over the past editions, the effects of exertion on energy expenditure and of regular supervised exercise in obese children have been analysed. Their results are presented in articles 2 and 3. More recently, the evaluation protocol for the medium and long term effectiveness of the Nereu Programme has been launched (article 4).

The CPG guidelines on the treatment of child and adolescent obesity are mainly focused on strategies aiming to modify lifestyles (Grupo de trabajo de la Guía, 2009). These guidelines recommend carrying out interventions that combine diet, physical activity and psychological strategies for behaviour modification, all linked to the family. Moreover, they state that the surgery or health clinic and the family contexts are the most appropriate ones to implement these interventions. In this regard, they point out that clinical trials evaluating the effectiveness of brief interventions in primary care settings promoting a healthy diet, increasing physical activity and reducing sedentary behaviour and its long-term effectiveness are needed. They also highlight the need to evaluate the effectiveness of supervised physical exercise as part of the treatment for child obesity.

Benefits of physical exercise and physical activity in children

As mentioned in the previous section, the CPG guidance shows little evidence of the effectiveness of physical exercise as part of the treatment of child obesity, a fact that was also previously reported by other authors (Epstein, Roemmich, Stein, Paluch, & Kilanowski, 2005; Golan, Kaufmanb, & Shahar, 2006), and shows even fewer interventions focused on the needs and interests of children with regards to physical exercise (Daley, Copeland, Wright, & Wales, 2005).

In this regard, Connelly, Duaso, and Butler (2007) consider that supervised moderate-to-vigorous intensity exercise is the main factor that differentiates effective programmes from ineffective programmes in the treatment of child obesity. This statement agrees with the results observed by Weintraub et al. (2008) when comparing two groups of overweight/obese children: the first group would play football while the second was advised on healthy habits. The results showed that the group that played football had a significant decrease in BMI z-score after 3 and 6 months and an increase in daily physical activity (moderate to vigorous) after 3 months compared to the group receiving advice. However, the results obtained in recent years in this regard are contradictory and in some cases, programmes were ineffective in modifying adiposity and/or physical activity habits (Campbell, Waters, O'Meara & Summerbell, 2001; Doak, Visscher, Renders & Seidell, 2006). For example, some child obesity programmes offered three sessions per week of supervised exercise and they were not enough to reduce adiposity (Carrel et al. 2005, Daley, Copeland, Wright, Roalfe & Wales, 2006; Gutin, et al. 2002). The revisions carried out by Atlantis, Barnes, and Singh (2006), McGovern et al. (2008) and Spruijt-metz (2011) showed that only between 12% and 14% of treatment programmes for childhood obesity, including supervised physical exercise, had a positive effect on adiposity. According to Trinh, Campbell, Ukoumunne, Gerner, and Wake (2013), treating child obesity with physical activity alone is not enough, since its correlation with body mass index (BMI) is not clearly quantified. This is probably because the isolated effects of exercise on body weight may be moderate or non-existent, since the negative energy balance created by physical exercise may not be enough, if aspects such as energy consumption or the intensity of exercise and activities taking place in the sessions and interventions are not taken into account. Therefore, it is essential to evaluate the acute effects of exercise in overweight and obese children during the sessions, mainly at an energy level, in order to achieve the required energy imbalance. Also, it is necessary to control the calorie intake, because if this also increases, this energy imbalance can be easily countered.

Despite the disparity observed between studies related to the supervised practice of physical exercise for the treatment of child obesity, according to Connelly et al. (2007) and Sallis et al. (1993) the practice of physical exercise is an essential element in the establishment of an ideal health context, since physical exercise is considered a staple in child development. Scientific evidence supports the beneficial effects of exercise physically, psychologically and socially (Warburton, Nicol & Bredin, 2006). Also, if the practice of physical exercise is essential to any child, it is even more so to an overweight or obese child, as it represents an important component of the energy balance that determines their body weight. Therefore, a reduction in energy expenditure would probably translate into an increase in body weight. In addition, exercise is a modifier of mortality and morbidity factors associated with overweight (Moreno & Cervello, 2005). In this regard, they emphasised the need for physical exercise in the treatment of overweight and obesity, regardless of its more or less evident effects on body weight.

However, despite knowing the benefits generally associated with systematic physical exercise, this theoretical knowledge does not usually translate into a stimulus for the practice of physical exercise in OW/OB children. Therefore, despite the need to transmit theoretical or conceptual knowledge, this should be complemented with the practice of supervised physical exercise, in order to promote and create this more active habit during childhood and adolescence and to try to maintain it into adulthood.

Behavioural factors in the treatment of childhood obesity

As mentioned above, the practice of supervised physical exercise seems to be a useful tool in the treatment of childhood obesity. However, focusing the treatment of child obesity on physical activity alone may not be sufficient (Trinh et al. 2013). For this reason, this practice needs to go hand in hand with other content in order to generate and maintain energy imbalance. Oude Luttikhuis et al. (2009), after a systematic review of interventions for the treatment of obesity in children and youngsters, showed that the most effective programmes are those that integrate different strategies in the management of obesity. They mainly emphasise the value of family interventions that incorporate contents of physical activity, nutrition and behaviour modification (Golan, Kaufman, & Shahar, 2006, Hughes et al., 2008; Kitzmann et al., 2010; Waters et al., 2011; Whitlock, Orleans, Pender, & Allan, 2002), with the role of the family being even more essential in pre-school children (Golan et al., 2006; Munsch et al., 2008). This content is also reflected in most guides, study protocols, interventions and strategies for the prevention and treatment of child obesity (AESAN, 2011; CECC, 2010; Christie et al., 2011; Cohen et al., 2013; COM, 2005; Strategy Naos, 2005; Guide Working Group, 2009; Perseus Program, 2005; Robertson et al., 2013; WHO, 2010). Furthermore, Whitlock et al. (2002) added that the effectiveness of the intervention also depends on the total duration of the intervention, where the activities of a moderate duration (26-75 hours / intervention) to high (> 75 hours / intervention) are the most effective.

All these aspects have been considered and included in the proposed intervention for the treatment of childhood obesity that is presented in the 4th article of this thesis.

AIMS

The purpose of the thesis was to analyse the relationship between physical activity habits, physical exercise practice, sedentary behaviour and food habits in overweight / obese children, specifically:

- To determine the physical activity habits, sedentary behaviours and food habits in a sample of Lleida and how they are distributed according to their degree of obesity and gender.
- To assess energy expenditure during physical exercise in children according to their degree of obesity (overweight and obesity).
- To evaluate if an intervention programme would favourably impact on physical activity and sedentary behaviours and adiposity in sedentary overweight and obese children.
- To propose an intervention (study protocol) to determine the effectiveness of the Nereu programme in the medium and long term.

This thesis has been produced as a compendium of articles, the objectives of which are presented below.

AIM OF EACH PAPER

1st PAPER:

1. *1st Paper:*

Aim: To assess differences in sedentary conduct and physical activity behaviour, physical fitness and quality of life in school-age children according to their adiposity status (BMI z-score) and gender.

1. *2nd Paper:*

Aim: The aim of the present research is to assess differences in frequency of eating at school, adherence to the Mediterranean diet, participation in structured sport programmes and parental level of education in school-age children according to their adiposity status.

2nd PAPER:

Aim: This study aimed to evaluate differences between low active overweight and obese children in terms of energy expenditure, ventilation and cardiac response during graded submaximal treadmill testing at constant speed.

3rd PAPER:

Aim: To evaluate if the Nereu Programme would favourably impact on physical activity, sedentary behaviour and adiposity in low active overweight and obese children as a public health intervention tool for the management of children's obesity.

4th PAPER:

Aim: To evaluate the effectiveness of an intensive family-based behavioural multi-component intervention (NP) compared to counselling intervention (CG; advice on physical activity and dietary healthy behaviour) as a health centre intervention tool for the management of children's obesity.

METHODOLOGY

(Methodology summary used in the current Thesis)

The methods section of the present thesis is summarised in the table below, which includes the most relevant methodological information of the articles part of the present thesis.

Table 1. Methodology summary used in the current thesis

Article	Study Design	Participants	Sub-groups for comparison	Main variable	Methods (Instruments)/ References
1.1 Physical activity behaviour, aerobic fitness and quality of life in school-age children	Cross-sectional study	352 children aged between 8 and 13 years old (11.99 ± 1.5 years)	Gender (boys vs. girls) Adiposity (non-obese vs. overweight/obese)	- Body composition (weights, height, BMI z-score, BMI, WC and WHtR)	- Weight with weighing scale (SECA model 755, SECA Corp, Hamburg, Germany, 2006) - Height with Stadiometer (Añó Sayol, Barcelona, Spain) - BMI z-score with the LMS method (Pan & Cole, 2007)
				- Sedentary and physical activity behaviours	- 7-day recall physical activity Questionnaire (Sallis, et al., 1993)
				- Physical fitness test: 6-min walk tests (TM6) Medicine ball toss Standing broad jumps and Sit-Ups	Physical fitness test: - TM6 (Morinder, et al., 2009) - Medicine ball toss (Legido, Segovia, & Ballesteros, 1995) - Standing broad jumps and Sit-Ups (EUROFIT, 1989)
				- HRQOL	- EQ-5D-Y (Gusi, et al., 2009)
1.2 How important is focalising on a healthier lunch at school?	Cross-sectional study	352 children aged between 8 and 13 years old (11.99 ± 1.5 years)	Gender (boys vs. girls) Adiposity (non-obese vs. overweight/obese)	- Body composition (weights, height, BMI z-score, BMI, WC and WHtR)	- Weight with weighing scale (SECA model 755, SECA Corp, Hamburg, Germany, 2006) - Height with Stadiometer (Añó Sayol, Barcelona, Spain) - BMI z-score with the LMS method (Pan & Cole, 2007)
				- Dietary habits Adherence to the Mediterranean diet Frequency of eating at school	 - Serra-Majem, Aranceta-Bartrina & Rodríguez-Santos, 2003 - Structured questionnaire
				- Sport practice	- Structured questionnaire
				- Parental education level	- Structured questionnaire

2. ***Energy Expenditure in Low Active Overweight and Obese Children at Varying Treadmill Grades***	Cross-sectional study	20 overweight and obese low active children aged between 8 and 12 years old (10.1 ± 1.4 years)	Gender (boys vs. girls) Adiposity (obese vs. overweight)	- Body composition (weights, height, BMI, BMI z-score, BSA, FM, FMM)	- Weight with weighing scale (SECA model 755, SECA Corp, Hamburg, Germany, 2006) - Height with Stadiometer (Añó Sayol, Barcelona, Spain) - BMI z-score with the LMS method (Pan & Cole, 2007) - BSA (Gehan & Georges, 1970) - BIA (Promis Body Composition) - FM and FMM (Cole & Cole, 1941)
				- Submaximal treadmill test Measured: HR,VO2, VCO2, RER, VE - Calculated: EE, VE/VO2, VE/VCO2)	- HR (Polar electro YO, Kempele, Finland) - VO2, VCO2, RER, VE: Indirect calorimetry System (VO2000; Medical Graphics Corporation, St. Paul's, Minnesota) - EE (Robergs & Roberts, 1997)
3. ***Multidisciplinary friendly and uncompetitive behavioural intervention in public health for the management of sedentary and overweight or obese children: Nereu Programme***	Longitudinal prospective study with post-test at 9 months	86 overweight and obese low active children aged between 8 and 12 years old (10.65±2years)	Gender (boys vs. girls) Adiposity (obese vs. overweight) Age	- Body composition (weights, height, BMI, BMI z-score, Body fat distribution)	- Body fat distribution (Promis Body Composition; Promis Corp, Puerto de Santa Maria, Spain) - BMI z-score (Cole, & Green, 1992)
				- Sedentary and physical activity behaviours	- 7-day recall physical activity Questionnaire (Sallis, et al., 1993)
				- Adherence to the intervention	- Registered by the instructor
				- Satisfaction	- Structured questionnaire
4. ***Evaluation of a family intervention programme for the treatment of overweight and obese children (Nereu Programme): a randomised clinical trial study protocol***	Randomised clinical trial study protocol	At least 100 overweight and obese low active children aged between 8 and 12 years old	Not measured in the article	- Presented in Table 3. Measurements of the article	- Presented in Table 3. Measurements of the article

BIA: bioelectrical impedance analysis; BMI: Body Mass Index; BMI z-score: Body Mass Index Standard deviation; BSA: Body surface area; EE: Energy expenditure; FM: Fat Mass; FFM: Free Fat Mass; HR: Heart Rate; HRQOL: Health related quality of life; PC: Physical Condition; VO2: Oxygen consumption; VE: Ventilation; VE/VO2: Ventilatory equivalents for VO2; VE/VCO2: Ventilatory equivalents for VCO2; RER: Respiratory exchange ratio; WC: Waist circumference; WHtR: Waist-to-height ratio.

RESULTS

(Compendia of articles)

1.1 st ARTICLE:

Physical activity behavior, aerobic fitness and quality of life in school-age children

This article has been accepted and it will published in the Procedia - Social and Behavioural Sciences (WCES, 2014)

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Physical activity behavior, aerobic fitness and quality of life in school-age children

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Abstract

The aim of this article is to assess the differences in sedentary and physical activity behavior, physical fitness and quality of life in school-age children according to their adiposity state (BMI z-score) and gender. 352 children participated in the study (11.99 ± 1.5 years). Children were assigned to a normal weight group (NW) (n=175) or to an overweight/obese group (OW/OB) (n=177). The percentage of OW/OB was significantly superior ($p<0.05$) in boys (55.4%) than in girls. Boys reported spending 2:19h/week (sd= 2:33; $p<0.01$) watching TV and 3:21h/week (4:28; $p<0.001$) more than girls practicing moderate-high intensity physical activity. In contrast, in weight groups differences appeared only at high intensity activities to which NW children devoted 52minuts/week (2:33; $p<0.01$) longer than OW/OB children. NW and OW/OB groups

presented significant ($p<0.05$) differences in all the physical fitness tests, except for the medicine ball toss one. Children´s involvement in at least three hours a week of physical activity were associated to a lower prevalence of overweight or obesity, and to higher physical fitness in children.

Keywords: children, school, quality of life, sport practice, physical fitness

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Introduction

Childhood obesity has mainly been attributed to factors related to lifestyle (Ballabriga & Carrascosa, 2001), specifically to the lack of physical activity and to unhealthy eating (ACSM, 1999; Fullana, Momparler, Quiles, & Redondo, 2009). This excess of weight is associated with an overload of the musculoskeletal system, an increase in the prevalence of cardiovascular risk factors, psychological and social problems. Obesity can also lead to having a poor body image and a sense of inferiority and rejection (Serra & Aranceta, 2002).

This has important health, social and economic consequences. It is important to know how obesity affects children of school age. In that sense, the aim of the study is to assess the differences in sedentary conduct and physical activity behavior, and in physical fitness and quality of life in school-age children according to their adiposity state (BMI z-score) and gender.

Method

This is a cross-sectional study that took place in several schools in Lleida, Catalonia. Eligible participants were children aged between 8 and 13 years old that attended these schools. Before proceeding with the measures, informed parental and children consent and authorization from their schools was obtained. All procedures were conducted in accordance with the Declaration of Helsinki and its subsequent revisions.

Waist circumference, waist-to-height ratio and body mass index (BMI) measures were collected as anthropometric parameters. Children were grouped as overweight/obese (OW/OB) or normal weight (NW) based on their BMI z-score according to the LMS method (Pan & Cole, 2007). Sedentary and physical activity behaviors were assessed with a modified version of the 7-day recall physical activity questionnaire, which had previously been validated for children (Sallis, Buono, Roby, Micale, & Nelson, 1993). Following Ainslie, Reilly & Westerterp (2003) recommendations, the activities were classified according to their metabolic cost as sedentary, light, moderate and high-intensity. The physical fitness test comprised aerobic endurance (6 minutes walking test) (Morinder, Mattsson, Sollander, Marcus & Larsson, 2009), medicine ball toss (Legido, Segovia, & Ballesteros, 1995), standing broad jumps and sit-ups (EUROFIT, 1989). The children's health related quality of life (QoL) was assessed by means of the Spanish version of the EQ-5D-Y (Gusi, Badía, Herdman, & Olivares, 2009).

Data analysis

All statistical analyses were conducted with SPSS version 15.0 (SPSS Inc., Chicago, IL, 2007). Data are reported as mean ± standard deviations (SD). Student t-test was used to compare independent samples (NW versus OW/OB and girls versus boys). Statistical significance was set at $p<0.05$.

Results

The main anthropometric results are presented in table 1. More than half (55.4%) of the boys were OW/OB. For girls, this percentage was also high (44.6%) but significantly lower ($p<0.05$) than in boys. Nevertheless, between genders, no differences in any other anthropometric parameter were observed.

On the other hand, as it could be expected all the adiposity parameters, were significantly ($p<0.001$) higher in OW/OB children compared to their NW peers.

Table 1. Anthropometric parameters of participants.

	Boys (n=184) Mean±SD	Girls (n=168) Mean±SD	Non-Obese (n=175) Mean±SD	Overweight/Obese (n=177) Mean±SD
Age (years)	12.02±1.45	11.90±1.50	12.10±1.33	11.82±1.58
Weight (kg)	50.28±13.06	48.62±12.13	41.80±7.60	57.08±12.03 δδδ
Height (cm)	1.53±0.11	1.51±0.09	1.51±0.09	1.53±0.11
BMI (kg/m^2)	21.35±4.15	21.10±4.10	18.12±1.63	24.31±3.47 δδδ
BMI z-score (units)	1.11±1.07	0.93±1.03	0.16±0.56	1.88±0.64 δδδ
Waist circumference (cm)	76.84±11.70	75.44±11.13	68±5.53	84.25±9.92 δδδ
Waist-to-Height ratio (cm/m)	50.39±7.48	49.93±6.80	44.98±2.73	55.30±6.43 δδδ

BMI: body mass index; δδδ p<0.001 Significantly different in respect to normal weight

As shown in table 2, boys devoted more time than girls to watching TV (2:19 ± 2:33 h/week; p<0.01) and in physical activities as moderate and high (MH) intensity activities (3:21 ± 4:28 h/week; p<0.001). However, girls spend more time into light intensity activities (3:29 ± 7:21h/week; p<0.001) than boys. In contrast, among adiposity groups, differences were observed only at high intensity activities, where NW children spent 52 minutes/week (2:33; p<0.01) longer than OW/OB children. There was a modest but significant correlation (p<0.01) between BMI z-score and TV-time (r = 0.168) and high (r = -0.245) or MH (r = -0.133) intensity activities.

Table 2. Sedentary and physical activity behaviors.

