Energy balance and physical activity in obese children attending day-care centres

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Objective: To evaluate energy balance and physical activity in obese preschool children attending day-care centres.
Design: Cross-sectional study.
Subjects: Twenty-four 3–5 years old obese children selected at random from four different day-care centres in Santiago City, Chile. Total energy expenditure (TEE) was measured by doubly labelled water and physical activity as recorded by TRITRAC R3D motion sensor. Energy intake was assessed by measuring food intake while at the centre, along with the recording of additional food intake in the home.
Results: Obese children had a 5.4% higher weighed energy intake than their energy requirements 2001. Energy intake during the week was 7716 ± 1092 kJ/day and 7401 ± 1023 kJ/day in boys and girls, respectively. Minimal activity was higher in the day-care centres (62%) compared to 52% during the weekend at home. Light activity was higher during the weekend at home than during the week (25 versus 20%), but moderate-intense activity was similar (3–5%).
Conclusions: Reduction in dietary energy provided at the day-care centres helps to balance energy requirements during the week. Obese children had marked sedentary characteristics with regards to physical activity, although children are more active at home in weekends. This situation suggests that educators and parents need to improve children's physical activity levels and nutrition habits.

Keywords: preschool children; energy intake; requirements

Introduction

Childhood obesity is steadily increasing in developed countries as well as in less-developed societies that are immersed in the epidemiological transition (WHO, 1997). In Chile, 8.5% of children 2–5 years old are obese according to the National Centre for Health and Statistics standard (>2 s.d. *Z*-score Weight for Height, WHO, 1986). Additionally, obesity prevalence in the schools that receive aid from the National Board of Day Care Centres was 10.8% in the year 2002, compared to 6.2% in 1992 (Food and Nutrition Program, 2002). At present, one in 10 preschool children is obese and one in four is overweight (Burrows, 2000). The National Board of Day Care Centres (JUNJI) provides care for 60 000 children during the full 8 h day and for 40 000 children during the half-day. Owing to the increment in the prevalence of obesity and the already identified excess of energy recommended (FAO/WHO/UNU, 1985) for this age, the energy supply provided at JUNJI centres was decreased to approximately 60% of total daily energy recommendations in the year 2000.

The increment in the rate of obesity has been associated with a change in dietary pattern and physical activity (Tojo *et al*., 1999; Burrows, 2000; Vio and Albala, 2000). It is now known that children who are obese at 5 years old double the chance of remaining in that condition during adulthood (Rolland-Cachera *et al*., 1987). Furthermore, it is in the first 6 years of life that children establish their food and physical activity preferences (Vera *et al*., 1991; Pellegrini and Smith,

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1998). Thus, this age is a key period of life to prevent obesity and its consequences in adolescence and adulthood (insulin resistance, diabetes, hypertension and hyperlipidemia, among others).

The main objectives of the present work were to assess energy intake during the week, plus energy expenditure and physical activity patterns in obese children, both at the centres and in the home. Children spend two-thirds of their waking hours at JUNJI, making this time-window amenable to health promotion interventions. Additionally, parents of children of this age are open to incorporating changes in their child's daily routine, a factor favouring the child's health and well-being.

Finally, the data collected in this study along with previous information collected for children of normal nutritional status attending similar day-care centres are being used to attempt to modify energy intake and physical activity patterns in these children (Cardona, 2001).

Materials and methods

Subjects

Obesity was classified as being two-standard deviations (s.d.) above the median of the NCHS *Z*-score Weight for Height indicator (WHO, 1986). Consistent with the current prevalence of obesity in JUNJI centres at the national level, 5–8 children were expected to be obese in each centre. Thus, in each day of the four day-care centres in the North section of Santiago City, obese children were chosen on a first-come basis, from a total of 252 children of different nutritional status. Twenty-four obese children were selected (12 boys and 12 girls) and five of these children were excluded, three girls and two boys. Of these excluded children, three children were sick during the measurement, and the parents of the remaining two children did not allow their participation in the study.

As mentioned above, these centres provide education to the child, plus three daily meals (prepared at the centre), containing 75% of daily protein, mineral and vitamin needs and 60% of energy requirements.

Methods

The study was designed to evaluate energy expenditure, energy intake, physical activity levels and body composition in obese girls and boys.

Inclusion criteria

- Healthy preschool children 3–5 years old
- Weight for Height *Z*-score >2 s.d. (WHO, 1986)
- Full day attendance (8 h)
- Parent/caretaker consent to allow child's participation

Prior consent approval was obtained from the Ethical Committee of the Institute of Nutrition and Food Technology (INTA), University of Chile.