	Boys (n=184) Mean±SD	Girls (n=168) Mean±SD	Non-Obese (n=175) Mean±SD	Overweight/Obese (n=177) Mean±SD
TV time (h/w)	15.83±9.01	13.51±7.90**	14.26±7.69	15.19±9.35
Computer time (h/w)	9.28±9.18	9.06±8.19	9.66±8.74	8.70±8.68
Sedentary intensity (h/w)	123.20±12.68	125.54±11.91	123.97±11.83	124.67±12.88
Light intensity (h/w)	8.62±7.35	12.10±8.06***	9.88±7.29	10.68±8.43
Moderate intensity (h/w)	8.10±6.98	5.60±5.40***	7.16±6.28	6.66±6.51
High intensity (h/w)	2.93±2.76	2.08±2.63*	2.96±2.99	2.09±2.36 δδ
Moderate-High intensity (h/w)	11.03±7.70	7.68±6.22***	10.12±7.35	8.75±7.04

h/w: hours per week ; *** p<0.001; ** p<0.01; * p<0.05 Significantly different in respect to boys.

δδ p<0.01 Significantly different in respect to normal weight children.

Boys and girls presented similar results in the physical fitness tests (table 3), apart from the sit-ups, where boys did 1.69 (2.49; p<0.05) extra sit-ups compared to the girls. OW/OB children achieved lower results than their NW peers in all physical condition tests where weight was a determinant of performance. In contrast, no differences were observed in the medicine ball toss test.

Table 3. Physical fitness test results.

	Boys (n=184) Mean±SD	Girls (n=168) Mean±SD	Non-Obese (n=175) Mean±SD	Overweight/Obese (n=177) Mean±SD
Medicine ball toss (cm)	3.59±1.22	3.56±1.26	3.55±1.29	3.60±1.18
Sit-ups (n)	22.42±6.01	20.73±6.42**	22.57±5.66	20.74±6.66 $^{\delta\delta\delta}$
Standing broad jump (cm)	1.36±0.40	1.35±0.37	1.40±0.42	1.32±0.34 $^{\delta}$
Aerobic endurance (m)	478±127	467±118	511±108	437±125 $^{\delta\delta\delta}$

** p<0.01 Significantly different in respect to boys

$^{\delta\delta\delta}$ p<0.001; $^{\delta}$ p<0.05 Significantly different in respect to non-obese

Apart from the data where all participants were pooled together, several differences within gender groups were observed between OW/OB and NW children. The prevalence of obesity was higher among boys, where 55.4% (n=102) of them were OW/OB, while the proportion of NW was 44.5% (n=82). Surprisingly, OW/OB boys showed similar results to NW ones in sedentary conduct, physical activity behavior, the medicine ball toss, sit-ups, standing broad jumps and QoL tests. Both groups only differed on the aerobic endurance test results, where NW children obtained better scores compared to their OW/OB peers (531.49±103.45 meters vs. 438.18±128.71 meters; p<0.001, respectively).

In contrast, more differences were observed between NW and OW/OB girls. The percentage of OW/OB girls was high (44.6%; n=75), but slightly lower than in boys. The rest, 55.4% (n=93) were NW. Compared to NW girls, OW/OB girls devoted more weekly time to light intensity physical activities (10.87±6.96 h/week vs. 13.62±9.06 h/week; p<0.028) and less weekly time to high intensity activities (2.70±3.06 h/week vs. 1.31±1.68 h/week; p<0.001). They obtained lower results in the sit-ups (22.12±5.50 vs. 19.11±7.05 number; p<0.003) and the aerobic endurance test (494.29±110 meters vs. 435.72±119.66 meters; p<0.002).

No differences in QoL scores were observed between groups determined by gender or by adiposity, the mean of the total score for the whole group being 80.45±17.22 over 100.

For the whole group, correlation analysis between adiposity parameters and TV-time showed a significant positive correlation and a significant negative correlation with physical activity behavior (time devoted to high or MH physical activities). Adiposity parameters also showed a significant negative correlation with the physical fitness test, except in the medicine ball toss test.

Discussion

The main finding of the study is the discrepancy found in sedentary conducts and physical activities when comparisons were made between gender and weight groups or subgroups of gender and weight. Differences were found when comparing boys and girls. Unexpectedly, differences between weight groups were almost inexistent and the only difference was nearly 1 hour/week extra of high intensity activities in the NW group in relation to the OW/OB group. However, surprisingly, when children were subdivided into NW vs. OW/OB boys, no differences were found. However, we still observed them when comparing NW vs. OW/OB girls. The present discrepancies are probably reflecting the results existing in the literature about the influence, or not, of sedentary and physical behavior in the degree of obesity in children. On the one hand, OW/OB children seem to be less active than NW children (Page et al., 2005). On the other hand, no difference between them was found (Ebenegger et al., 2012; Ortega, 2007). In preschool children, this controversy has already been mentioned (Metallinos-Katsaras, Freedson, Fulton & Sherry, 2007; Trost, Sirard, Dowda, Pfeiffer, & Pate, 2003). Due to design limitations, it is not possible to conclude a cause-effect relationship. However, it could be suggested that some of these discrepancies could account for the differences existing between NW vs. OW/OB boys and NW vs. OW/OB girls, as observed in the present study.

In relation to their physical fitness, several differences were also found when all the groups were compared. Probably, it is difficult to explain these differences bearing only in mind weight and gender. According to Klein Fröhlich & Emrich (2013), other characteristics should be taken into account (socio-economic status, living situation, leisure behavior, school performance). However, the biggest difference between the groups seems to be their aerobic endurance.

Despite the existing controversy, data could indicate that it is necessary that OW/OB children change their lifestyle into a more active one, increasing at least one hour longer of high physical activity intensity a week. It could be a good tool to reduce obesity and help their physical fitness, reducing the possibility of several health diseases in their youth and adult life (Delgado, Gutiérrez, Castillo, 1999).

Children's behavior was self-reported by children and this could be in itself a limitation, as non objective measures could be not recorded. However, the tests were specific for children and it was a self-administered version. In addition, the data was collected with their teachers´ help and with experimented and formed collaborators.

Conclusion

Practicing at least three hours a week of physical activity is associated to a lower prevalence of overweight or obesity and to higher physical fitness in school ages.

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The authors are grateful to all the schools, children and their families for their participation, to the colleagues in Programa Nereu (Lleida, Catalonia) for their valuable contributions and the IDIAP – Jordi Gol Foundation. This study was supported by a grant from the Institute of Physical Education of Catalonia (INEFC), University of Lleida, Spain, (PRE/2730/2012, de 4 de desembre, DOGC NÚM. 6272 – 12.12.2012)

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1.2 nd ARTICLE:

How important is focalizing on a healthier lunch at school?

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How important is focalizing on a healthier lunch at school?

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Abstract

The aim is to assess the differences in frequency of school lunches, the adherence to the Mediterranean diet, sport practice and the parents' educational level in school-age children according to their weight status. 352 school-age children recruited from schools in Catalonia participated (11.99 ± 1.5 years). Body weight status groups were grouped as follows: overweight and obese (OW/OB; n=175) versus normal weight (NW; n=177). The percentage of NW children who had school lunches on weekdays was significantly ($p < 0.001$) higher than the percentage of peer children with OW/OB. The percentage of OW/OB children who reported to practice structured sport was significantly lower ($p < 0.05$) than in the NW children group and the mean time spent on it as well (2.05 ± 2.36 vs. 2.99 ± 3.03 hours/week; $p < 0.001$, respectively). No differences were found in the parental studies or the Mediterranean diet variable between groups. The results support the role of the educator at school and it is

suggested that a healthy and regulated food supply could favor lower adiposity in children. Promoting physical exercise at school could also help with the degree of obesity.

Keywords: children, school, eating, parental studies, sport practice

Introduction

Obesity is a chronic disease associated with negative effects on health. It is considered a risk factor for many diseases such as hypertension, type II diabetes, locomotor disorders, and it increases the risk of cardiovascular events considerably. In addition, obese children also have to face social problems (Salas-Salvadó et al., 2007) that can be important, especially at school age.

Moreover, childhood obesity seems to be refractory to treatment, subsequently obese children are more likely to be obese in their adult life than non-obese ones (WHO, 2014). Obesity is mainly attributed to an energy imbalance thus the acquisition of good eating habits and physical activity, together with healthy habits are central for the prevention and treatment of obesity. Childhood is the best time to acquire these behaviors/habits, which might persist during adulthood. The school setting is a suitable place to acquire them by means of specific curricular content, as well as offering children and their families the opportunity to be engaged in healthy eating and in structured physical activities. In this regard, it is essential to know the habits of children, to create specific programs for the management of obesity in school-age children.

In that sense, the aim of the present research is to assess the differences in frequency of eating at school, adherence to the Mediterranean diet, participation in structured sport programs and the parental level of education in school-age children according to their adiposity status.

Method

This is a cross-sectional study that took place in several schools of Lleida, Catalonia. Eligible participants were children aged between 8 and 13 years old who attended regular schooling. Before proceeding with the measures, informed parental and children consent and authorization from their schools were obtained. All procedures were conducted in accordance with the Declaration of Helsinki and its subsequent revisions.

Body weight and height were collected to determine their body mass index (BMI), which was calculated as weight (kg) divided by height squared (m^2). The children were divided into two groups: overweight or obese (OW/OB) versus normal weight (NW)) based on BMI z-score following the LMS method (Pan & Cole, 2007). Waist circumference and waist-to-height ratio were also measured as adiposity variables. Frequency of eating at school, adherence to the Mediterranean diet (Serra-Majem, Aranceta-Bartrina & Rodríguez-Santos, 2003), participation in structured sport (SS) practice and the parental education level (classified as low, medium and high level) were all assessed by self-reported questionnaires. All measures were taken at school during physical education classes.

Data analysis

All statistical analyses were conducted with SPSS version 15.0 (SPSS Inc., Chicago, IL, 2007). Descriptive data are reported as mean ± standard deviations (SD).

Student t-test was used to compare independent samples (NW versus OW/OB and girls versus boys). Frequency differences were evaluated using corresponding x^2-techniques. To analyze the influence between the variables and the different adiposity parameter, a Pearson correlation was conducted. Statistical significance was set at $p < 0.05$.

Results

In the study, 352 voluntary school-age children participated (11.99 ± 1.5 years) distributed in 184 boys and 168 girls. The OW/OB group consisted of 175 children and 177 children in the NW one. As table 1 shows, all adiposity parameters were superior ($p<0.001$) in the OW/OB group. No differences in adiposity parameters were observed between boys and girls.

Table 1. Anthropometric data of participants.

	All (n=352) Mean±SD	Non-Obese (n=175) Mean±SD	Overweight/obese (n=177) Mean±SD
Age (years)	11.95±1.47	12.10±1,33	11.82±1.58
Weight (kg)	49.48±12.64	41.80±7.60	57.08±12.03*
Height (cm)	1.52±0.10	1.51±0.09	1.53±0.11
BMI (kg/m^2)	21.23±4.112	18.12±1.63	24.31±3.47*
BMI z-score (units)	1.02±1.05	0.16±0.56	1.88±0.64*
Waist circumference (cm)	76.17±11.43	68±5.53	84.25±9.92*
Waist-to-Height ratio (cm/m)	50.17±7.15	44.98±2.73	55.30±6.43*

BMI: body mass index. * $p<0.001$

During weekdays, the percentage of NW children (76.4%) who had lunch at school was significantly ($p<0.001$) higher than in their OW/OB peer group (55.7%). Eating at school also differed between genders, where 58.3% of boys had lunch in school, meanwhile this percentage raised to 75.6% for the girls ($p<0.01$). However, results from the adherence to Mediterranean diet indicate that 43.4% of NW and 41.8% of OW/OB children had poor adherence and no differences were observed between adiposity groups or between genders.

The percentage of OW/OB children (53.7%) who reported to participate in SS programs was significantly lower ($p<0.05$) than in NW children (65.1%). Moreover, the weekly time devoted to them was also lower in OW/OB children (2.99±3.03 vs. 2.05±2.36 hours/week; $p<0.001$, respectively). As figure 1 shows, children who practice more sport are less fat than children who devote less time to sport practice. Parental studies did not differ between groups in any of the 3 classified categories.

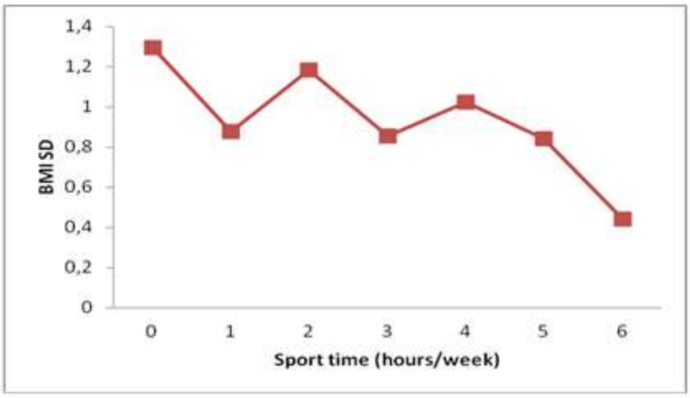

Figure 1. Relationship between BMI z-score and weekly time devoted to sport.

Correlation analysis shows modest but significant correlations between adiposity parameters and having lunch at school, SS and parental education. Having lunch at school was the most significant correlated variable with the BMI z-score (r=0.277; p<0.001). However, it was higher in relation to Waist-to-Height Ratio (r=0.336; p<0.001). Adherence to the Mediterranean diet did not correlate with adiposity parameters.

Table 2. Correlations between the analyzed variables and different adiposity parameters

	BMI z-score	Waist Circumference	Waist-to-Height Ratio
Eating at school	-.277*	-.223*	-.336*
Sport practice	-.220*	-.271*	-.270*
Sport time (hour/week)	-.259*	-.321*	-.297*
Father Education level	-.205*	-.304*	-.232*
Mother Education level	-.203*	-.275*	-.204*
Mediterranean Diet	-.02	-.062	.01

*p<0.001

Discussion

The increasing prevalence of childhood obesity is attributed to a behavior modification during the last few years due, mainly, to a shift to more caloric intake, associated also with a decrease in the time spent on physical activity (Andersen &

Mechelen, 2005). The present results reported that OW/OB children practice less SS than NW children and they are in accordance with the results found by other authors (Eisenmann, DuBose, & Donnelly, 2007). However, no differences between genders or obesity degree groups were found in the Mediterranean diet. This could be due because they do not exist or despite the questionnaire being specific for assessing the adherence to the Mediterranean diet in Spanish children, but it could not be detailed enough to evaluate the caloric intake.

Data from that study puts forward the idea that having lunch at school is associated with a lesser degree of adiposity. Due to design limitations, it is not possible to infer a cause-effect relationship, however it could be suggested that eating at school might play a beneficial role on eating behavior. It remarks the importance of following healthier habits at school and the important role that schools have in the prevention and treatment of childhood obesity. Not only with regards to the diet intake, but also offering physical activity opportunities and helping children to take healthier options. These results are in accordance with the main focus of most of the guidelines for the prevention of childhood obesity. These guides are principally based on strategies for improving diet intake, reducing sedentary behavior and offering opportunities for increasing activity levels and the majority of these strategies focus on the prevention or/and intervention at schools (Grupo de trabajo de la Guía de Práctica Clínica sobre la Prevención y el Tratamiento de la Obesidad Infantojuvenil, 2009).

Several studies report that the lower the socio-economical level of the parent, the higher the level of obesity. However, in the present results these differences were not appreciated, nonetheless it was correlated with the anthropometric parameters. These results are partially in accordance with data from the AVENA study (Moreno et al., 2004). They did not find any difference in socio-economical status and obesity prevalence in girls, however differences were found in boys. The lowest obesity prevalence was observed in both extreme socio-economic groups. Their results remark that obesity prevalence increases as the socio-economic status decreases.

The data were self-reported by the children, which could be a limitation. However, the tests were specific for children and to be self-administered. In addition, the data was collected with their teachers´ help and with experimented and formed collaborators

Conclusion

Although it is a cross-sectional study, the results support the role of the educator at school and it is suggested that a healthy and regulated food supply could favor lower adiposity in school-age children. Promoting or/and offering physical exercise at school could also help manage the degree of obesity.

Acknowledgements

The authors are grateful to all the schools, children and their families for their participation, to the colleagues in Programa Nereu (Lleida, Catalonia) for their valuable contributions and the IDIAP – Jordi Gol Foundation. This study was supported by a grant from the Institute of Physical Education of Catalonia (INEFC), University of Lleida, Spain, (PRE/2730/2012, de 4 de desembre, DOGC NÚM. 6272 – 12.12.2012)

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2nd ARTICLE:

Energy Expenditure in Low Active Overweight and Obese Children at Varying Treadmill Grades

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Energy Expenditure in Low Active Overweight and Obese Children at Varying Treadmill Grades

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Abstract

This study aimed to evaluate differences between low active overweight and obese children in terms of energy expenditure (EE), ventilation (VE), and cardiac response during graded submaximal treadmill testing at constant speed. We categorized 20 children into two weight groups according to the International Obesity Task Force criteria: overweight (n=10; age=9.7 ±1.34 years) and obese (n=10; age=10.4±1.4 years). Children performed treadmill testing at a constant speed (1.53 $m \cdot s^{-1}$) and increasing grade (0%, 4%, and 8%), every 3 min. The EE across all grades was significantly higher ($p<0.001$) in obese than in overweight children. Differences at each grade disappeared when EE was adjusted by body mass; however, several differences remained when the EE was adjusted by fat-free mass or body surface area. The increase in EE with increasing grade was greater in obese children (effect size between 0% and 8% for EE was 1.17). BMI z-score and fat mass (kg) were the main predictors of EE ($Kcal \cdot min^{-1}$) and contributed to explaining 66%, 70% and 83.4% of the variance in EE at 0%, 4% and 8% gradients respectively. We suggest that when assessing EE response to exercise, the degree of obesity should be taken into consideration.

Keywords: Obese, overweight, treatmil test, children, energy expenditure, ventilation

Introduction

Research suggests that obesity has become the most prevalent disease in developed countries (38) and that its prevalence continues to rise. Obesity is a chronic disease associated with a significant negative impact on health and quality of life. In general, childhood obesity is associated with a greater risk of obesity in adulthood (36), and with the development of weight-related comorbidity and increased mortality (19). These conditions can be counteracted with regular exercise (20). Indeed, the World Health Organization (WHO) (37) states that there is strong evidence to support regular physical activity as an important modifying factor for obesity-related increased mortality and morbidity.

According to Ravussin and Gautier (26), although the etiology of obesity is complex, the most important factor in childhood is the long-term imbalance between energy intake and energy expenditure (EE). Therefore, the amount of energy expended in physical activity plays a significant role in both the prevention of weight gain and the process of weight reduction (25). A shift in behaviour towards a sedentary lifestyle and decreased physical activity is central to the development of childhood obesity (8, 33). Compared with their normal weight peers, obese children spend less time engaged in moderate physical activity during the day such as walking, and more time in sedentary behaviors (12). An increase in EE through physical activity can lead to a negative energy balance, thus enabling a loss of body mass. Aerobic exercise is a key factor in weight reduction and is widely used to control childhood obesity (21).

Body mass and body composition are major predictors of EE, particularly in weight bearing activities such as walking or running (39). According to Zakeri et al. (39) the relationship between EE and body mass cannot be fully explained by a linear model. They observed that at low levels of exertion (i.e., walking), accounting for body composition did not eliminate the interaction of EE with body mass status. They also noted that, in overweight children, the contribution of body mass to EE was greater than in normal weight children. However, most studies focus on the comparison of EE between obese and lean or normal weight children (25, 35). To our knowledge, few studies have investigated EE at different submaximal aerobic exercise intensities while taking into account the degree of obesity (overweight versus obese) (10). In obese adolescents, even a small weight reduction increases walking economy (i.e., a reduction in EE at different walking speeds) (22). The lack of consistent EE in obese children may be partly explained by the lack of control over factors such as the degree of obesity (1).

It has also been reported that obese children have greater difficulties adapting to physical exercise in absolute terms. This is reflected in higher ventilation parameters (16, 30) and heart rates than in their non-obese peers during exercise of equal intensity. Several studies have also shown that obese children are less fit than their normal weight peers, regardless of sex (5, 9). This difference is probably due to their extra fat mass and the resulting increase in load, thereby preventing physical activity.

Knowing the EE for physical activity according to weight will allow a better estimation of daily EE, thereby facilitating the development of more accurate recommendations for caloric ingestion. In addition, it will help physical activity instructors to design workouts adapted to planned EE goals. EE data have been established for physical activity in adults, but only minimal data are available for children; what is more, most of these data were obtained from normal weight children (28). EE has been evaluated in obese youngsters while performing different physical exercise activities, including walking outdoors at 4-5 $km \cdot h^{-1}$ (34), but neither the effect of a vertical component (grade) nor the impact of the degree of adiposity on walking EE have been examined.

The present study aimed to assess the differences in EE, pulmonary response, and cardiac response between overweight and obese children with low levels of activity. The research comprised submaximal treadmill testing at constant speed and different inclines. Differences at each treadmill inclination were considered in terms of both the absolute values and the values relative to body mass.

Methods

This is a cross-sectional study where overweight and obese children with low levels of activity performed a walking treadmill test at a constant speed with increasing grades.

Participants

Twenty white European children (mean age 10.1 ± 1.4 years; overweight, n = 10; obese, n = 10) from the Paediatric Health Services took part in the study. Participants were aged between 8 and 12 and were overweight or obese. Overweight and obese groups were determined according to the body mass index (BMI) standard deviation (SD) score (the BMI z-score) following the LMS method (22) based on the International Obesity Task Force (IOTF) criteria defined by Cole et al (3). Children were also required to report low levels of activity (less than 3 hours per week of physical activity outside school hours), as established in the questionnaire by Serra-Majem and Aranceta (32), which is specific for Spanish children between the ages of 4 and 14 years. Patients with comorbidities or diseases that contraindicated physical exertion, patients with obesity related to endocrine or genetic disease, comorbid cardiac or neurological disorders, and those receiving any medication that could interfere with physical performance were excluded.

Prior to definitive inclusion, the children and their families were informed about the nature of the study, and written informed consent was obtained from the parents. The hospital ethics committee and institutional review board approved the study and procedures.

Procedure and Instruments

The treadmill test was performed at a constant speed of 1.53 $m \cdot s^{-1}$ (5.5 $km \cdot h^{-1}$) with an increasing incline. The grade increased every 3 minutes and was established at 0%, 4%, and 8% inclines. The test was initiated after a standardized period of habituation to the treadmill and a warm-up of 3 minutes. The speed and these grades were chosen because they represent moderate to vigorous intensity for the majority of children and, in theory, they were achievable for participants with low levels of activity.

During the test, the heart rate was measured using a chest heart rate monitor (Polar 610s; Polar electro YO, Kempele, Finland). The oxygen uptake (VO_2), carbon dioxide output (VCO_2), respiratory exchange ratio (RER), and ventilation (VE) were measured by means of breath-by-breath gas exchange using an indirect calorimetry system (VO2000; Medical Graphics Corporation, St. Paul's, Minnesota); the mean values from the last 30 seconds of each stage were used for the analysis. The VO2000 has demonstrated reliability and validity during rest periods and sub-maximal exercise intensities (4). For further analysis, the EE and its ventilatory equivalents were calculated. The EE was calculated using the following equation (29): EE ($kcal \cdot min^{-1}$) = VO_2 ($L \cdot min^{-1}$) × (RER × 1.232 + 3.815). The ventilatory equivalents were calculated from the relationship between the VE and VO_2 (VE/VO_2) and the VE and VCO_2 (VE/VCO_2). The tests were conducted by the same researchers under identical conditions for each child. Before each test, the gas analyzers were calibrated using gases of known concentration, while the flow meter was calibrated using a 3 L syringe. Body mass was measured with a weighing scale (Seca model 755, Hamburg, Germany; accuracy 0.05 g) and height was measured with a stadiometer (Añó Sayol, Barcelona, Spain). Participants were lightly dressed and barefoot. The body surface area (BSA) was calculated using the Gehan and George formula (7): BSA (m^2) = 0.02350 × $Ht^{0.42246}$ × $Wt^{0.51456}$, where Ht is height (cm) and Wt is weight (kg). Waist circumference was measured following the International Society for the Advancement of Kinanthropometry protocol (15). Body composition was estimated by multichannel bioelectrical impedance analysis (BIA); total body resistance and reactance were measured with a multisegmental and multifrequency bioelectrical impedance analyzer (Promis Body Composition; Promis Corp, Puerto de Santa Maria, Spain), where fat free mass (FFM) and fat mass (FM) are calculated using the Cole–Cole equation (2). The BIA has been shown to be valid and reliable for the assessment of body composition in children (11). Blood pressure was recorded on the right arm in the recumbent position using an automated digital sphygmomanometer. The children had rested for 5 minutes before measurement.

Participants were referred to the Functional Assessment Laboratory between 6:00 pm and 7:00 pm for their anthropometric assessment and for the subsequent exercise tests. They had been instructed to attend without having eaten during the previous four hours, and without having drunk or performed any physical exertion during the previous two hours. All participants confirmed their adherence to these requirements.

Statistical Analysis

The outcome variables EE and VE were expressed in both absolute values ($Kcal \cdot min^{-1}$; $L \cdot min^{-1}$) and values relative to body mass ($Kcal \cdot kg \cdot min^{-1}$; $mL \cdot kg \cdot min^{-1}$), fat free mass ($Kcal \cdot kgFFM^{-1} \cdot min^{-1}$; $mL \cdot kgFFM \cdot min^{-1}$), and body surface area ($Kcal \cdot min^{-1} \cdot m^{-2}$; $mL \cdot min^{-1} \cdot m^{-2}$). Descriptive data are presented as mean and SD. An independent sample *t*-test was used to examine the differences between overweight and obese children in anthropometric and exercise test variables.

Stability of VO_2 during the last 30 s of each stage was evaluated by subjective assessment of the graphic representation of VO_2 ($ml \cdot min^{-1}$) versus time during the treadmill test and by the coefficient of variation (CV) analysis of the data obtained during the last minute of the 8% gradient. To evaluate the interactions between the overweight and obese groups and the differences across intensity grades, we performed a mixed effects model with the random effects as the grades (0%, 4% and 8%) and the fixed effect as the adiposity group (overweight versus obese). Changes in outcome variables between different treadmill grades (0% versus 8%) were tested using the *t*-test for paired samples. Pearson correlations and linear regression models were used to test the relationships between parameters across the varying grades. The normality of residual distribution was checked using the Kolmogorov–Smirnov test. A $p\text{-value} < 0.05$ was considered significant. Data analysis was performed using SPSS statistical software (version 17.0, SPSS Institute Inc, Chicago, Illinois).

Results

The participant characteristics are shown in Table 1. The overweight group comprised 5 boys and 5 girls, and the obese group comprised 6 boys and 4 girls; the groups did not differ in mean age, sex distribution, and resting heart rate. Height and resting systolic and diastolic blood pressures were significantly higher in the obese group. As expected, all adiposity parameters were also significantly greater in the obese group. The FM/FFM ratio indicated that obese children carried 240 ± 83 g of extra FM per kg of FFM in comparison to the overweight children, but the difference was not statistically significant (p = 0.8).

Table 1. Anthropometric characteristics of participants.

Variable	Overweight (n=10) Mean ± SD	Obese (n=10) Mean ± SD	Group effect p-value
Age (years)	9.7±1.3	10.4±1.4	0.273
Height (cm)	142.1±7.9	152.9±7.7	0.006
Body mass (kg)	44.3±8.1	67.1±9.9	<0.001
BMI (kg/m^2)	21.8±1.7	28.5±2.3	na
BMI z-score (Units)	1.76±0.35	2.81±0.33	na
Waist Circumference (cm)	74.5±15.7	96.0±7.9	<0.001
FM (kg)[a]	14.2±5.5	27.6±7.9	<0.001
FFM (kg) [a]	31.1±3.9	39.6±4.2	<0.001
Body Fat (%)[a]	30.6±7.8	40.4±6.8	0.006
Central Fat (%)[a]	31.0±9.5	46.6±4.5	<0.001
BSA (m^2)	1.49±0.16	1.84±0.16	<0.001
HR rest (bpm)[a]	71±10.3	75±9.52	0.440
SBP rest (mmHg)	99.6±11.8	114.4±8.1	0.004
DBP rest (mmHg)	57.9±4.7	71.8±4.9	<0.001

SD (Standard Deviation) – BMI (Body Mass Index) – FM (Fat Mass) – FFM (Free Fat Mass) – BSA (Body surface area) **-** HR (Heart Rate) – SBP and DBP (Systolic and Diastolic Blood pressure).
na (Not applicable)
[a] n=9, in the overweight group

Stability of VO_2 was confirmed by visual inspection and the CV analysis (mean CV 3.0% ± 5.4%). Furthermore, the variability was lower than the differences noted between gradients (19% between the 4% and 8% gradients for absolute VO_2) or between adiposity groups (52% between overweight and obese groups for VO_2 at the 8% gradient) (Table 2).

Absolute VO_2, EE, and VE values were significantly higher in obese than in overweight children at each grade. Additionally, obese children had significantly higher

HR levels at the 0% and 4% gradients, but not at 8%. In contrast, when RER and ventilatory equivalents were assessed, no differences were observed between groups (Table 2).

The EE relative to body mass (Kcal·kg^{-1}·min^{-1}) did not differ between obese and overweight children at any grade (Table 2). However, despite adjustment of the EE by FFM (Kcal·kg^{-1}FFM·min^{-1}) and BSA (Kcal·min^{-1}·m^{-2}), differences were still observed between obese and overweight children at each grade (Table 2). In contrast, when VE was normalized for total body mass (ml·kg^{-1}·min^{-1}), FFM (ml·kg^{-1}FFM·min^{-1}), or BSA (ml·min^{-1}·m^{-2}), differences between groups were only significant for VE/FFM and VE/BSA at the 8% grade, as shown in Table 2.

Table 2. Physiological and cardiorespiratory variables in 10 overweight and 10 obese children at 3 grades during treadmill testing.

Variable/Grade	Overweight (n=10)	Obese (n=10)	Group effect P value [a]	Grade x Adiposity P value [b]
	Mean ± SD	Mean ± SD		
VO_2 (ml·min^{-1})				
0 %	690±171	1110±161	<0.001	
4 %	877±157	1340±173	<0.001	<0.033
8 %	1049±183	1601±188	<0.001	
RER				
0%	0.81±0.06	0.80±0.10	0.756	
4%	0.86±0.06	0.86±0.07	0.896	0.710
8%	0.9±0.06	0.90±0.05	1	
EE (Kcal·min^{-1})				
0 %	3.32±0.80	5.33±0.77	<0.001	
4 %	4.28±0.76	6.54±0.88	<0.001	0.019
8 %	5.16±0.86	7.89±0.95	<0.001	
EE/kg (Kcal·kg^{-1}·min^{-1})				
0 %	0.07±0.02	0.08±0.01	0.442	
4 %	0.1±0.01	0.1±0.01	0.791	0.709
8 %	0.12±0.01	0.12±0.01	0.504	
EE/FFM (Kcal·kgFFM^{-1}·min^{-1})				
0 %	0.11±0.02	0.13±0.02	0.027	
4 %	0.14±0.02	0.17±0.03	0.045	0.292
8 %	0.17±0.02	0.20±0.02	0.008	
EE/BSA (Kcal·min^{-1}·m^{-2})				
0 %	2.23±0.55	2.89±0.39	0.006	
4 %	2.86±0.37	3.56±0.51	0.002	0.941
8 %	3.46±0.40	4.28±0.35	<0.001	
VE (L·min^{-1})				
0%	16.31±3.84	24.16±5.20	<0.001	
4 %	21.82±4.04	31.36±6.52	<0.001	0.968
8 %	26.43±4.25	39.35±6.33	<0.001	
VE/kg (L· kg^{-1}·min^{-1})				
0 %	0.37±0.09	0.36±0.08	0.834	
4 %	0.5±0.09	0.47±0.10	0.571	0.807
8 %	0.6±0.07	0.59±0.72	0.709	

VE/FFM (ml·kgFFM^{-1}·min^{-1})				
0 %	0.57±0.08	0.62±0.14	0.300	
4 %	0.74±0.14	0.80±0.19	0.438	0.172
8 %	0.86±0.10	1±0.17	0.051	
VE/BSA (ml·min^{-1}·m^{-2})				
0 %	10.96±2.54	13.12±2.69	0.081	
4 %	14.65±2.50	17.02±3.29	0.086	0.882
8 %	17.71±1.97	21.30±2.54	0.002	
VE/VO$_2$				
0%	23.76±1.62	21.69±3.07	0.075	
4%	24.99±3.21	23.28±2.77	0.220	0.258
8%	25.35±2.20	24.52±1.83	0.371	
VE/VCO$_2$				
0%	27.90±4.36	27.23±2.40	0.676	
4%	28.01±2.36	26.93±2.30	0.313	0.636
8%	28.07±1.37	27.16±1.81	0.220	
HR (beats/min)				
0 %	119±10.15	131±9.90	0.017	
4 %	124±11.02	145±13.92	0.002	0.009
8 %	152±17.61	161±10.37	0.160	

[a] P value Significance by Independent T-Student Sample

[b] P value Significance by mixed effects model analysis of the main effects of grade and adiposity groups.

SD (Standard Deviation) - HR (heart rate) - VO_2 (oxygen consumption) - FFM (Free Fat Mass) - BSA (Body surface area) - VE (ventilation) – EE (energy expenditure) – RER (respiratory exchange ratio), VE/VO_2 and VE/VCO_2 (ventilatory equivalents for VO_2 and VCO_2, respectively).

As expected, nearly all outcome variables increased significantly in both groups as the treadmill grade increased (Table 2). The increases in absolute VO_2, EE and HR differed between overweight and obese children as shown by the significance of the interaction between the grade effect and adiposity effect (Table 2). This increase was more pronounced in obese children with a relatively large effect size, in particular for EE and VE (Table 3). Conversely, when EE and VE were adjusted by body mass, FFM, or BSA the increase with increasing grade did not differ between the obese and overweight groups, as suggested by the lack of interaction between the grade effect and the adiposity effect (Table 2), as well as by the non-significant effect size (Table 3). For ventilatory equivalents and HR, the magnitude of increase was also similar in the two groups, as shown in Table 3.

Table 3. Changes in energy expenditure and cardiorespiratory variables across the grades (0% - 8%) for overweigh and obese children.

Difference between 0% and 8%	Overweight (n=10) Mean ± SD	Obese (n=10) Mean ± SD	Effect size[a]	P value[b] Group effect
VO2 (ml·min^{-1})	358.91±151.03	491.90±100.96	1.06	0.033
EE (Kcal·min^{-1})	1.9±0.73	2.56±0.51	1.17	0.019
EE/kg (Kcal·kg^{-1}·min^{-1})	0.04±0.01	0.04±0.007	-0.18	0.709
EE/FFM (Kcal·kgFFM^{-1}·min^{-1})	0.06±0.02	0.06±0.01	0.50	0.292
EE/BSA (Kcal·min^{-1}·m^{-2})	1.22±0.43	1.38±0.21	0.50	0.304
VE (L·min^{-1})	10.1±3.74	15.19±3.66	1.37	0.007
VE/kg (L· kg^{-1}·min^{-1})	0.23±0.09	0.22±0.0.39	-0.07	0.891
VE/FFM (ml·kgFFM^{-1}·min^{-1})	0.31±0.10	0.38±0.09	0.84	0.083
VE/BSA (ml·min^{-1}·m^{-2})	6.8±2.39	8.18±1.62	0.71	0.135
VE/VO_2	1.58±2.20	2.80±2.55	0.52	0.258
VE/VCO_2	0.17±4.99	0.07±1.03	-0.03	0.880
HR (beats·min^{-1})	32±20	30±4.5	-0.20	0.704

[a] Standardized effect size was computed as the mean difference between overweight and obese groups divided by the pooled standard deviation. Values 0.2-0.5 represent small changes; 0.5-0.8 moderate changes and >0.8 large changes.

[b] P value by independent T-student test;

SD (Standard Deviation) - HR (heart rate) - VO2 (oxygen consumption) - FFM (Free Fat Mass) - BSA (Body surface area) - VE (ventilation) – EE (energy expenditure) - VE/VO_2 and VE/VCO_2 (ventilatory equivalents for VO2 and VCO2. respectively).

For all children, the increase of EE at each grade was influenced by their degree of obesity, as shown in Figure 1. In general, EE was greater with higher BMI z-scores. This finding was consistent for each grade. However, changes in EE with increases in the BMI z-score appeared to be less prominent at 0% and 4% grades than at 8%. Beta-coefficients for BMI z-score were 1.68, 1.82 and 2.20 at 0%, 4% and 8% treadmill inclines respectively (Figure 1). Nevertheless, the value of BMI z-score as a predictor of EE did not differ substantially across gradients.

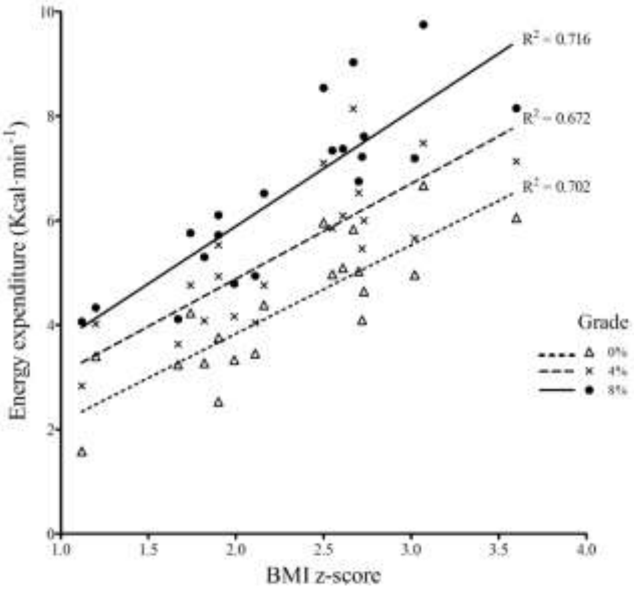

Figure 1. The relationship between EE (Kcal·min^{-1}) and BMI z-score at the three grades.