Exclusion criteria

- Psychomotor impairment
- Use of drugs influencing energy expenditure or physical activity

Energy intake (EI). Meals during the 8 h of stay at the day-care centre are prepared by private caterers, which must comply with providing 60% of energy and other nutrient requirements for the child.

Food intake during the 8 h the child stays at the centre was measured twice a week on non-consecutive days by one of the authors (FV). Food intake was calculated by weighing each meal on the tray and by subtracting the weight of the food leftover on the tray. The food components of each preparation were known in advance and its chemical composition was provided by the food suppliers. All children ate from the same menu; hence, there were no differences in the type of foods served, but only in the amount eaten by each child. The children were discretely supervised during the mealtime.

Measurement of intake during the week. On the same day, food intake was measured at the day-care centre, and the mother was provided with a questionnaire on which she recorded all foods eaten by the child from 1630 until bedtime and for breakfast the following morning.

The same trained nutritionist (FV), who weighed the food ingested at the day-care centre, checked with the mother the information on home intake on the immediate next day of the measurement. The mother came to the centre the following day to review the information regarding the types of preparations, amounts or portions consumed and name of brand foods, if any. Dietary information on energy and macronutrient composition during the week was obtained via an *ad hoc* computational program based on the Chilean food composition table (Schmidt-Hebbel *et al*., 1992). This program was used to evaluate dietary data obtained by both questionnaires and food intake measurement at the centres.

Measurement of intake during the weekend. Mothers were provided with a questionnaire to record all food intakes at home on one weekend day. The mother (or caretaker) was interviewed the following Monday in order to review with her the portion sizes, food types, ingredients of food preparations and name of brand foods. This value will be utilized in the evaluation of weighted energy intake (week and weekend).

Energy expenditure determination

A dose of doubly labelled water (DLW) containing 1.5 g/kg of H_2O^{18} (10%) and 0.2 g/kg of 99.9% of ^2H_2O was administered to each child in the morning on arrival to the day-care centre between 0900 and 0930 hours. On the previous day, mothers were asked not to give any food to their children after 2100 hours. On the morning of the study, 2 h before the dosing, the child was permitted to have 100 ml of milk without any solid incorporated.

From the second urine void in the morning, a basal urine sample was collected before the administration of the DLW dose. To evaluate the isotopic decay in body water, a daily 6 ml urine sample was collected in the morning on each of 7 days thereafter. Deuterium and oxygen-18 concentration in the samples were evaluated in a continuous flow IRMS (HYDRA, Europe Scientific, Crewe, UK), at the Energy Metabolism and Stable Isotopes Laboratory (INTA, University of Chile).

Measurement precision for deuterium concentration was 2–3 deltas (0.3–0.4 p.p.m.) and 0.2 deltas (0.05 p.p.m.) in the case of oxygen-18 samples, as determined by alternate standard samples within the run. Values were fitted into the multipoint Coward's protocol, with Livingstone's adaptation for evaluation of energy expenditure in children (Livingstone *et al*., 1992). Raw CO_2 production was adjusted by fractionation effects (0.991, 0.994 and 1.037) and percentage of fractionated water used was 30%, similar to that used in children (Livingstone *et al*., 1992). The corrected CO_2 rate was converted to energy by using the Weir equation (Elia, 1991) and a calculated Food Quotient value of 0.87 was used, according to measured energy intake, in order to evaluate the respiratory quotient (RQ) within the measurement period.

The Schofield equations adopted by FAO/WHO/OMS 2001 were utilized to calculate basal metabolic rate (BMR) in these children. These equations are based on body weight and are specific to 3–10 year-old girls and boys (Schofield, 1985). Tverskaya *et al*. (1998) have found that these equations are valid for 3–10-year-old obese children.

Energy requirements and growth

This variable was calculated using FAO/WHO/UNU (2001) for the age groups of 3, 4 and 5 years old. Accordingly, the 2001 energy requirements for boys and girls were calculated applying the quadratic polynomial regression equations. In both cases, actual weight was considered.

Additionally, an estimation of measured energy requirements (Measured EReq) was made as assessed by doubly labelled water, with the addition of the energy cost of growth. In order to assess energy expended as growth, children were weighed on the first and last days of the DLW measurements and the mean daily value was used. The average daily growth within the period of DLW measurement was multiplied by 22.9 kJ/g (5.48 kcal/g), according to the calculation revised by Butte and Ellis (2003), on the original estimation by Hill *et al*. (2003).