BMI z-score (Body Mass Index z-score) - EE (Energy Expenditure); Beta- coefficients for BMI z-score were 1.69 (IC95%: 1,15 to 2,24); 1.82 (IC95%:1,19 to 2,45); 2.20 (IC95%: 1,52 to 2,89) at 0%, 4% and 8% treadmill grades, respectively.

Multiple regression models confirm the influence of the extra body mass (degree of obesity) on EE (Kcal·min^{-1}). BMI z-score contributed strongly to explaining EE across all gradients; however its contribution fell slightly at 4% and 8% inclines, due to a greater influence of FM. The contribution of the models to explaining the variance in EE (Kcal·min^{-1}) was greater at the 8% incline than at 0%.

Table 4. Multiple regression models that best explain the variance in EE (Kcal·min^{-1}) of walking at 0%, 4% and 8% grade and constant speed of 1.53 m·s^{-1} during treadmill testing in overweight and obese children (n=20).

Grade (%)	Variables in the model	R^2	B-Coefficient		
			B-Coefficient	**95% CI**	**P-value**
0	**BMI z-score**	0,665	1,22	0,41 to 2,04	0,006
	FM (kg)		0,03	-0,02 to 0,08	0,236
4	**BMI z-score**	0,705	1,08	0,21 to 1,96	0,019
	FM (kg)		0,06	0,005 to 0,11	0,034
8	**BMI z-score**	0,834	1,23	0,43 to 2,02	0,005
	FM (kg)		0,09	0,04 to 0,13	0,001

BMI z-score (Body Mass Index z score) - FM (Fat Mass); CI (confidence interval)

Discussion

This study demonstrates that EE, VE, and HR increased significantly in both overweight and obese children with increasing treadmill gradients, and that EE and VE were significantly higher in obese children than overweight children at each grade. These differences declined (or disappeared) when the respective variables were adjusted for total body mass. However, several differences persisted between overweight and obese children when these variables were adjusted for FFM and BSA.

This study is the first to compare the physiological responses of overweight and obese children during treadmill walking at different grades. Importantly, it demonstrates that both groups differed in their response to low and vigorous intensity exercise, which is consistent with our understanding of the difference between obese and normal-weight children in other locomotion activities (1, 14, 16, 25). To our knowledge, only one study (10) has considered overweight and obese children separately during a cycling exercise. Even though cycling is not a weight-bearing activity, obese children presented greater VO_2 and EE in absolute terms than overweight children. Jabbour et al (10) attributed this supplementary energy cost to the greater VO_2 and EE recorded at rest in obese children rather than to differences in the energy cost of the activity.

Data from the present study indicate that the greater the excess body mass (BMI z-score), the higher the EE, which is consistent with previous studies (1, 12, 14, 25, 35). Results also suggest that fat mass (kg) has a greater impact on EE with increasing workload. To a certain extent, our results support those of Volpe Ayub and Bar-Or (35), who reported that weight was the main determinant of EE at each intensity, but that when adjusting EE to body mass, the EE was similar between groups. This finding has already been reported by other researchers when comparing obese and non-obese children (14, 35), but is at odds with the results of Peyrot et al. (25), who found that differences between obese and non-obese children persisted at different walking speeds. Those authors attributed the higher metabolic cost observed in obese participants to mechanical parameters such as the need for isometric muscular contraction in order to maintain balance during walking (24). Moreover, it should be borne in mind that fat mass does not participate in the transfer of energy to movement during exercise, but represents an extra burden; therefore, when expressing EE in relation to FFM, obese children again present higher energy costs than overweight children.

In addition, EE at each grade was greater in obese children even when adjusted to BSA, which reflects weight and height factors. The question remains: Why is there a difference between groups across each grade? Although obese children might be expected to expend more energy because of their greater height, being taller should also be associated with a longer, more efficient, stride length. However, higher EE could be caused by the greater circumference of the thigh (25), which causes chafing between the thighs with each stride, or because obese children are biomechanically less efficient in transferring energy through to their hips (27).

Increases in adiposity may also induce changes in the cardiopulmonary response to exercise. As already mentioned, body fat constitutes an additional load during activity, particularly during weight-bearing activities. Obesity has also been reported to impair ventilatory function by reducing pulmonary compliance and increasing the cost of breathing due to the extrinsic compression of the fat mass on the chest wall (23).

VE increased significantly with the exercise load in both groups. Nevertheless, obese children at each grade had significantly greater ventilation values than their overweight peers. The pattern of increase in these values along the treadmill test was also significantly steeper in the obese group. This may suggest that obese children are more burdened by their excess mass than overweight children, a finding that would corroborate previous reports (17, 35) comparing obese children with their normal weight peers during treadmill tests at different intensities (speed/grade). Nonetheless, Marinov (16) also observed that the influence of adiposity diminishes when the VE is adjusted by body mass, FFM, or BSA at moderate loads, but persists for vigorous exercise loads. This may be the consequence of a greater VE cost, as Volpe and Bar-Or suggest (35).

The ventilatory equivalents for oxygen and carbon dioxide, as indicators of ventilatory efficiency, were not altered by the elevation gradient of the test or by the extra fat mass of obese children. This may reflect the fact that during moderate–vigorous submaximal walking, both overweight and obese children compensate for the additional metabolic requirements during exercise (O_2 uptake and CO_2 output) regardless of the degree of adiposity. These results are consistent with previous studies showing that obese children and adolescents have similar ventilatory equivalents (VE/VO_2, VE/VCO_2) to leaner peers when performing maximal (16), or submaximal treadmill walking tests at different intensities (speed/grade) (17). However, Prado et al. (23) reported that ventilatory efficiency at the ventilatory threshold load (VE/VCO_2 at VT) was lower in obese children.

As expected, HR increased between the grades of the test. At lower inclines, overweight children had lower HRs than obese children, possibly reflecting the effect of extra fat mass. However, as reported by Rowland (30), it could reflect an association in which moderate adiposity increases cardiac functional capacity, while morbid obesity lowers cardiovascular fitness. Higher HRs are also reported in obese children compared with lean children during submaximal treadmill tests (35, 17). In this study, vigorous exercise resulted in similar elevations in HR in the two groups.

Several potential limitations of this study deserve attention. First, normal developmental differences may have influenced the outcomes, and the degree of maturity should have been recorded. In future studies we recommend examining and adjusting for pubertal stage and anthropometric measurements, such as waist-size index. Second, all comparisons were made at absolute levels of exercise; for safety reasons, peak values were not obtained. We established that the exercise testing should be submaximal because only overweight and obese children with low levels of activity were enrolled. Therefore, it was not possible to analyse data relative to maximal exertion levels. Nonetheless, the lack of maximal data does not preclude the study of EE at different absolute testing intensities (grades) in relation to the degree of adiposity. Third, because ventilation parameters were below the range of detection of the flow pneumotach used, VO_2 could not be recorded at rest in the majority of participants. Consequently, we were unable to calculate the net VO_2 during exertion (VO_2 of the stage minus VO_2 at rest), or the ensuing net EE parameters. For this reason, it is not possible to attribute the differences observed in EE between the obese and overweight groups to a deficient mechanical transference of energy during walking, because we cannot rule out the possibility that their energy consumption at rest was dissimilar. As reported by Jabbour (10) recently, obese children consume more energy at rest than their overweight and normal weight peers, even though they do not differ in the net mechanical efficiency during cycling. Another concern that should be mentioned is that BIA values are affected by several variables, including age, sex, level of body fat and fluid (6). Although standardized guidelines were followed, no specific measurements for body water balance were performed and we assumed that all the children presented a dynamic hypohydrated-euhydrated state. BIA prediction equations have been developed for children (13). However, both children (18) and adults (31) showed dissimilar results in BIA. The criteria used (dual-energy X-ray absorptiometry) reported increasing levels of fat. Thus, data derived from BIA (FFM and FM) should be interpreted with caution.

Finally, the small sample size may have affected the statistical power of several parameters and the error estimation of the variables. For this reason, we should be cautious when extrapolating the data. However, this caveat does not apply to our main hypothesis.

Conclusion

The study shows that overweight and obese children have different physiological adaptations to exercise. Indeed, for the same absolute effort, the EE, VE, and HR demands increased with the degree of obesity. Although extra body mass, as well as fat mass (kg), appear to have an important influence on the increase in EE, other variables, such as thigh thickness, may also contribute to the increase. Further research is necessary and should consider other contributing factors such as the kinetic or kinematic aspects of walking. In addition, differences in EE and VE persisted between overweight and obese children when the variables were adjusted to FFM or BSA, which may reflect a greater cost of physical activity due to the excess fat mass and its impact on walking balance. However, ventilatory efficiency was not affected by the degree of adiposity. In future studies, we propose that the degree of obesity should be considered when assessing either the EE or the ventilatory response to exercise. For this reason, overweight and obese children should be considered separately.

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3rd ARTICLE:

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Multi-Disciplinary and Uncompetitive Intervention in Public Health for the Treatment of Sedentary and Overweight or Obese Children:Nereu Programme

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Abstract

The aim was to evaluate if the Nereu Programme would favourably impact on physical activity (PA), sedentary behaviour and adiposity in low active overweight and obese children as a public health intervention tool for the management of children's obesity. The design was a longitudinal prospective study with post-test at 9 months, consisted of PA for children with behavioural components, family behavioural sessions for parents and behaviour strategies for both. Eighty-six (10.65 ± 2 years) low active and overweight or obese children according the International Obesity Task Force (IOTF) Criteria and their parents participated. PA, sedentary behaviours and adiposity were collected at baseline and 9 months after the intervention. The children reported more time ($p < 0.01$) on moderate (2.4 ± 5.3 h·week-1) and high (3.1 ± 1.62 h · week^{-1}) intensity PA and less time ($p < 0.001$) on sedentary activities (5.4 ± 6.3 h · week^{-1}). BMI z-score was reduced by 0.2 ± 0.29 units ($p < 0.001$). These results may induce a positive change in PA, sedentary behaviours and BMI z-score in low active overweight and obese children. This intervention could be an interesting public health intervention tool for the management of children's obesity. However, future studies should clarify these associations.

Keywords: behaviours, children, motivation, obesity, public helath, sedentarity

Introduction

Childhood obesity has become one of the most prevalent health disorders in developed countries. According Spanish health inquiry in 2010, in Spain, 28.6% of children and adolescents aged 2-17 years are overweight or obese (National Health System of Spain, 2010). Apart from the immediate repercussion of excess fat mass on body image and its consequences on psychological well-being, the major concerns of childhood obesity are the relationship with the presence of comorbidities during childhood, such as metabolic syndrome (Weiss, Dziura, Burgert, & Tamborlane, 2004) or inflammatory markers, (Burke, 2006) and a greater risk of suffering cardiovascu- lar events in adult life (Baker, Olsen, & Sorensen, 2007; Bibbins-Domingo, Coxon, Pletcher, Lightwood, & Goodman, 2007).

In developed societies, obesity is attributed mainly to an energy imbalance (Davison & Birch, 2002), it indicate that due to changes in physical activity behaviour, the caloric intake of fat rich diets may not be counterbalanced with a greater energy expenditure. In the last years in developed countries, time spent on physical activity tasks has decreased, whereas that devoted to sedentary behaviours, like watching TV or playing computer games has increased (Agarwal, 2008).

The relevance of the problem raised is also reflected in the large number of reviews and recommendations issued by different institutions and researchers (Biddle, Brehm, Verheijden, & HopmanRock, 2012; Nishida, Uauy, Kimanyika, & Shetty, 2003; SEEDO, 2000). Most of these guidelines are based on intensive multidisciplinary interventions that combine strategies for improving diet composition with strategies for reducing sedentary behaviour and offering opportunities for increasing activity levels. However, results are contradictory (Campbell, Waters, O'Meara, & Summerbell, 2001; Doak, Visscher, Renders, & Seidell, 2006) and in some cases intervention programmes are ineffective in modifying adiposity and/or physical activity behaviour. Van Sluijs, McMinn, & Griffin (2007) reviewed evidence on the effectiveness of interventions designed to increase physical activity in children. The results concerning family interventions to increase physical activity in children were inconclusive. According to Connelly, Duaso and Butler (2007) neither nutrition education, nor nutrition skills, nor physical education differentiate between effective or ineffective childhood obesity prevention programmes. Connelly et al. (2007) found that effective programmes were those that provided compulsory physical activity from moderate to high intensity. Compared to the research, on the role of physical exercise programmes for childhood obesity prevention, there are relatively few studies focused on the effectiveness of su- pervised physical exercise programmes for obesity treatment among children (Epstein, Roemmich, Stein, Paluch, & Kilanowski, 2005; Golan, Kaufmanb, & Shahar, 2006), and few interventions address the specific needs and interests of obese children (Daley, Copeland, Wright, & Wales, 2005), especially their physical activity needs. Therefore, the purpose of this study was to determine whether a noncompetitive multidisciplinary programme of physical exercise, associated with behavioral components for low acti- ve overweight and obese children, coupled with theoretical sessions for parents on healthy ha- bits and behavior strategies for both would have a favorable impact on physical activity levels, sedentary behavior and obesity degree (BMI-z score and body fat distribution).

Methods

Design

The intervention design is a longitudinal prospective study of 9 months duration. Measures were collected at the beginning (baseline) and at the end of the intervention (9 months later). We collected BMI, BMI z-score, physical and sedentary behaviours by a questionnaire and total body mass and regional fat mass distribution was estimated by multichannel bioelectrical impedance analysis (BIA). Before proceeding with the programme, informed parental consent and children's assent were obtained. Ethical approval was granted by the Arnau Vilanova hospital Ethics Committee (Lleida) and all procedures were conducted in accordance with the Declaration of Helsinki.

Participants

Eighty-six children (10.65 ± 2 years) were recruited from their paediatric healthcare centre. The inclusion criteria of the intervention programme were participants between 8 to 12 years old, overweight or obese according to the International Obesity Task Force criteria defined by Cole, Bellizi, Flegal and Dietz (2000) and low active (less than 3 hours per week of physical activity outside school hours) according to the questionnaire of Serra-Majem and Aranceta (2001), specific for Spanish children between 4 and 14 years old (Table 1). Also at least one parent or tutor should commit to attend the theoretical sessions about healthy habits. Furthermore, the participants should be free of comorbid medical conditions preventing physical exertion. All participants were recruited from their paediatric healthcare centre by their paediatrician and participated voluntarily in the programme. The majority of the families came from a low socio-economic neighbourhood.

Table 1. Baseline characteristics of the study children.

Baseline Characteristics	Total (n = 86)	Boys (n = 56)	Girls (n = 30)
Age (years)	10.65±2	10.65±2.1	10.67±1.7
Height (cm.)	147.3±11.9	147±12.9	147.5±10
Weight (kg.)	57.39±15	58±16.3	56±12.6
BMI z-score (units)	2.44±0.56	2.53±0.57*	2.27±0.50
BMI (kg·m^{-2})	25.97±3.6	26.23±3.7	25.48±3.3

BMI: body mass index (weight (kg) / height (m^2)
Values are expressed as mean±sd
Mean value significant different than girls, *p < .05

Procedure

The program is a 9 month duration (from October to June, that is, an academic year) multidisciplinary behavioural intervention consisting of (a) physical exercise training for children, (b) family behavioural counselling sessions for parents, and (c) behaviour strategies, that involves parental and child participation (Table 2). All intervention groups had a maximum of 12 children or parents. The children's physical activity intervention took place in a school sports centre and the theoretical sessions in the paediatric healthcare centre, next to the school. Both sessions were performed simultaneously.

The physical exercise training offered to children consisted of 105 sessions (3 sessions per week, each lasting 60 minutes). Sessions aimed to increased active behaviour and promote enjoyment during physical activity. All training sessions had a similar structure but differed in the contents of the main part. Sessions had a four part structure, and consisted of assembly, warm-up, main part and cool-down periods. During the assembly, the coach explained the day's training task, introduced some content and games related to healthy behaviour of physical activity and diet, and attempted to motivate the children. During the warm-up part, dynamic activities, such as walking or jogging, were performed at low intensity. The main part of the session focused primarily on being physically active but as participants were children not especially fit, exercises were of short duration (4-5 minutes), moderate-high intensity, and intersected by periods of low intensity. This structure was used because obese children tend both to be sedentary and to have had poor experiences with exercise (ACSM, 2000). Furthermore, short bouts of intermittent exercise are considered most appropriate for this population (Daley et al., 2005). Training tasks were mainly aerobic, but strength, joint mobility, and balance were also included (table 2). These were planned according to 3 essential pillars: playing, enjoying oneself and moving. All activities were performed in a friendly uncompetitive atmosphere and were adapted to children's needs, because motivating obese children to be physical active cannot be achieved in the same approach as for children of normal weight (McWhorter, Wallmann, & Alpert, 2003). Obese children are physiologically different from those who are normal weight, and have significant emotional differences (Sothern, et al., 1999). The cool-down period comprised recovery exercises and static stretching allowing children to recover. All the physical activity training for children was programmed by specialists with at least 3 years of experience of physical activity with obese children and following the physical activity guidelines for children (ACSM, 2010; Aznar & Webster, 2006; WHO, 2010).

The family behavioural counselling sessions for parents consisted of 21 theoretical lessons, each lasting 60 minutes, during which trained nurses from the paediatric healthcare centre and Physical Education & Sport Sciences graduates conducted the sessions dealing with multidisciplinary behaviour including physical activity, diet and healthy habits (table 2).

The three behaviour strategies sessions for parents and children were planned to reinforce the acquisition of physical activity and eating habits within the family behaviour (table 2). The assembly of physical activity training for children, the sessions of the family theoretical counselling lessons for parents and the behaviour strategies sessions for parents and children were planned according the recommendation of the guidelines of different organisations (AESAN, 2011; CECC, 2010; COM, 2005; WHO, 2010). Additionally, four extra family physical activities (e.g. skiing, water party) were organized to foster this more active behaviour in an experiential way.

Table 2. Contents of physical activity training for children, family theoretical counselling sessions and behaviour change strategies for both.

Term	Children physical activity sessions	Family counselling sessions
1st TERM (October-December) GETTING INFORMED	Physical activity and diet games[♯] Personal knowledge games Interaction group activities Collaboration games Traditional games Balance	Risk of sedentary behaviour and obesity Physical exercise benefits Myths related to nutrition Different physical activities and sports Emotions and Social skills Healthy lifestyles benefits Behaviour strategies*
2nd TERM (January-March) BECOMING AWARE	Physical activity and diet contents[♯] Different kind of adapted sports without competition Games with alternative equipment Aerobic games Joint mobility Strength games	Awareness of healthy behaviour Food categories Breakfast is important! Barriers to exertion (social, physical, psychological) Physical activity and eating strategies *
3rd TERM (April-May) COMMITTING AND KEEPING UP	Physical activity and diet behaviour strategies[♯] Motor and physical abilities Aerobic tasks Strength exercise Different kind of sports and activities Outdoor sports and games	Planning and checking physical exercise and nutrition schedule Relapse prevention Psychological strategies to increase healthy and active behaviour Behaviour family strategies *

* Behaviour strategies, that involves parental and child participation.

♯ Theoretical contents deal during the assembly part of the children physical activity sessions

Instruments

Before and after the programme, daily sedentary and physical activity behavior of children was assessed by a modified version of a 7-day recall physical activity questionnaire (Sallis, Buono, & Roby, Micale, & Nelson, 1993). The questionnaire obtained a correlation coefficient of r = .81 in the test-retest reliabilities for the Godin-Shephard to the self-administered survey and a correlation of r = .53 ($p < 0.001$) for the total group that supported the validity of the questionnaire for children (Sallis et al., 1993). Questionnaires were filled in under supervision of experienced interviewers. Physical activities were classified according to their metabolic cost as sedentary activities (< 1.4 METs), light intensity activities (1.5 to 2.9 METs), moderate intensity (3 to 4.9 METs) or high intensity (>5 METs), following the recommendations of Ainslie, Reillyco & Westerterp (2000).

All anthropometric measurements were taken at the beginning of the programme and 9 months later, at the end. Body weight was measured with a weighing scale (SECA model 755, SECA Corp., Hamburg, Germany, 2006) and height with a stadiometer (Añó Sayol, Barcelona, Spain). Children were lightly dressed and without shoes. Body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2). To overcome limitations of BMI due to changes associated with growing and maturity, BMI z score was used. To determine BMI z score, the LMS method (Cole & Green, 1992) was used as a reference. Regional fat mass distribution was estimated by multi-channel bioelectrical impedance analysis (BIA). Total body resistance and reactance were measured with a multisegmental and multifrequency bioelectrical impedance analyzer (Promis Body Composition, Promis Corp., Puerto de Santa María, Spain, 2006).

It has been indicated that BIA is a valid and reliable technique for the assessment of body composition in children (Jensky-Squires et al., 2008). The collected data,- age, gender, weight and height-, were entered into a computer program associated to the device. Skin was cleaned and adhesive electrodes placed on the back of hands and feet. During measurements children were asked to be as still as possible in supine position.

On both occasions, all anthropometric measures were taken by the same experienced professional. Children went to the Functional Assessment Laboratory of the INEFC-Lleida between 6:00 pm and 7:00 pm. and had been required to come to the appointment, fasting at least four hours, or having performed any physical exertion for two hours prior to the test. Children’s attendance to the PA sessions was recorded with the purpose of assessing adherence to the intervention.

At the end of the programme, both children and parents/tutors filled out a satisfaction survey. The questions of the children were: 1. Did you know the games that you performed during the programme? 2. Are you happy with your instructor? 3. Would you like to repeat the programme? The questions to the parents were: 1. Has your child enjoyed the programme? 2. Are you satisfied with your child's instructor? 3. Would to you like your child to participate in the programme again? The format of the scale was between 1 (always) and 4 (never) for the first and second questions and for the third question in both questionnaires the answer was yes or not. These questionnaires were administered by specialists, designed specifically for the intervention and had been used satisfactorily in a pilot trial, with a sample of children having the same characteristics

Data analysis

All statistical analyses were conducted with SPSS program version 15.0 (SPSS Inc., Chicago, IL, 2007). Descriptive data are reported as mean ± standard deviations.

Student t-test was used to compare pairedsamples (beginning and end of the intervention) or independent samples (girls versus boys, degree of obesity). When group samples were too small, or when variables did not show normality, non parametric tests were used. To analyze the influence of age, gender and degree of obesity on changes in indicators of obesity a multiple regression analysis was conducted. The level of significance was set at $p<0.05$.

Results

Thirty-six children successfully completed the 7-day recall physical activity questionnaire at the beginning and at the end of the programme. Results show that at the beginning of the programme, they devoted 87 % of their weekly time to sleep or to sedentary activities and only 3 % and 1 % to physical activities of moderate and high intensity respectively. At the end of the programme, sedentary activities decreased to 84 % and moderate and high increased to 4.5 % and 3 %, respectively. In that sense, children stated they spent more time on moderate (2.4 ± 5.3 h · week^{-1}; $p < 0.01$) and high (3.1 ± 1.62 h · week^{-1}; $p < 0.01$) intensity physical activities and less time on sedentary activities (5.4 ± 6.3 h · week^{-1}; $p < 0.001$). The reduction is due in part to a decrease in amount of time dedica- ted to sedentary activities, like video-computer games 1.6 ± 4.6 h · week^{-1} (5.9 ± 5.2 h · week^{-1} vs. 4.27 ± 5.08 h · week^{-1}; $p < 0.05$) or/and to watching TV 3.2 ± 4.8 h · week^{-1} (12.7 ± 6.83 h · week^{-1} vs. 9.48 ± 5.02 h · week^{-1}; p <0 .001) between the beginning and the end of the intervention respectively. Results were similar for sex, age or the degree of obesity (overweight or obese).

Changes in BMI z-core and BMI are shown in table 3. BMI z-score at the end of the program was significantly reduced 0.2 ± 0.29 units (2.44 ± 0.56 units vs. 2.23 ± 0.59 units; $p < 0.001$) for the whole group (table 3). Results were similar for sex, age or the degree of obesity.

Table 3. Body mass index at the beginning and at the end of the intervention program.

	All children (n = 86)		**Boys (n = 56)**		**Girls (n= 30)**	
	Before	End	Before	End	Before	End
BMI z-score (units)	2.44±0.56	2.23±0.59*	2.53±0.57	2.33±0.61*	2.27±0.5	2.05±0.51*
BMI (kg·m^{-2})	25.97±3.6	25.85±3.9	26.23±3.7	26.1±3.8	25.48±3.3	25.39±3.9

Values are expressed as mean±sd
Difference between before and end of the intervention *P <0.001

BIA results showed that body composition and fat distribution were different for boys and girls (Figure 1). For any measures taken, boys presented, in relative terms, a smaller amount of fat than girls (p <0 .05), except trunk fat that was similar for girls and boys (p = 0.512). Fat percentages were higher in trunk fat mass than in extremities among boys, whereas among girls fat showed a homogenous distribution between trunk and extremities.

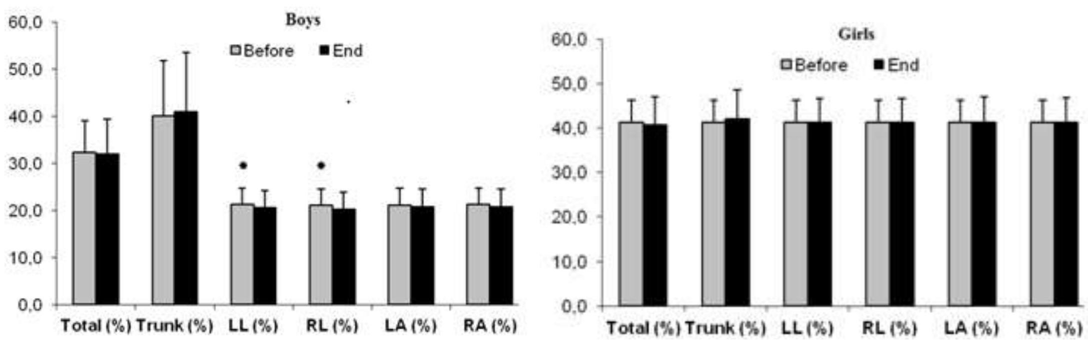

Figure 1. Body fat distribution before and after the intervention, for boys and girls .

Values are expressed as mean±sd. Significant differences between before and after the intervention *p < .001. Total= whole body fat; trunk= fat located at abdominal level; LL= left leg fat; RL=right leg fat; LA= left arm fat; RA= right arm fat.

At baseline fat distribution for boys and girls was different, the regression analysis indicated that neither sex, nor age or the degree of obesity (overweight or obese) had a significant effect on changes in whole body adiposity parameters (BMI-z score, BMI and % Total Fat) during the programme. Nevertheless, as shown in figure 1, boys presented a significant reduction of percentage of fat mass in lower extremities. The reduction for the left lower extremity was 0.69 ± 1.7 % of fat (21.21 ± 3.46 vs. 20.52 ± 3.71; $p < 0 .01$) and for the right lower extremity was 0.75 ± 1.67 % of fat (21.05 ± 3.56 vs. 20.30 ± 3.57; $p < 0.01$) between the beginning and the end of the intervention respectively.

Adherence to the programme was high and 85 % of children attended more than 80 % of the sessions, 13 % attended between 56 % and 80 % of the sessions and only one participant (2 %) was present in less than 56 % of the sessions.

At the end of the programme, in the satisfaction survey for children, 85 % (n = 73) of children indicated that they always enjoyed the games and activities they performed during the programme and that they liked their instructor, and 95 % (n = 82) of the children would like to repeat the programme. In relation to the parental satisfaction survey (n=70), 79 % (n=55) of the parents declared that their child always enjoyed the programme and liked the his/her instructor, and 90 % (n=63) of the parents wanted to repeat the programme.

Discussion

The aim of this study was to determine whether a non-competitive multidisciplinary programme of physical exercise associated with a behavioral component for low active overweight and obese children, coupled with theoretical sessions for parents on healthy habits and behavior strategies for both would a favorable impact on physical activity levels, sedentary behavior and obesity degree (BMI-z score and body fat distribution).

The results from the 7-day recall physical activity questionnaire reflected a behaviour change in the sense of increasing the number of hours dedicated to physical activities and decreasing those devoted to sedentary ones. These data are promising, taking into account that behaviour in society and school is highly sedentary (Kain, Albala, García, & Andrade, 1998), and physical activity participation rates decline sharply with age (Biddle, et al., 2012). However, children did not reach the recommended 7 weekly hours of moderated-high intensity exercise (Strong, et al., 2005). To achieve this physical activity level, children together with their families, have to acquire autonomy and, apart from attending to the three weekly supervised physical exercise sessions, it is necessary that they change their lifestyle to a more active one (Gortmaker et al., 1999).

Increasing moderate to vigorous physical activity to 5 hours per week was associated with a significant decrease in BMI z-score for the whole group, although, fat mass was not significantly modified during the intervention, except in boys' lower ex- tremities. Nonetheless, one of the main limitations of the study has been the absence of a control group, making it difficult to separate effects of puberty and growing from those of the intervention itself. Nevertheless, as already indicated, age, sex or the degree of obesity did not have significant effect on the reduction in the whole body adiposity parameters. Additionally, multichannel bioimpedance analysis confirmed that, even among young children, differences in fat mass distribution due to gender already exist (Rowland, 1996). Another limitation was using a non-objective measure of physical activity making it difficult to confirm the benefits of the intervention. However, as said before, the questionnaire used is validated for the study population.

According to Connely et al. (2007) provision of compulsory moderate to high intensity physical activity is the main factor in distinguishing between effective or ineffective programmes for childhood obesity prevention. On the contrary, in childhood obesity treatments, participation in supervised physical exercise programmes (pro- posing 3 sessions per week) is not enough to reduce indices of adiposity (Carrel et al., 2005; Daley, et al., 2005; Gutin et al., 2002). According to Atlantis, Barnes and Singh (2006), McGovern et al. (2008) and Spruijt-metz (2011) between 12 % and 14 % of the programmes for childhood obesity treatment that include physical exercise have a positive effect on the degree of adiposity. Programmes in which more hours per week are spent on physical exercise are the ones that have a higher likelihood to be successful (Weintraub et al., 2008). However, the effects of isolated physical exercise on body fat reduction are moderate probably because the negative energy balance generated by physical exercise can be easily overcome by means of an increase of food consumption. Moreover, as Oude Luttikhuis et al. (2009) and guide of Ministry of Health and Social Policy of Spain (2007) recommend, interventions based on physical exercise and aiming at weight control have to be supplemented with a familiar intervention (Kitzmann et al., 2010; Waters et al., 2011). In a revision in depth, Oude Luttikhuis et al. (2009) remarks that the most effective programmes are those that integrate different treatment strategies, and highlights the importance of family interventions that combine diet, physical activity and behavioural components. Regarding the study depicted here, the intervention is comprised of both physical activity practice and theoretical counselling sessions, where diet, physical activity and behaviour components were addressed.

Other very positive aspects of the intervention have been a good attendance and satisfaction with the programme, because one of the most common limitations in medical intervention programmes is the relatively low medium-term adherence (Barja, 2005). Furthermore, considering the fact that children were low active overweight and obese children, who were not especially willing to participate in physical exercise, this high level of attendance may reflect that a favourable change has been produced regarding children's perception and attitude concerning physical activity. This excellent participation response and satisfaction can be explained by aspects related to recruitment and family information, and/ or to the development of the programme. Firstly, inclusion into the programme was prescribed by the paediatrician and it has been proved that doctor's or paediatrician's counselling may have a great repercussion on their patients (Albright et al., 2000; Ortega, et al., 2004). Secondly, the content and running of the intervention programme may have also had important repercussions on the attendance and satisfaction. Activities were planned according to 3 essential pillars: playing, enjoying oneself and moving. Thus, aspects of friendship, motivation, collaboration and participation were also boosted. Others factors which could have had a positive effect were involvement of professionals specially trained for the programme, availability of sports facilities and sports material. Also sessions for children and parents were run simultaneously to facilitate the family schedule, plus family activities were proposed during weekends.

Conclusions

In view of the results, this intervention based on a friendly uncompetitive physical activity induce a positive change towards more moderate-intense physical activities and a reduction of the sedentary behaviours and BMI z score in low active overweight and obese children. The results are encouraging and it could be an excellent tool to the paediatricians, however, future studies should clarify these associations.

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4th ARTICLE:

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BMC Public Health

Evaluation of a family intervention programme for the treatment of overweight and obese children (Nereu Programme): a randomized clinical trial study protocol

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Abstract

Obesity is mainly attributed to environmental factors. In developed countries, the time spent on physical activity tasks is decreasing, whereas sedentary behaviour patterns are increasing. The purpose of the intervention is to evaluate the effectiveness of an intensive family-based behavioural multi-component intervention (Nereu programme) and compared it to counselling intervention such as a health centre intervention programme for the management of children's obesity. The study design is a randomized controlled multicenter clinical trial using two types of interventions: Nereu and Counselling. The Nereu programme is an 8-month intensive family-based multi-component behavioural intervention. This programme is based on a multidisciplinary intervention consisting of 4 components: physical activity sessions for children, family theoretical and practical sessions for parents, behaviour strategy sessions involving

both, parents and children, and lastly, weekend extra activities for all. Counselling is offered to the family in the form of a monthly physical health and eating habits session. Participants will be recruited according the following criteria: 6 to 12 year-old-children, referred from their paediatricians due to overweight or obesity according the International Obesity Task Force criteria and with a sedentary profile (less than 2 hours per week of physical activity), they must live in or near the municipality of Lleida (Spain) and their healthcare paediatric unit must have previously accepted to cooperate with this study. The following variables will be evaluated: a) cardiovascular risk factors (anthropometric parameters, blood test and blood pressure), b) sedentary and physical activity behaviour and dietary intake, c) psychological aspects d) health related quality of life (HRQOL), e) cost-effectiveness of the intervention in relation to HRQOL. These variables will be then be evaluated 4 times longitudinally: at baseline, at the end of the intervention (8 months later), 6 and 12 months after the intervention. We have considered necessary to recruit 100 children and divide them in 2 groups of 50 to detect the differences between the groups. This trial will provide new evidence for the long-term effects of childhood obesity management, as well as help to know the impact of the present intervention as a health intervention tool for healthcare centres.

Trial registration: ClinicalTrials.gov, NCT01878994

Keywords: Obesity, Children, Physical activity, Nutrition, Behaviour, Health, Sedentary, Paediatric unit.

Introduction

Obesity in children is one of the most important public health a problem in the 21st century, as it is has been voiced for years by the World Health Organization. It is considered the most common nutritional or metabolic disorder and the main non-contagious illness in developed countries. The National Health Survey in Spain [1], in its three last editions [2003, 2006, 2010], has shown a continuous increase in overweight [18.2- 18.7- 19.2%] and obesity percentages [8.5- 8.9- 9.4%], in children between 2 and 17 years old. More recently, the results of Aladinos' study [2], indicated that 45.2% of children between 6 and 9.9 years of age are either obese or overweight.

Obesity is a complex and multifactorial cronical illness, with its origin in a behavioural and environmental interaction [3], leading to an imbalance between energy intake and expenditure [4]. It usually begins in childhood or adolescence and it is considered a risk factor for metabolic, cardiovascular and pulmonary diseases [5]. We need to take also into account the psychosocial problems of obese child [5] and their lower quality of life compared to their healthy-weight peers [6].

Due to its important health, social and psychological consequences [7], the prevention and treatment of childhood obesity has become one of the leading priorities of public health. It is critical to begin prevention during childhood as childhood obesity tends to persist into adulthood [7]; about 70% of obese children continue to be obese into their adulthood [8].

Connely et al. [9] consider that physical activity at moderate-to-high intensity is the principal factor to distinguish between effective and ineffective childhood obesity prevention programmes. However, in childhood obesity treatment programmes, performing physical activity 3 times per week was not enough to reduce adiposity [10-12]. According to Trinh [13], focusing treatment of childhood obesity only in physical activity is not enough, as its relationship to body mass index (BMI) is not clearly quantified.

Reviews from Atlantis [14], McGovern [15] and Spruijt-metz [16] have shown that 12% -14% of the programmes treating childhood obesity that include physical exercise have a positive effect on the amountof adiposity. Oude Luttikhuis et al.[17], after performing a systematic review on the interventions to treat obesity in children and youngsters, show that the most effective programmes are those which integrate different strategies in obesity management besides physical activity. They emphasize the value of family interventions involving physical activity, nutrition and behaviour. Furthermore, in a meta-analysis, Whitlock [18] adds that intervention effectiveness depends on the total length of the intervention, considering moderate (26–75 hours/intervention) to high (>75 hours/intervention) intensity interventions the most effective ones.

Thus, this increase on physical activity practice needs to be linked to changes in other important habits such as nutrition, psychological aspects and the behaviour of the nuclear family [17,19-21], the latter being even more necessary in pre-adolescent children [20,22].

These other factors can be responsible for obesity maintenance and one of the limiting factors in childhood obesity interventions.

Recent bibliographic reviews [7,14-18,21] show that this is a growing research field but there are still questions to resolve, such as the high percentage of incomplete follow-ups, which make it difficult to assess the long-term effectiveness of the programmes/interventions. In addition, paediatric units still lack effective tools to treat obesity in children. In this sense, the Nereu programme (NP) has been developed in order to give paediatric units a tool to help them in the management obesity long-term.

The aim of this study is to evaluate the effectiveness of an intensive family-based behavioural multi-component intervention (NP) compared to counselling intervention (CG; advice on physical activity and dietary healthy behaviour) as a health centre intervention tool for the management of children's obesity.

Secondary objectives are the evaluation of the effectiveness of the intervention changes in the following parameters at short, medium and long term following the intervention referred to as baseline:

a) Cardiovascular risk factors: Anthropometric parameters (BMI, BMI z-score, waist-size index and waist circumference), blood pressure (diastolic and systolic pressure) and blood tests (LDL cholesterol, HDL cholesterol, triglycerides, glucose, insulin, TSH and cortisol).
b) Physical condition evaluated by a physical fitness test.
c) Sedentary and physical activity behaviour and dietary intake.
d) Psychological aspects such as self-efficacy and self-concept.

e) Health related quality of life (HRQOL).
f) Cost-effectiveness of the intervention in relation to HRQOL.