Body composition

Total body water (TBW) and body fat were determined from the back-extrapolated logarithmic line of energy expenditure data (Coward, 1990). Fat-free mass (FFM) was calculated from Fomon's hydration coefficients (Fomon *et al*. (1982), adjusted by Schoeller (1996). Fat mass (FM) was obtained by subtracting FFM from the total weight.

Physical activity

A triaxial movement sensor was used (TRITRAC-R3D RESEARCH ERGOMETER, Professional Products, Division of Reining International, Madison, WI, USA). This sensor collects information on three-dimensional movement (lateral, vertical and horizontal) every minute and this information is stored as Vector of Magnitude, which is the square root of the sum of each vector in directions X, Y, Z elevated to the square power. The information was collected in the desired period and downloaded to a computer where it could be analysed as needed.

The Tritrac sensor is able to provide information on energy expenditure through physical activity in the adult population. Cutoff points for activities have been set for children >9 years old (Rowlands *et al*., 2004) and for men for moderate and intense physical activities.

Preschool children have several differences as compared to older children, such as lower height and weight and ongoing motor ability development, both of which make it necessary to set distinct activity cutoff points for this group. Children's activities were categorized into four ranges after direct observation of 20 children of normal nutritional status (Table 1). It is notable that the cutoff counts for moderate and intense activities in our group is similar to three Mets activities (around 1000 counts) as found in Rowlands *et al*. (2004).

Tritrac motion monitors were used during three full days (two weekdays and one weekend day). The monitor was connected to the child immediately after waking up and disconnected once asleep; the mother or caretaker was asked to register those times as well as any other moment of disconnection of the equipment (i.e., shower, swimming) in an *ad hoc* questionnaire.

In order to avoid the child handling the instrument, the movement sensor was firmly attached to the child's chest in a stitched pocket. This ensured the monitor's tight positioning and avoided the possibility for shifting in order to reflect the real activity of the child without deterring the child's freedom of movement.

Positioning the monitor at the hip was either not accepted by the children owing to their stature, especially at 3 years of

Table 1 Cutoff points used to classify physical activity levels based on Tritrac measurements

Activities	*Activity counts (vector of magnitude)*
Resting and minimal movements	<188
Sedentary activities in the classroom	188–349
Light effort activities in the playground	350–1074
Moderate and intense activities in the playground	>1074

age, or manipulated frequently. Therefore, the chest, which is on average about 8–10 cm away from the hip in 3–5-year-old children, was used as a proxy for the hip. In a non-published investigation, it was demonstrated that the chest position of the Tritrac in children of the same age gave similar results for activity as compared to heart rate monitoring and treadmill variable intensity measurements (unpublished information, Hernandez *et al*., 2005).

Analysis of data
Data were processed using Statistic for Windows Release 4.5, 1993 and Primer 3.02, 1992. The mean and standard deviation (s.d.) were used to characterize variables in the sample; if normal s.d. distribution did not exist, median and centiles were used. Homogeneity of s.d.'s was assessed using Levene's test and differences; in the case of medians, it was assessed using the Wilcoxon test.

Results

Boys and girls had similar characteristics in age, weight height and fat and fat-free mass percentage (Table 2). No significant differences between sexes were found in any of the variables, although it should be stressed that at this early age, mean fat proportion is nearly 30% of body composition.

The mean values of BMR, TEE and physical activity level (PAL) are shown in Table 3; also indicated are the values of EI and the requirements calculated for Measured EReq and EReq 2001. Significant differences were found by gender in TEE and Measured EReq ($P<0.05$).

With respect to energy balance, energy intake for boys was 6.7±25.3% higher than their EReq 2001 (7716±1092 vs 7401±1023 kJ) and was correspondingly 4.1±15.9% higher in girls (7224±703 vs. 6947±1131 kJ).

Activity was classified as minimal, sedentary, light or moderate-intense as described in Table 1. Children slept for an average of 10.5 h daily. Figure 1 describes physical activity patterns, excluding sleep time. During the week, the children dedicated 58% (488 min) of their time to minimal activity and 4% (32 min) to moderate activity, whereas on the weekend, the minimal activity reaches 52% (405 min) and moderate-intense was 3% (22 min). On a weekday, children tended to expend a higher amount of time in minimal activity at the day-care centre (62%) than at home (54%).