Methods

Trial design

The study design is a randomized controlled multicenter clinical trial over a period of 20 months (Figure 1) for overweight and obese children. They will be randomly allocated to study groups previous to participant's recruitment. The study is children and family-based and includes an 8 month intervention of physical activity sessions for children, family sessions for parents, behaviour strategy sessions for children and parents, and weekend extra activities. Briefly, at least 100 obese children will be randomly allocated to either NP or CG. An assessment will be made before the intervention, 8 months later (at the end of the intervention), and 6 and 12 months of the follow-up period. All measurements will be taken at the same research unit and by trained researchers or HPU professionals blinded to the allocated study group.

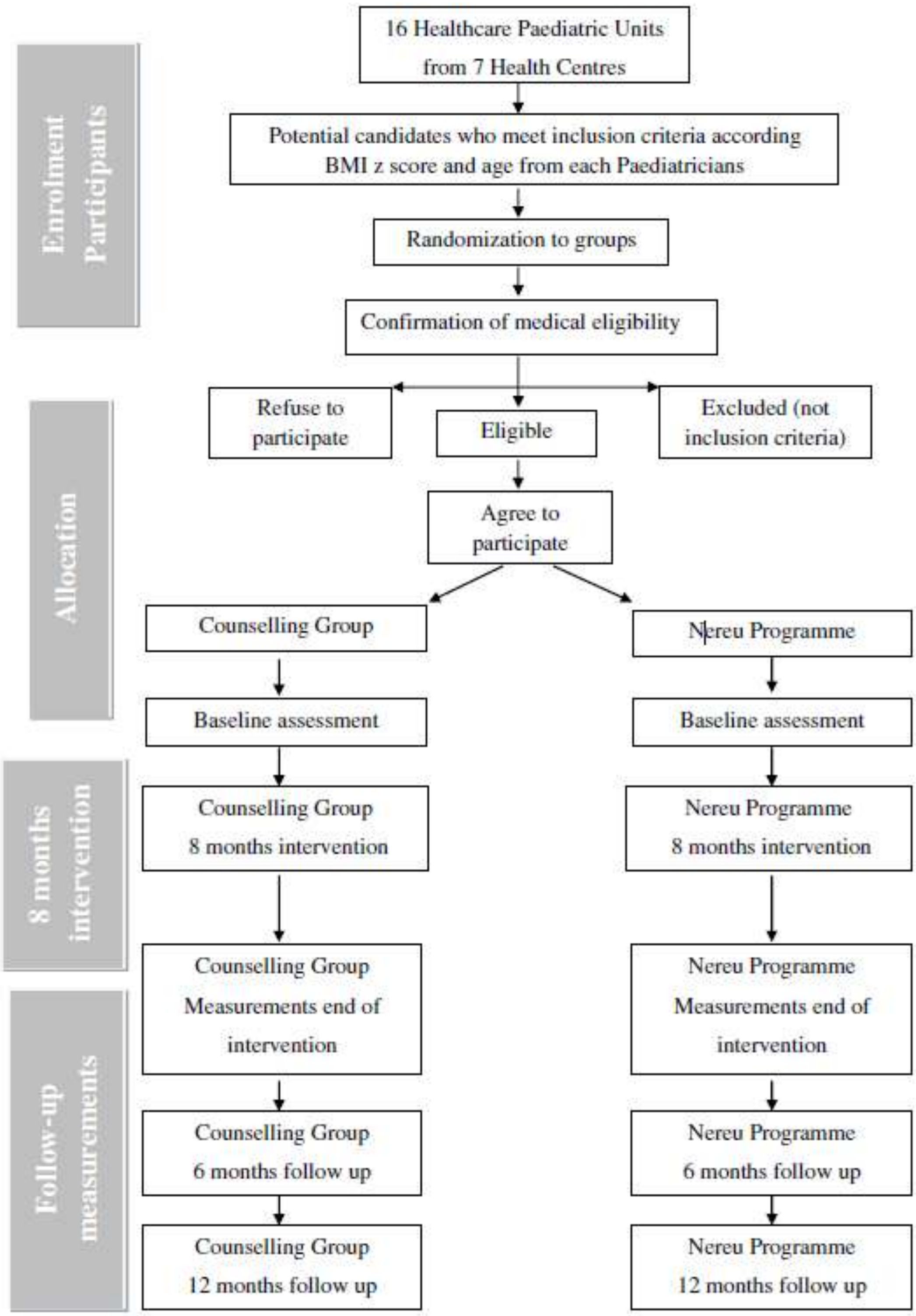

Figure 1. Flow design.

After the follow-up period, the children in the control group will be offered to participate in the next season of the NP.

Participants

Eligible participants will be children aged between 6 and 12 years old who are overweight or obese according the International Obesity Task Force Criteria (IOTF) defined by Cole et al. [23]. They are sedentary (less than 2 hours per week of physical activity outside school hours), live in or near the municipality of Lleida (Spain) and their healthcare paediatric unit (HCP) has previously accepted to cooperate in this study. In addition, at least one of the parents or guardians of the child must accept to actively participate in the study.

Exclusion criteria are: a) medical co-morbidities, such as Cushing disease, hypotiroidism, cardiovascular diseases or other serious chronic illnesses; b) use of medication that might have an effect on weight loss or adaptations to exertion; c) previous enrolment in other obesity treatment interventions; d) regular participation in physical exercise programs in the past 6 months.

Randomization

On a first phase, professionals of the HCP in Lleida are informed of the purpose and the methodology of the study and are invited to participate in it. Sixteen HCPs accepted to cooperate in this study. Each HPU is responsible for the recruitment of participants and for the checking of their eligibility. Randomization will be centralized at the Primary Care Research Institute (IDIAP) Jordi Gol in Lleida. Each cooperating healthcare paediatric unit (HPU) will provide a random list of their patients/children fulfilling age and BMI z-scores inclusion criteria according to the data from their health clinical records. These eligible children will be randomly assigned to one of the study groups. Randomization will insure that patients are distributed to the 2 groups homogenously in terms of age and gender. Group homogeneity with regard to age will be assured by stratified randomization according to the age group: 6,7,8,9,10,11,12 years old (7 groups) in each HPU (16 HPU).

Recruitment strategy

Next, each HPU will phone/contact eligible families and will invite them to participate in the study. At that point participants will be informed about their study/case group. HPUs will recruit participants consecutively and on an alternate list mode basis, i.e. once they have recruited one eligible child from the intervention group list, they move on to recruit another participant from the CG list. Families of eligible children that accept to participate will be referred to their healthcare paediatric unit office for anin-depth explanation, followed by a medical assessment (basic exploration and blood test to check for inclusion and exclusion criteria). Children's assent and written parental informed consent will be obtained from children who fulfil the inclusion criteria and with no exclusion criteria. The family will be finally included in the study.

Sample size

The aim of the research team is to recruit 50 subjects per group, computing a total of at least 100 participants. The calculation of the sample size takes as its primary outcome intervention efficacy - the reduction of BMI z-scores after the intervention, as specified in a published meta-analytic review of trials [24]. The sample size was calculated in order to detect one BMI z-scores reduction (effect size = 0.60 [24]), according an 80.0% statistical power, 5% significance level to detect differences between groups with two independent samples. It is assumed a 20% dropout rate was estimated.

Ethical aspects/Considerations

The study will be carried out according to the principles of the "Declaration of Helsinki" and subsequent revisions [25] and to the Guidelines for Good Practice in Primary Care Research of the IDIAP [26]. This protocol has been approved by the Clinical Research Ethics Committee (CEIC) of the Primary Care Research Institute (IDIAP) Jordi Gol. The study methods are in agreement with the CONSORT guidelines for reporting randomizated trials [27].

Intervention

Nereu programme

The NP is an 8-month intensive family-based behavioural multi-component intervention (from October to May, that is, an academic year), consisting of 4 components (Table 1): (a) physical activity sessions for children, (b) family theoretical and practical sessions for parents, (c) behaviour strategy sessions, that involve both parental and child participation and (d) weekend extra activities.

Table 1. Contents of the assembly of children, the family theoretical counseling sessions for parents and the behavior strategies sessions for both.

Target/Term	Parents/Children			Parents' sessions contents	Children's assembly contents
	Phase	**N**	**Behavior change strategy**		
1st Term (October-December) Getting informed	Concienciation (**Attention**)	1	Explaining expectations	Presenting the programme	What is Nereu Programme?
			Information on health components of the programme	Understanding the expectations of the parents at the beginning of the Nereu Programme	What do you want to know?
		2	Information about healthy food Barrier identification	Reflecting on the current diet and healthy food benefits	Benefits of healthy food
		3	Information on outcomes	Making them aware of the importance of PA	Why should we take part in sport?
		4	Provide information about healthier diet	Knowing the behaviours and actions that help us improve our diet	Let's go to eat healthy and funny!
		5	Provide information about healthier behaviour	Becoming familiar with their lifestyle and how to make it more active	How can I go to the school?
		6	Explaining how the programme aims to encourage healthier lifestyles	Setting short-term goals (behaviour strategy session I)	
2nd Term (January-March) Becoming aware	Modelation (**Retention**)	7	Instructions about nutrition	Understanding and knowing eat quantities	The traffic light game
		8	Ways in which they can achieve a more active lifestyle/Identifying barriers to participation Self-monitoring of existing PA	Becoming familiar with their availability and requirements in order to be more PA. What we should be doing!	Family photography!! Which sport will you Take part in?
		9	Provide information about healthier eating	Myths related to nutrition	What do we know about nutrition?
		10	Encouraging healthier lifestyle	Using different tools to become more active	The weather is good, let's go and have fun!!
		11	Overcome specific barriers	Giving options to eat on specific days (Christmas, restaurants…)	Ticket-aaaa!!! Eating out side!!
		12	Social support and change	Behaviour modification strategies day-to-day	Where are we going next weekend?
		13	Provide instructions about healthier food	knowledge about how to interpret advertising and how buy food	Let's go to buy!
		14	Provide feedback on performance	Ways in which they can incorporate PA into their lifestyle.	Why do we use the elevator?
		15	Encouragement and setting goals on PA and nutrition	Setting medium-term goals (behaviour strategy session II)	

			Maintaining behaviour strategies		
3rd Term (April-Mai) Committing and keeping up	Autonomy (**Reproduction**)	16	Provide knowledge about healthier eating	Learning to make a balanced menu	How do a balanced menu?
		17	Specific encouragement Decisional balance	Relation between PA and food intake	Burning sweets!
	Evaluation (**Motivation**)	18	Self PA evaluation	Evaluating the implementation of PA	How active are we?
		19	Self-Diet evaluation	Evaluating the implementation of Diet	How well you eat?
		20	Encouraging PA and nutrition Maintenance behaviour strategies	Keeping up medium and long-term behaviour (behaviour strategy session III)	
	Closure	21	Enjoying a healthy day together	Closing Party	
1 each term	3 weekend extra activities	--	Encouraging active behaviour in an experiential manner and social support	3 extra family physical activities: Ski, FC Barcelona, Aqua party	

The whole intervention will take place in 3 different school centres and health care centres, which have been recruited especially for the intervention and with a strategic localization around the city, in order to facilitate their accessibility. The children's physical activity sessions will take place using the sport equipments of the school, the theoretical sessions for parents at the same school or at the health care centre next to the school, and the behaviour strategy sessions will be performed in both places. Parents' and children's sessions will be performed simultaneously in order to facilitate their attendance. All intervention groups will have a maximum of 15 children and parents.
The four structured components are:

a). Physical activity sessions for children

The physical exercise programme offered to children will consist of 90 sessions (3 sessions per week, each lasting 60 minutes). The main aim of the sessions is to enhance a physical active behaviour, to look for greater enjoyment during physical activity tasks and meet and practise new sports and games in order to keep practising them for a long time.

All sessions are planned to be performed in a friendly uncompetitive atmosphere and adapted to the participants' needs, because motivating and encouraging obese children to be physically active cannot be achieved following the same approach as for normal weight children [28]. Obese children are physiologically different from those who are normal weight, and they also have significant emotional differences [29]. In that sense, the sessions have been planned by specialists with at least 4 years of experience in physical activity with overweight and obese children and following the physical activity guidelines for children [30-32]. All the sessions will be performed by two coaches who have the sport science degree with specific knowledge and experience in sport treatment for children with overweight and obesity and who have also attended the specific Nereu course. The Nereu course has been addressed specially to teach and help coaches, nurses and physical activity professionals before starting with the intervention, with specific contents about obesity management.

All physical activity sessions have a similar structure but differ in their contents. Sessions have a four-part structure: assembly, warm-up, workout and cool down periods. During the assembly, the coach explains the day’s training task, attempts to motivate children and introduces contents related to health behaviour based on behaviour change strategies. The assembly’s contents (Table 1) are the same as the family theoretical and practical sessions’ contents for parents, but taught in a playful and experimental atmosphere. Teaching the same health behaviour contents and on the same day and at the same time to both parents and children looks for an improvement in the effectiveness of these contents and their application at home by the family unit. Afterwards, during the warm-up part, dynamic activities such as walking or jogging will be performed at low intensities looking for their activation before the main part. The main part of the session (workout) is primarily focused on being physically active, but as overweight and obese children generally are not especially fit and tend both to be sedentary and tend to have had poor experiences with sport [33], exercises will be planned in short periods of duration such as 4–5 minutes of moderate-high intensity activities intersected by periods of low intensity. Short bouts of intermittent exercise are considered most appropriate for this population [34]. The sessions are also designed looking for their enjoyment through practising and learning different kinds of sports, activities and abilities. Training tasks will be mainly aerobic, but strength, joint mobility and balance will be also included (Table 2). These have been planned according to 3 essential pillars: playing, enjoying oneself and moving in order for children to get rid gradually of their fear and reluctance to sports. The cool-down period is comprised by recovery exercises and static stretching allowing participants to recover.

Table 2. Contents of physical activity training for children, family theoretical and practical sessions and behaviour change strategies.

Term	**Children Physical Activity Sessions**
1st TERM (October-December) GETTING INFORMED	Personal knowledge games
	Interaction group activities
	Collaboration games
	Traditional games
	Balance
2nd TERM (January-March) BECOMING AWARE	Different kinds of adapted sports without competition
	Games with alternative equipment
	Aerobic games
	Joint mobility
	Strength games
3rd TERM (April-MaicbCOMMITTING AND KEEPING UP	Motor and physical abilities
	Aerobic tasks
	Strength exercise
	Different kinds of sports and activities
	Outdoor sports and games

In addition, each session from the workout part has been planned to be a moderate-high intensity activity. In that sense, one session every two weeks in each centre will be recorded by an accelerometer and heart rate monitor and followed with an assessment in order to be sure that children from the 3 PA centres follow and reach the same indications in terms of intensity.

b). Family theoretical and practical sessions for parents

The family programme consists of 21 theoretical and practical counselling sessions with a duration of 60 minutes each. The sessions will be in group and will take place once a week atthe same time as their children's sessions, giving the family the opportunity to exchange experiences and establish shared compromises later at home.

The sessions will be carried out by trained nurses and physical activity education professionals skilled inmultidisciplinary behaviour including physical activity, nutrition and healthy behaviours (Table 1).

The overall focus of the parental sessions is to help families to make better healthy behaviour choices mainly in terms of physical activity and nutrition inside the family unit.

c). Behaviour strategy sessions, involving children and parents

The three behaviour strategies sessions for parents and children, one each term, have been planned to reinforce the acquisition of healthier physical activity and eating habits within the family in a more experimental and practical manner (Table 1).

The contents of the family theoretical and practical sessions, the behaviour strategies sessions as well as the assembly of physical activity sessions, are planned mainly according to the Social Cognitive Theory (SCT) of Bandura [35], and the guidelines of several institutions [32,36-38].

d). Weekend extra activities

Additionally, three extra weekend family physical activities (e.g. ski or water party) will be organized, one each term following the school calendar, in order to encourage and achieve this more active behaviour in an experiential way (Table 1). Participants' friends or relatives will be also invited to take part in the activities, looking for their social and familial support. At the same time, plans are in place to help them to achieve the minimum recommendations of 60 minutes a day of moderate-vigorous physical activity [39].

Counselling group

Each family will be offered 8 individual monthly 10-minute-duration meetings. These sessions will take place at the paediatrician's office and will be delivered by the child's nurse or/and paediatrician.

The sessions' contents will be about tips for the promotion of healthy eating and physical activity habits.

Measurements

As the intervention is principally focused on a family-based behavioural multi-component intervention for children's obesity, both children and parents will be assessed. The main measure parameters are described in table 3.

Table 3. Measurements

Aim		Nereu and Counselling Group Measures	
		Children	**Parents**
Cardiovascular risks factors	Anthropometry	Weight	Weight and Height
		Height	
		BMI z score	
		Waist circumference	
		Waist-size index	
		Triceps skinfold	
		Subscapular skinfold	
	Blood pressure	Diastolic and systolic pressure	NOT analysed
	Blood test	Cholesterol (LDL, HDL), triglycerides, glucose, insulin, TSH and cortisol [1]	NOT analysed
Physical condition	Physical condition	ALPHA test set [42]	
Behaviours	Physical activity	Seven-days Accelerometry	International Physical Activity Questionnaire IPAQ [74]
		Seven days recall physical activity questionnaire (PAQ-C) [46]	
	Nutrition	24 h dietary recall (x 3 days)	Frequency consumption (CFCA – adults version)
		Frequency consumption (CFCA – children version)	
Psychological aspects	Physiological, physical and cognitive	Physical activity self-efficacy [64]	Health-specific self-efficacy [82]
		Physical self-concept (MIFA) [66]	
		Body-image: Figure Rating Scale [67]	
		Physical activity enjoyment (PACES) [69]	
Health related quality of life	HRQOL	PedsQL 4.0 [70]	
Health economic data	Cost-effectiveness	CHU 9D [73]	EQ-5D EuroQol Group [84]
Modifiers variable	Pubertal maturity	Tanner pubertal stage [88]	
	Socio-economical and demographic parameters	Some questions from de National Healthy Survey for children [89] and for parents [90]	
	Adherence	Attendance log	
	Satisfaction	Survey	

[1] the measurement will be undertaken 2 times: at baseline and at the end of the intervention

Measurements will be assessed before and at the end of the intervention, and 6 and 12 months after the end of it.

Children's outcome

Anthropometry

Anthropometric parameters will be measured using standard practice: weight will be measured to the nearest 0.1 kg using an electronic scale (Tanita Model SECA 214, Hamburg, Germany) and height (Ht) to the nearest of 0.1 cm with a stadiometer (Seca

214, Hamburg, Germany) with children lightly dressed and barefoot. The BMI will be calculated as weight (kg) divided by squared (m^2) height and standard deviation score (BMI z-score) will be determined from the LMS method [40]. Waist circumference (WC) will be measured in centimetres with an anthropometric tape (precision: 0.1 mm), placed horizontally at the level of the maximum abdominal protrusion at the end of a gentle expiration [30]. Waist-to-height ratio (WHtR), will be calculated as waist circumference (cm)/height (cm).

Triceps and subscapular skinfold thickness will be measured at the right side of the body with the child standing up, with a Holtain skinfold calliper (Holtain, Crymych, United Kingdom) to the nearest 0.2 mm. Triceps skinfold is a vertical fold measurement performed on the posterior midline of the upper arm, half way between the acromion and the olecranon processes. Subscapular skinfold measurents will be taken about 20 mm below the tip of the scapula diagonally (at 45º angle to the lateral side of the body). Both skinfold measurements will be performed with the arm held freely to the side of the body. Waist circumference and skinfold measurements will be done in order (not consecutively; rotating sites) and repeated three times.

Blood pressure

Blood pressure assessment will be performed at the level of the brachial artery of the dominant arm using an automated (i.e. oscillometric) device (Omrom) with children in a relaxed sitting position, after 3 minutes of rest. Measurements will be taken in duplicate and the last of both measurements will be recorded.

To determine hypertension, the normative values from Spanish children published by Fernández-Goula, et al. [41] will be used.

Blood tests

With the participants in the sitting position, blood samples will be drawn by venipuncture after an overnight fast. These samples will be used to assess cholesterol (LDL, HDL), triglycerides, glucose, insulin, TSH and cortisol levels. Blood samples will be analysed with an automated method at the laboratory of the Hospital Universitari Arnau de Vilanova, in Lleida.

Physical condition

To evaluate physical activity and fitness levels, children will perform the ALPHA fitness test battery [42]. The ALPHA fitness test was specially created to assess the health-related fitness status in children and adolescents within the European Union. The physical measurements of the ALPHA fitness test that will be measured from the children are: handgrip strength, standing long jump and 4x10m shuttle run test. Procedures will follow the standard guidelines indicated in the test manual [42]. To measure their aerobic capacity, the 6-minute walk testwill be used [43]. This test has been validated and has shown reproducibility in obese children [43].

Sedentary and physical activity behaviours

Sedentary and physical activity behaviours will be assessed by means of a) the objective measurement of physical activity levels during seven days and b) the filling in of a self-report activity questionnaire.

The objective measurement of physical activity level will be done using ActiGraph GT3X + accelerometers (ActiGraph, Pensacola, USA). Accelerometers will be worn by participants all day for eight consecutive days; however data from the first day will be discarded for analysis. Accelerometers will be placed on a small elastic belt and positioned on the waist. Data will be collected and stored in 30-second epochs and the mean activity counts per minute will be calculated and analyzed with ActiLife 6.0 software application (ActiGraph, Pensacola, USA). Age and gender specific cut-off points will be used to categorize behaviours into sedentary, light, moderate and vigorous intensity activity [44]. Before its placement, a researcher will give oral and written information about the procedure to the children and family. Families will be given a contact telephone number in case of problems during the period.

Additionally, on the day of the accelerometer is removed, children will fill out the Spanish version [45] of the Physical Activity Questionnaire for Children (PAQ-C) [46]. This is a self-administered questionnaire that assesses physical activity levels in children during the last 7 days ofthe school year [46]. The PAQ-C is one of the most widely used questionnaires of physical activity level assessment and its internal consistency and validity for children has been well established [47-50]. The PAQ-C provides a summary physical activity score derived from 9 items, each scored on a 5-point scale, which is designed to collect children's information about different physical activities and moments: (1) spare time activity, (2–8) physical education, recess, lunch, right after school, evening, weekends, and describes-you-best, (9) take the mean of all days of the week. Questionnaires will be analysed using the scoring of the PAQ manual [51].

Dietary behaviour

To assess and monitor the dietary status of participants, a dietary 24 h-intake-recall for three days and an eating frequency questionnaire will be performed.

The dietetic record will be done for three days, in which the families will annotate what the child has eaten during these days. It will cover two weekdays and one weekend day, and later a nutritionist will help them to interpret their annotations and power as recorded in the programme by means of the quantitative dietary diary proposed by Burke, as shown by Martin-Moreno [52] revisited and updated by Willet [53,54]. Families will be individually taught how to fill out the dietary 24 h-intake form, before they carry it out at their own home.

On the other hand, children will also complete the eating frequency questionnaire CFCA [55]. The questionnaire consists of a list of nutrients or group of nutrients. Children will be asked to indicate the intake frequency (daily, weekly or monthly) of each component of the list. This may be considered as a report card on the overall quality of diet consumed. However, if the information is combined with quantitative data about mean portions, the assessment could be semi-quantitative [56-58]. This method has already been used in longitudinal nutritional studies in children [59,60] and to assess eating patterns in children [61]. Both questionnaires are included in the diet assessment survey developed by Burke and have been performed in longitudinal studies of large populations of different ages [62]. The combination of both methods has also been applied to the assessment of eating patterns in Spain [63]. Both questionnaires will be conducted by a trained/experienced interviewer.

Psychological aspects and physiological factors

The physical activity self-efficacy for children [64] will be used to provide a self-report of their PA self-efficacy. The scale is a specific Spanish scale that consists in 12 items and a dichotomous scale (yes or no) will be used instead of the five-point scales commonly used for this type of instruments in order to facilitate their understanding to children [64]. The Cronbach alpha consistency is .733 and test-retest reliability is .867[64].

The physical self-concept of children will be measured with the physical self-concept scale (MIFA) by Moreno [65], as a predictor of the intention of being physically active. It is the Spanish version of the physical activity enjoyment scale [66]. It is a questionnaire composed by 5 items, especially created for children in order to know their intention to be physically active after school. The response scale is a Likert scale ranging from 1 (strongly disagree) to 5(strongly agree).

Body image will be assessed using the Body Figure Perceptions by Collins [67]. This instrument is useful to investigate body figure perceptions and preferences among young children [67]. This measure consists in seven gender-specific line drawings of increasing size, labelled from 1 (thinnest figure) to 7 (heaviest figure). There is a specific figure for boys and girls.

Evaluation of the physical activity enjoyment will be measured according to the Spanish version [68] of the physical activity enjoyment scale (PACES) [69]. The questionnaire consists in 16 items rated from 1 (strongly disagree) to 5 (strongly agree). The PACES is for a single enjoyment factor that can be negative or positive. The results found by Moreno [68] revealed that the scale is a valid and reliable tool to measure sport enjoyment in Spanish population.

Health related quality of life

The HRQOL for children and parent proxy-report will be determined by the Paediatric Quality of Life Inventory (PedsQL4.0) [70]. The PedsQL 4.0 is one of the most widely used measures of HRQOL in children and adolescents aged 2 to 18 and have proven its validity in clinical and population samples [70-72]. It has 4 generic scales (Physical, Emotional, Social, School) and consists of 23 items applicable for healthy school, as well as paediatric populations.

Health economic data for children

The Child Health Utility 9D (CHU 9D) [73] will be filled out by all the children in order to assess the cost-utility of the intervention. The CHU 9D is a validated measure of paediatric health-related quality of life. It has been specifically developed for use with children aged 7 to 11 years and contains 9 dimensions, each with 5 levels and it is designed to be self-completed by children. The CHU 9D will be administered at baseline, at the end of the intervention (8 months later of the baseline), 6 and 12 months post intervention.

The present questionnaire will allow for aprospective economic evaluation alongside the trial with the aim of estimating the cost-effectiveness of the NP intervention versus the CG intervention.

For collecting the resource use data and on the cost linked to the NP and CG, structured observational research methods, interviews and surveys in a sample of children will be conducted.

Parents' outcome

Anthropometric parameters

Parents' weight and height will be measured during the children assessment appointments, following the procedures previously indicated.

Sedentary and physical activity behaviours

Parental sedentary and physical activity behaviours will be evaluated using the short 7-day-recall self-administered Spanish version [74] of the International Physical Activity Questionnaire (IPAQ) [74,75]. The IPAQ is one of the most widely used questionnaires of physical activity level assessment and its reliability and validity for adults has been previously established [76]. The short IPAQ allows to compute a total score of the duration (in minutes) and frequency (days) of sedentary- intensity, walking, moderate-intensity and vigorous-intensity activities. Guidelines for data processing of the International Physical Activity Questionnaire [77] will be used to analyse these questionnaires.

Dietary intake

To assess and monitor parents' dietary status, the adult version of the eating frequency questionnaire (CFCA) [55] will be administered. The main difference between the adult and the children version is that parentalingestion of drinks containing alcohol will also be registered [78,79].

This questionnaire has been used previously in longitudinal dietary studies and in studies relating eating patterns and biological parameters in adults [80,81].

Psychological aspects

To assess the nutrition and physical exercise self-efficacy in parents, the health-specific self-efficacy scales will be used [82]. The test for the nutrition and physical exercise part has been created following the same semantic structure: "I am certain that I can do xx, even if yy (barrier)" [83]. The internal consistency (Cronbach's alpha) for the nutrition self-efficacy scale was alpha = .87 and for the exercise self-efficacy scale it was alpha = .88 [82].

Health economic data for parents

The EQ-5D [84] from the EuroQol Group will be filled out by all the parents to measure the cost-utility of the intervention. The EQ-5D descriptive system comprises the following 5 dimensions: mobility, self-care, usual activities, pain/discomfort and anxiety/depression. Each dimension has 5 levels: no problems, slight problems, moderate problems, severe problems and extreme problems [85]. The EQ-5D also has the EQ visual analogue scale (EQ VAS). The EQ VAS records the respondent's self-rated health on a vertical, visual analogue scale where the endpoints are labelled 'Best imaginable health state' and 'Worst imaginable health state' [85]. The EQ-5D has demonstrated a reliability of 0.86 to 0.90 [86]. The fill out analysis of the questionnaire will follow the user's guide [87]. As for children, the questionnaire will be administered at baseline, at the end of the intervention (8 months later of the baseline), 6 and 12 months post intervention.

Information on resource use and on the cost associated to the part of the programme for parents (economic evaluation) will be also collected using the same structured as for children.

Modifier variables

It has been shown that pubertal development, socio-economic and demographic parameters, the degree of satisfaction and other factors could modulate the outcome. For that reason, a part from outcome measurements, during the study, the following control information will also be recorded.

Pubertal stage

Pubertal stage will be assessed by the paediatrician using Tanner criteria [88] at baseline, at the end of the intervention and during the follow-up appointments.

Socio-economic and demographic parameters

To control the participants' sample for these parameters, a 10 item-questionnaire has been created. Some questions have been selected from the National Healthy Survey for children [89] and for parents [90], while some other extra questions have been designed specifically for the intervention. Briefly, all these extra questions and all the questionnaires for the intervention have been satisfactorily implemented in a pilot trial, with a similar sample of children and parents during the last edition of the Nereu programme.

Adherence

To control adherence rate a registerof children's and parent's attendance to sessions will be carried out. To consider that attendance has been satisfactory each children/parent should attend at least 80% of the scheduled sessions. Those that do not attend the 80% of the sessions will be excluded of the per protocol analysis.

Degree of satisfaction

At the end of the intervention, children and parents will also fill out a satisfaction survey about the intervention and the coaches.

Economic evaluation

The economic evaluation analysis of the cost data, the CHU-9D for the child and the EQ-5D for the parent questionnaire data and the cost-effectiveness analysis will be conducted according to the current practice methods for conducting economic evaluation. The primary cost-effectiveness outcome will be the percentage of reduction in overweight and obese children. The secondary outcome will incorporate quality adjusted life years (QALYs) as an outcome measure with the primary focus being on the impact of the child and parent quality of life, measured over a time horizon of 1 year based on the CHU-9D and EQ-5Dscore collected during the trial. The results will be expressed through the incremental cost-effectiveness ratio (ICER). The ICER is a measure that compares the difference in cost and effectiveness between the two compared interventions (NP and GC). It expresses the result as cost per QALY which can then be benchmarked against established cost-effectiveness thresholds. For example in the UK, anything costing under £20,000 per QALY is deemed cost-effective. Both parametric and non-parametric bootstrap estimates of the confidence interval for the ICERs will be estimated.

Statistical methods

Management and data analysis

All data will be recorded in an electronic data sheet. Two samples will be drawn; one by intention-to-treat (ITT) and another per protocol (PPT). The ITT sample will get-together all participants assigned to each group independently of whether they complete or not the entire protocol. The PPT sample will only assemble the participants who complete the entire protocol. The analysis of the results will be carried out according to the statistical analysis plan.

Statistical analysis plan

An initial data analysis to debug and validate the data entered in the dataset will be performed. To assess the comparability of baseline characteristics between study groups, chi-square test (or Fisher's exact test) for nominal variables and Student's *t* test (or the Mann–Whitney test) for continuous variables will be used.The evolution of the quantitative efficacy parameters will also be assessed, by group, for the different time periods, using a repeated measures analysis (at Baseline, 9, 15 and 21 months; see Table

1). In the case of a homogeneity violation in any relevant variable of the study groups, the multivariate analysis will be performed (Multiple regression analysis). The percentage of participants who reach to reduce their BMI z-score per study group will be evaluated, also by logistic regression models. For this analysis, the estimations will be adjusted by baseline factors such as demographic and predictive factors for the other dependent variables. As a sensitive analysis, unadjusted estimates will also be presented in different scenarios to assess the robustness of the results. The 95% confidence interval will be estimated for all parameters. Statistical analysis will be performed using the Statistical Package for Social Sciences SPSS v17 and the level of significance will be set to 5%.

Possible risks and burdens

This is a long term intervention that requires children and parental attendance tothe scheduled sessions as well as to the assessment appointments for the evaluation of the short, medium and long term effects. The risk of abandonment is high but we will try to reduce it by providing constant feedback to participants and their families.

On the other hand, our previous experience shows that the potential physical risks in the study are minimal. Further, the physical sessions for children have been designed and chosen especially for them. Attention has been put on enjoyment and on lack of excessively (physical and psychological) challenging situations, as well as on trying to minimize the risk of injury, even if this cannot be eliminated completely. Moreover, sessions have been scheduled to avoid overloading children. In the case that of one of these situations happens, the child will immediately be derived to their paediatrician or specialist.

Discussion

To the authors' knowledge, this is the first intensive family-based behavioural multi-component intervention for childhood obesity management led from the healthcare paediatrician with a longitudinal design in Spain. It targets the same principal contents for both parents and children in the easiest manner for each age group, focusing on their posterior application in their home unit. The study aims to establish a long-term healthy behaviour related to achieving a healthy weight status, physical activity and eating behaviour in order to improve their quality of life and reduce possible health problems. The study design is a randomized controlled multicenter clinical trial using two types of treatment (Nereu and Counseling) with follow-up measurements at 9, 15 and 21 months after the intervention. We believe that our study is in agreement with the principal recommendations, mentioned by Oude Luttikhuis [17], where it is recommended for family interventions to combine diet, physical activity and behavioural components focused on behavioural changes with good methodological interaction and assessing the effects in a long term period [7]. In addition, the present study has a longitudinal design with a long-term follow-up, and as it is well known, it makes it possible to gather a higher level of evidence than a cross-sectional analysis.

Following the previous editions of the Nereu programme, we expect a low drop-out and the probable drop-out rate/percentage has been contemplated in the sample size. However, if we have a high drop-out and we do not achieve the sample provided, it could occur that, the outcome variables do not become statistically significant due to the lack of statistical power. However, we must take into account that paediatricians use the Healthy Child Programme which computerizes medical records of all children, and also during the recruitment period paediatricians can look for a higher sample of children if required. In the recruitment period contamination between groups could occur, as children are randomized from the same healthcare centre or district. We are going to try to prevent this by doing the NP in an external school facility and the assessment periods will be undertaken on different days.

The results from the present study will provide new scientific evidence of the long-term effects of the childhood obesity management, as well as help to know the impact of the present intervention as a health intervention tool for healthcare centres.

Competing interest

Sr. JM and IC declare that they are members of the Nereu Association. The rest of the authors declare that they have no competing interests.

Author's contributions

NS, AE, GG and CT designed the study. IC and AZ designed the intervention materials and study forms. IC and JM carried out all the interventions. AE, IC, NS and AZ organized and conducted all of the assessments. NS and IC supervised the implementation of the whole intervention. JR is responsible for the accuracy of the preliminary data analysis. GG, ES, JB, CT, JR, AE and NS contributed to developing the protocols and reviewing, editing, and approving the final version of the paper. All the authors read and approved the final manuscript.

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(Adapted to the journal requirements)

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DISCUSSION

The purpose of the thesis was to analyse the relationship between physical activity/exercise habits, sedentary behaviour and food habits in overweight/obesity in children. The effect of obesity on the acute response to exercise and the effects of regular physical exercise intervention (Nereu Programme) on the degree of obesity were also examined.

The study population in article 1 showed that boys had a higher prevalence of obesity than girls. These results are consistent with data obtained in Spain (Serra-Majem et al., 2006; Aladino, 2011; ENS, 2011-12). However, the prevalence observed in the present study is higher than the one reported at a national level by the Aladino study (2011). This could be partly due to an increase in prevalence in recent years, to the age difference of the participants in both studies, to the socio-demographic characteristics of the study population or finally, to the method used to classify obesity, as reported throughout the thesis. For example, the Aladino study, which followed the benchmarks established by the World Health Organization (2006), reported the prevalence of overweight and obesity at 44.5%. According to the criteria followed by Hernández et al. (1988), the prevalence would be 30.8% and if we rely on the classification by the International Obesity Task Force (IASO / IOTF) put forward by Cole et al. (2000), it was 35.2% (Aladino, 2013). In this thesis, even when using the same benchmarks as the Aladino study (IASO / IOFT), the results report a higher prevalence of obesity.

In relation to physical activity habits, the fact that the average daily MVPA reported by children exceeds the international recommendation of 60 minutes per day of MVPA (WHO, 2010) is noteworthy. Boys report spending more time on MVPA than girls. On the other hand, girls invest longer in light-intensity activities than boys. These results are in agreement with most studies that claim that, in general, boys are more active than girls (Sallis et al., 2000; Ruiz et al. 2011; Chillon et al., 2011; Tercedor et al., 2007; Troiano et al., 2008). In the present study (article 1.1 and 1.2), both boys and girls report spending more time per day on MVPA than in the study by Ruiz et al. (2011). These differences could be partly due to our study population being more active. Other possible causes could be related to the system used to elicit the time spent in MVPA activities from participants. Here, it was measured using a self-reporting questionnaire, while the results reported by Ruiz et al., (2011) were obtained by electronic devices. In this respect, there have been studies where physical activity habits were measured by means of questionnaires and electronic devices and that found self-reported data to overestimate the actual practice time (Epstein, Paluch, Coleman, Vito, & Anderson, 1996). Another reason may be that the average age in Ruiz et al.'s study (2011) was greater than in the current study. Unpublished data in articles 1.1 and 1.2 showed that the time devoted to practising physical exercise declines with age. These results are in agreement with most authors, who show that practising exercise and the time devoted to it decreases with age (Goran et al., 1998; Ruiz et al., 2011; Strong et al., 2005; Troiano et al., 2008).