Discussion

In this paper, children in the sample are not representative of the whole population of preschool children in Santiago, Chile, as the main objective was to have initial data on the comparison of energy requirements 2001 to their energy intake, in the day-care centres and home. Obesity had been steadily growing since 1992, so it was feasible that energy supplied at the day-care centre could be contributing to obesity prevalence.

Table 2 Anthropometrical data and body composition in obese boys and girls

Variable	*Boys* (n = *12*)	*Girls* (n = *12*)
Age (years)	4.3±0.5	4.2±0.7
Weight (kg)	22.3±2.4	23.1±3.6
Height (cm)	107.7±5.2	108.4±8
Weight for Height *Z*-score	2.4±0.5	2.6±0.5
Mean daily weight gain (g)	4.8±6.3	3.6±5.7
TBW[a] (%)	53.7±3.1	51.4±5.2
FFM[b] (kg)	15.6±1.5	15.2±2.5
FFM[b] (%)	70.4±3.5	66.7±6.1
Fat (%)	29.6±3.5	33.3±5.5

[a]TBW: total body water.
[b]FFM: fat-free mass.

Table 3 Basal metabolic rate (BMR), physical activity level (PAL), total energy expenditure (TEE), measured energy requirements (Measured EReq), new Energy requirements (EReq 2001), energy intake (EI) and the difference between energy intake and Measured EReq

	Boys	*Girls*
BMR (kJ)	4225±230	3998±304
TEE (kJ)	6811±763*	6192±844*
PAL	1.61±0.18	1.55±0.14
Measured EReq (kJ/d)	7567±1470*	6759±941*
EReq 2001 (kJ/d)	7401±1023	6947±1131
EI (kJ/d)	7716±1092	7224±703
EI−EReq 2001 (%)	6.7±25.3	4.1±15.9

*$P<0.05$.

The current urban lifestyle is associated with changes in alimentary patterns and insufficient physical activity (Delany, 1998; Espinoza, 1998; Rojas and Uauy, 1999). Being obese at an early age has implications for higher risk for overweight in adult life, and a higher frequency of non-communicable chronic diseases (Albala and Vio, 1995; Gidding *et al*., 1995; Barlow and Dietz, 1998; Field and Colditz, 1999). Energy intake measurement using diverse methodologies usually overestimates the actual value of energy expenditure; studies in young children have shown a closer agreement among both factors in children of 4–6 years old (Black *et al*., 1993; Hill and Davies, 2001).

To date, the DLW method is considered the best standard for estimating energy requirements with a standard error of <5% in previous studies in preschool children (Stock, 1999). EReq 2001 was lower than their corresponding energy intake (6.7±25.3% in boys and 4.1±15.9% in girls).

As an initial conclusion, obese children of preschool age are at balance during the week, regarding EReq 2001, supporting the idea that the information provided by parents does not underestimate food intake in this range of age. This lack of under-reporting may be due to the methodology used during the week, plus the fact that in

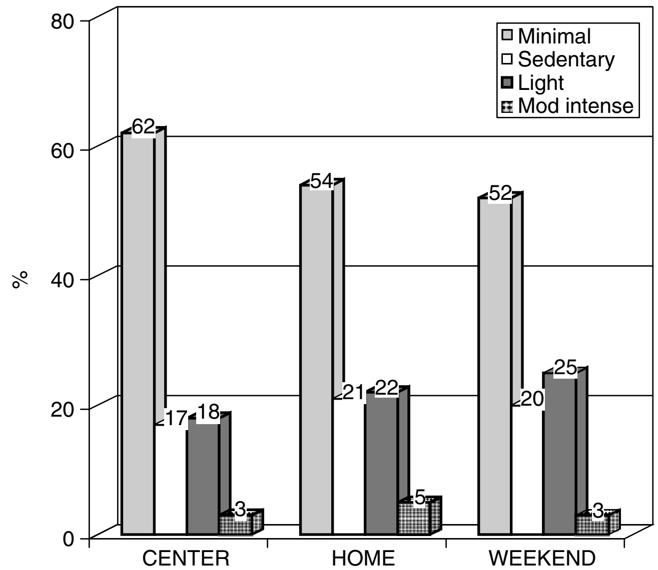

Figure 1 Physical activity pattern according to proposed category of activities (%), during the waking hours (week and weekend).

children < 7 years of age there is no under-reporting, as observed in normal weight children <7 years of age (Rennie *et al*., 2005).

In 6–9-year-old children, O'Connor *et al*. (2001) found a small group difference in energy intake of 7514 ± 1260 kJ/day vs TEE, 7396 ± 1281 kJ/day.

For daily mean energy intake during the entire week, 21% of energy came from non-nutritional sources, as sugar and fat contained in snacks, beverages, cakes and cookies (60% from sugar and 40% from fat). With respect to sweets' intake, recent results in similar children in Chile would suggest that a significant lesser satiety is observed after consumption of a high carbohydrate meal with a rapid digestion rate, indicating a decreased capacity of energy regulation in obese children (Alvina and Araya, 2004). It has also been suggested that a higher sugar intake decreases intake of fruit and beverages and was positively associated with BMI in 4-year-old Norwegian boys (Overby *et al*., 2004). Evidence also suggests that an excess in energy intake, and in particular as fat, is the main involved factor in obesity. In a longitudinal study, fat intake but not carbohydrate intake was associated with skinfolds (Magarey *et al*., 2002). Energy and fat intake was associated with obesity at 8 years of age in a follow-up of children from 2 years of age (Matheson *et al*., 2004). Another study indicated that fat intake was associated with body fat in French girls from 2 to 15 years old, with a tendency observed in boys (Maillard *et al*., 2000).

Another possible explanation for weekend energy intake excess in comparison to during the week intake in our children may be attributed to the regulations that during the 8 h stay at the day-care centre, energy supply is not to exceed 60% of energy recommendations. This was facilitated by the energy reduction in the JUNJI Food program during the year 2001, as well as by the inclusion of a greater amount of fruits, vegetables and milk (National Board of School Assistance and Scholarships, 2000). At home, the child has more freedom to eat sweets, snacks and beverages outside meal time (Magarey *et al*., 2002; Matheson *et al*., 2004). All together, the attendance of the child at the play-care centre seems to protect the child from unhealthy eating and weight gain.

Physical activity was determined by tri-axial accelerometry, which is an objective method to distinguish differences in activity levels between individuals (Westertep, 1999). Although Tritrac accelerometry tends to underestimate physical activity in sedentary periods (during class time or structured physical education), it is able to provide systematic results in subjects (Welk and Corbin, 1995). The measurement of physical activity in these obese children confirms that little time is spent on high energy cost activities (only 24 min/day during the week, and 32 min/day during the weekend), thus not reaching present recommendations for activity at this age (Reston, 2002). This is of concern because it is representative of the growing sedentarism in children (Reilly *et al*., 2004), and is in line with the low level of intense activity in the adult population (89% showed sedentary behaviour in Santiago, Chile) (Department of Health of Chile, 2000).

Physical activity levels in this group (group mean = 1.58; 1.61 in boys and 1.55 in girls) correspond to a moderate level of activity, which for boys is higher than for those in other publications (Trost *et al*., 2003). Physical activity level is also negatively associated with body fat percentage ($r = -0.40$), which may indicate a prolonged contribution of inactivity to the maintenance of obesity. Despite the use of a different classification system for physical activity, Rowlands *et al*.

(1999) found a similar pattern in boys 8–10 years of age ($r = -0.42$, $P < 0.05$). They used structured activities such as treadmill exercises and ball games among others, whereas our approach was more appropriate for describing typical activity patterns of children of preschool age such as sitting, drawing, running, jumping or playing supervised games.

In Figure 1, it is evident that there is a 10% increase in time spent on minimal activity when the child is at the day-care centre (week vs weekend). However, the sum of light- plus moderate-intense activities is higher in the home (28%) than in the day-care centre (21%). During the weekdays, the children do not dramatically vary their activity pattern between the day-care centres and home, although it is evident that the minimal activity decreases after 17 h (from 62 to 54%).

In conclusion, although energy balance is attained during the week, it is necessary to decrease minimal activity during the child's time at the day-care centres. Although the group of children in this study may not be representative, the physical activity and energy intake data suggest that there is an urgent need for the development of an educational programme for the day-care centres community in order to increase physical activity during school hours and to reduce energy and fat intake at home. Day-care centres in Chile have the capacity to increase children's free time, to motivate moderate/intense activities and to design an active curriculum to be administered during the child's time at the centres. There is a need to favour this change, which in turn, will strengthen the influence of regulated energy intake during the week. A further gain of great importance may be obtained by educating parents to improve their child's diet and to decrease energy supplied in the home as well as in the day-care centres. The contribution to the reduction of obesity at an early age that could be made with these changes could be quite substantial, given the large number of children (100 000) cared for by the public system.

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