According to the distribution by BMI z-score (non-obese vs OW/OB), it is worth highlighting the fact that OW/OB children spent less time doing high-intensity activities. The percentage of OW/OB children who practised supervised exercise, as well as the time they spent on it, were also lower in comparison with non-obese children. In addition, there is also a positive correlation between the time spent in physical exercise and/or high-intensity activities and a lower degree of obesity. Likewise, participants in the Nereu Programme (Article 3) reported habits of physical activity far below the recommendation of 60 minutes of MVPA before starting the programme. This trend to practise lower MVPA in OW/OB children in relation to non-obese children has also been observed by other authors (Ekelund et al., 2004; Lazer et al., 2003). For example, Ekelund et al. (2004) reported that non-obese children spent more time on MVPA ($p = 0.022$) than OW/OB children, after adjusting for gender, nationality and sexual maturity. These authors also observed an inverse correlation between the total time spent on physical activity ($r = -0.12$, $p < 0.001$), the time spent on MVPA ($r = -0.15$, $p < 0.001$) and the time spent exclusively on vigorous activities ($r = -0.13$, $p < 0.001$) relative to the thickness of 5 different skinfolds (triceps, biceps, sub-scapular, supra-iliac and calf). As previously mentioned, Martinez-Gomez et al. (2010) consider that practising 18 minutes/day of vigorous physical activity and 55 minutes/day of MVPA significantly discriminate between adolescents with normal weight and those with OW/OB. In the present study, this contrast between groups has been observed when the difference was of only 8 minutes/day vigorous PA. However, these differences related to the degree of obesity of children in both pre-pubertal age (Ebenegger et al. 2012) and adolescents (Ortega et al. 2007a) have not been observed by other authors. Regardless of the discrepancies observed in the present study, it can be concluded that mainly high-intensity physical activity habits such as the practice of supervised exercise and the time spent on it, are main factors that could determine the degree of adiposity, which has previously been reported by several other authors (Eisenmann, DuBose, & Donnelly, 2007; Ortega, Ruiz, & Sjöström, 2007b; Serra-Majem et al., 2003; Ruiz et al., 2011). Looking at the study population, and having considered all the results with caution due to its limitations, it can be concluded that a negative correlation between the daily time spent on MVPA and the existence of obesity exists. Therefore, increasing supervised practice or PA to vigorous-intensity exercise by about 1 hour a week (i.e. increasing physical activity from 2 to 3 hours a week or by eight minutes/day), could be a good long-term tool to enhance an active lifestyle and therefore, child obesity. Furthermore, it should be added that a positive correlation between MVPA and PC exists. It is important to remember that a good PC is associated with a lower prevalence of cardiovascular disease and promotes a better state of health, both during youth and adulthood (Delgado, Gutierrez, & Castillo 1999; WHO, 2004).

Regarding sedentary behaviours, the time spent watching TV and playing computer/console games exceeded the recommended 2 hours a day (Australian Government, 2014, Strong et al., 2005). However, the time spent on these sedentary behaviours resembles the time reported in previous studies (Ruiz et al., 2011; Troiano et al., 2008; Salmon et al., 2011). As in the study by Agarwal (2008) and Hardy et al. (2007), they highlighted the time children spent in sedentary behaviours, watching TV and playing computer/console games. In addition, non-reported results in article 1.1, showed that these sedentary behaviours increased with age, coinciding with the majority consensus in this regard (Agarwal, 2008; Biddle et al., 2012; Hardy et al., 2007; Kain et al., 1998; Pate et al., 2008; Salmon et al., 2011; Ruiz et al., 2011; Treuth et al., 2009; Treuth et al., 2009; Van Sluijs et al., 2010).

Regarding gender, no differences were observed either in the time spent in sedentary behaviours in general or playing computer/console games in particular. However, in the results it was observed that boys watched TV longer than girls. These results are similar to the results observed in Estonia where the boys were also more sedentary than girls (Van Sluijs et al., 2010). In contrast, the Helena study differed in the fact that girls spent more time in sedentary behaviours than boys (Ruiz et al., 2011). This could be due, in part, to the different measurement systems used, as previously discussed or cultural differences.

It is noteworthy that in the present study, no differences were observed in the degree of obesity in relation to the time spent in sedentary behaviours, watching TV or playing computer/console games. These data are at odds with most results obtained by other authors where it does appear that the time spent in sedentary behaviours or watching TV is associated with the development of child overweight (Agarwal, 2008; González-Jiménez et al., 2012; Gortmaker et al., 1996; Jago et al., 2005; Marshall et al., 2004; Serra-Majem et al., 2003; Ruiz et al., 2011; Tremblay et al., 2011; Ortega et al., 2007a). However, the data from the present study are in agreement with the results observed by Steele et al. (2009), Ekelund et al. (2004), and Purslow et al. (2008), since no associations were observed between the time spent in sedentary behaviours and different parameters of adiposity in boys/girls and adolescents. This could indicate that in the study population this association does not exist or, as noted above, it could be due to the methodology used to measure these behaviours. On the other hand, this could be because the analysis did not take into account confounding variables such as the time devoted to sports or other active habits, as these could offset the amount of time spent in sedentary behaviours. However, in article 1.1 the results indicate that sedentary habits were not significantly correlated with a higher degree of obesity.

As mentioned above, another key factor in the treatment of child obesity refers to adherence to the Mediterranean diet in Spanish children. The present study did not find any differences either between the groups studied when distributed by gender or weight, or in subgroups by weight and gender. These results are in agreement with the results observed by Maier et al. (2013) where no differences were observed between non-obese boys/girls and OW/OB peers. However, they differ from the results observed by other authors when comparing between both genders (Wardle et al., 2003) and between the non-obese and the OW/OB groups (Anta et al., 1996; Gillis et al., 2002). This could be due to the fact that differences do not exist in the study population or, conversely, they may exist but had not been observed due to the questionnaire limitations.

In spite of being a questionnaire specifically designed for the study population, data on the caloric intake or distribution of carbohydrates, fats or proteins cannot be obtained through this questionnaire. This fact limits finding out all of their dietary habits and thus, it is very difficult to conclude whether or not there are actually differences between study groups. However, differences were observed in relation to meals in the school canteen between groups both by gender and weight, as there were a higher percentage of non-obese girls and boys having their lunch at the school canteen. These data seem to underline the potential importance of schools in preventing child obesity and highlighting healthy habits and thereby promote the importance of prevention programmes in schools (Martínez-Vizcaíno et al., 2012).

Some studies report that the lower the educational level of the parents, especially the mother, the greater the level of obesity of their children (Gnavi, Spagnoli, Galotto, Pugliese, Charter, & Cesari, 2000). However, the results obtained in article 1.2, after dividing parents by level of education in 3 categories (no education, basic education and higher education) no differences were observed between the group of non-obese and OW/OB children. However, there was a significant correlation between the educational level of the parents and the degree of adiposity of their children. These results are similar in part to the data from Spanish children in the AVENA study (Moreno & Cervelló, 2004) where they found no difference in the socio-economic status and the prevalence of obesity in girls, but differences were found in the boys.

In short, as has been observed, aspects related to physical activity/exercise, sedentary behaviours and food, all within the family context, seem to be of great relevance in the interventions for the treatment of child obesity. However, as mentioned above, the different models that attempt to explain child obesity show that it is a much more complex and difficult problem to deal with.

Another aspect analysed in this thesis is the acute response of OW and OB children to physical exercise, in particular in relation to their EE, VE and HR during sub-maximal treatmill testing at constant speed while the slope increased. It was observed that the physiological adaptation of OW and OB children is not identical. Specifically, it was observed that, in absolute values, the higher the degree of obesity, the higher the EE and VE of children on all slopes. However, such differences disappeared when EE or VE was adjusted to the body mass. Nonetheless, some of these differences remained between groups when the EE or VE was adjusted to their FFM or BSA. These data suggest that the greater the body weight, the greater the EE. This effect could be attributable to a ballast effect of excess fat mass. However, it is also necessary to consider kinetic or kinematic aspects of gait, which could also explain some of these differences. According to Peyrot et al. (2009), this increased energy cost when walking in obese subjects may be explained in part by the higher energy costs they incur in the step-to-step transition. Especially in weight-bearing activities such as walking or running, body mass and body composition are important predictors of energy expenditure (Zakeri et al. 2006). For example, Lazzer et al. (2003), after assessing energy expenditure in non-obese and OW/OB adolescents, noted that during running/walking, EE and daily energy costs were significantly higher in the OW/OB than in non-obese, both in absolute terms and after adjustment for body weight or FFM. However, they found that the EE during sleep and sedentary behaviour was higher in the OW/OB children than in non-obese ($p < 0.001$), but after adjustment to the FFM, these differences disappeared.

These data could be of great importance in the treatment and prevention of childhood obesity, since as mentioned by Peyrot et al. (2009), the amount of energy used during physical activity plays an important role in the prevention of overweight and obesity and in the weight reduction process. Specifically, aerobic exercise is a key factor in reducing weight and widely used in the control of child obesity (Norman et al., 2005). In addition, knowing the energy expenditure of different activities will allow for a better estimate of the daily energy expenditure, which is difficult to calculate in children. From these, more precise recommendations regarding caloric intake, and thus, tailor-made interventions will be possible. Currently, probably due to the difficulty that this implies, there is hardly any evidence in children in this respect since most of the existing data have mainly been obtained from adults and, sometimes, from normal-weight children (Ridley & Olds 2008). This knowledge is hardly transposable to OW/OB children because the same absolute level of effort requires greater effort from them.

The long-term response to physical exercise was analysed by means of the Nereu programme. This is an intervention for the treatment of child obesity, which was carried out in article 3, and consisted of non-competitive supervised physical exercise with behavioural components for children, sessions to discuss healthy habits for parents and, finally, behavioural strategies for both.

It is important to note that after the intervention, there was an increase of more than 5 hours per week of MVPA, accompanied by a reduction of more than 5 hours of sedentary behaviour in both genders. These are very positive aspects considering, as mentioned above, that children are increasingly more sedentary and spend less time in MVPA (Salmon et al., 2011; Ruiz et al., 2011). However, participants failed to achieve the 60 minutes of MVPA recommendation (Australian Government, 2014; WHO, 2010; Strong et al., 2005). Nevertheless, it was sufficient to significantly decrease the mean BMI z-score of the group. Although fat mass did not decrease, except in the lower limbs of the boys. In addition, we should highlight the good attendance and satisfaction with the programme, because one of the most common limitations in medical intervention programs is the relatively low medium-term adherence (Barja, 2005).

Despite the discrepancies in earlier studies on the importance or not of physical exercise in the treatment of childhood obesity, in the present study, we can conclude that supervised non-competitive physical exercise for children together with behavioural components and a family intervention that includes physical activity, nutrition and behaviour and based on the main recommendations of various authors (Golan et al. 2006; Hughes et al., 2008; Kitzmann et al., 2010; Oude Luttikhuis et al., 2009, Waters et al., 2011; Whitlock et al., 2002) appears to be effective for the treatment of OW/OB children.

The data observed in the different articles indicate that physical exercise seems to be a crucial component in the treatment of child obesity, both, due to the benefits that regular practice poses to one’s overall health and because it reduces body weight (WHO, 2013; Peyrot et al., 2009; Norman et al., 2005). However, as mentioned earlier, the practice of physical activity or exercise can be easily countered if caloric intake is increased or if the increase in energy cost is not sufficient to achieve energy imbalance. Physical exercise practice, as mentioned before, must be adapted to the needs of children and it needs to go hand in hand with other content and the inclusion of the family, as well as diet and behaviour interventions in order to generate and maintain this important long-term imbalance (Golan, Kaufman, & Shahar 2006; Hughes et al. 2008; Kitzmann et al., 2010; Waters et al., 2011; Whitlock, Tracy Orleans, Pender, & Allan, 2002). However, many questions remain unanswered, such as the high percentage of participant loss during the interventions and their follow-up, preventing the long-term evaluation of the effectiveness of the interventions. Despite the high number of interventions for the treatment and prevention of childhood obesity, there are no effective tools in paediatric units to treat child obesity comprehensively despite them being the ones primarily involved in the diagnosis and treatment of childhood obesity. Neither are there studies measuring the cost-effectiveness of these interventions in relation to health results in order to know if their cost is actually quantified / justified and if they actually improve the quality of life of overweight and obese children. In this regard, and despite currently having no results, the 4th article shows the study protocol of the Nereu Programme, which has been developed in order to answer these questions of vital importance in the treatment of childhood obesity.

LIMITATIONS

Throughout the discussion various limitations have been noted. These are summarised below.

In article 1.1 and 1.2, the cross-sectional design does not allow causal relationships to be established. However, it meets the primary objective: finding out the main habits related to child obesity in the study population with the objective of targeting and identifying strategies and content of a future intervention to the participants’ needs.

In article 2, the pubertal maturation of children was not taken into account. However, the data were adjusted to BSA, which includes weight and height in its formula.

Secondly, all comparisons were made at absolute levels of exercise. This was considered safer because of the characteristics of the subjects. Subjects performed a sub-maximal test, therefore maximum values were not obtained. However, this did not prevent the analysis of the EE at different absolute intensities in relation to the degree of adiposity. Moreover, the VO2 at rest could not be registered, so the net VO2 could not be calculated. For that reason, in this study, it is not possible to attribute the observed differences in EE between the OW and the OB group to a deficiency in the transfer of mechanical energy when walking, since we cannot rule out that the resting power consumption was already higher in OB children in comparison with OW children. Finally, the sample size was small so it could affect the statistical power of some parameters, as well as the estimation error of the variables. For these reasons, we should be cautious in extrapolating the data. However, this was not a limitation for the interpretation of the main hypothesis of this research.

In article 3, not having a control group meant that a causal relationship could not be established since the results could have resulted from the intervention itself or could otherwise be due to the children's growth and/or own maturation age. On the other hand, a longitudinal study could not be done to show if the new habits acquired at the end of the intervention had been maintained in a medium- to long-term period. Nevertheless, and despite its limitations, the study meets most of its objectives, that is, being a first evaluation of the Nereu programme.

Article 4 is a study protocol and its main limitation is the lack of results. However, they will be available in the near future and it is expected that they will provide new data to help understand some of the above questions with regards to the treatment of childhood obesity, such as the lack of monitoring data after long-term interventions, knowing the cost-effectiveness of an intervention in relation to the health-related quality of life. Furthermore, this protocol aims to be the proposal for the future of this thesis and in turn, control many of the limitations noted in previous articles, being a controlled randomised clinical trial with long-term objective measures and with a sample of 120 children.

<u>CONCLUSIONS</u>

General Conclusion

The main findings in the study population in this thesis were the following.

Practising at least 3 hours a week of PE was associated with a lower prevalence of OW/OB and better PC in children. These differences have also been observed in the PA habits and PC or in participants eating in the school canteen by gender, degree of obesity (non-obese vs OW/OB) and, especially, among the non-obese and OW/OB girl subgroup. Furthermore, these gender differences were also observed in sedentary behaviours, especially in the amount of hours spent watching TV daily. However, these differences were not observed in any of the groups regarding adherence to the Mediterranean diet, quality of life or educational level of parents.

Regarding acute response to exercise, the values of EE and VE at the same intensities were higher in the group of obese children compared to their overweight peers in the exercise testing.

Following the Nereu programme intervention, children increased the time they spent in moderate- and high-intensity activities and, in contrast, BMI z-scores and sedentary behaviours such as watching TV and playing computer games were reduced.

Specific Conclusions

Obesity Prevalence:

- In the study population, the prevalence of OW /OB was very high. Boys have a greater prevalence of overweight and obesity than girls.

Habits of physical activity and sedentary behaviour:

- OW and OB children tend to perform 52 minutes / week (DE: 2:33 min/week, $p < 0.01$) less than non-obese children in high-intensity activities.

- Boys spend more time watching TV (2:19 ± 2:33 hours / week, $p < 0.01$) and in MVPA (3:21 ± 4:28 hours / week, $p < 0.001$) than girls.

- Girls spend more time on light-intensity activities (3:29 ± 7:21 h / week, $p < 0.001$) than boys.

- BMI z-scores were significantly and positively related ($p < 0.01$) with the time spent watching TV and negatively related with time spent on MVPA.

- In relation to subgroups by gender and degree of obesity:

    - o In the boy subgroups, no differences were found in physical activity habits or sedentary behaviour among OW/OB boys compared to non-obese boys.

    - o In the girl subgroups, OW / OB girls spend less time on high-intensity activities vs non-obese girls (2.70 ± 3.06 h / week vs. 1.31 ± 1.68 h / week, $p < 0.001$ respectively) but more time on light-intensity activities (10.87 ± 6.96 h / week vs. 13.62 ± 9.06 h / week, $p < 0.028$, respectively).

- The percentage of non-obese children (65.1%) who reported playing sports was significantly higher ($p < 0.05$) than OW / OB children (53.7%).

- The time non-obese children devoted to sport was superior to that of OW / OB children (2.99 ± 3.03 vs 2.05 ± 2.36 hours / week, $p < 0.001$, respectively).

- The more time devoted to sport, the lower the degree of obesity ($r = -0.220$, $p < 0.001$).

- The BMI z-score was negatively related to all PC tests (aerobic endurance (6MWT), feet together jumps, number of abs) except in the medicine ball throw.

- Subgroups by gender and degree of obesity:

  - In the boy subgroups, in the PC tests, differences were only observed in the aerobic endurance test (TM6), with the OW/OB boys being slower.
  - OW/OB girls did worse at the abdominal test and the aerobic endurance PC test compared to non-obese girls.

Eating Habits:

- The percentage of non-obese children (76.4%) who ate at the school canteen was higher ($p < 0.001$) than that of OW/OB children (55.7%).

- The percentage of girls who ate at the school was higher (75.6%) compared to boys (58.3%).

- Eating at the school canteen was significantly associated with BMI z-scores ($r = -0277$, $p < 0.001$).

- 42.6% of children had poor adherence to the Mediterranean diet.

- No differences in adherence to the Mediterranean diet were found between genders or according to the degree of obesity.

Family Influence:

- The level of education of the parents was correlated with the degree of obesity in children ($r = -0.27$, $p < 0.001$).

Quality of Life:

- No quality of life differences were found between any group or subgroup.

Acute effects of physical exercise:

- EE and VE were higher in OB children than in OW children, both in absolute values as in those adjusted to FFM and BSA.

- The BMI z-score and the FM were the major predictors of EE on all slopes.

<u>Long term effect of the Nereu Intervention Programme:</u>

- Children spent more time ($p < 0.01$) on moderate-intensity activities ($2.4 \pm 5.3 h \cdot set^{-1}$ and high-intensity ($3.1 \pm 1.62 h \cdot set^{-1}$) after the intervention.

- Children spend less time ($p < 0,001$) in sedentary behaviours ($5.4 \pm 6.3 h \cdot week^{-1}$), especially the time spent playing computer/console games $1.6 \pm 4.6\ h \cdot week^{-1}$ and watching TV $3.2 \pm 4.8\ h \cdot week^{-1}$.

- BMI z-score was reduced by 0.2 ± 0.29 units ($p < 0,001$).

- Both the adherence and the overall satisfaction with the programme were very high and positive.

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