

# Childhood and adolescent obesity: how many extra calories are responsible for excess of weight?

*Obesidade na criança e no adolescente: quantas calorias a mais são responsáveis pelo excedente de peso?*

*Obesidad en el niño y en el adolescente: ¿cuántas calorías de más son responsables por el exceso de peso?*

Helen Rose C. Pereira<sup>1</sup>, Tatiana Godoy Bobbio<sup>2</sup>, Maria Ângela R. G. M. Antonio<sup>3</sup>, Antônio de Azevedo Barros Filho<sup>4</sup>

## ABSTRACT

**Objective:** To review the main articles on energy imbalance and obesity in order to quantify the daily energy surplus associated with weight gain in children and adolescents.

**Data sources:** Articles published in the last ten years, indexed in electronic databases Medline (Pubmed) and SciELO-Br. In the Medline database, the descriptor “energy gap” was used and describes the energy values associated with changes in body weight in individuals or populations. In SciELO-Br database, the descriptors “obesity”, “energy metabolism”, “energy balance”, and “energy imbalance” were used, once it was not possible to find national articles discussing the energy gap.

**Data synthesis:** In the pediatric population, four studies were performed and indicate that children and adolescents are gradually gaining weight due to a small, but persistent, daily positive energy balance of 70 to 160kcal above the total energy suitable for growth. The results suggest that small changes in daily eating behavior as well as physical activity would be enough to prevent future weight gain in this population.

**Conclusions:** gradual weight gain can be explained by small daily average of positive energy balance, from 70 to 160kcal above the total energy suitable for growth. The incentive to small changes in eating behavior and physical activities that promotes daily reduction of 160kcal can be an accessible practice in order to block weight gain in this population.

**Key-words:** obesity; child; adolescent; energy metabolism; energy intake; weight gain.

## RESUMO

**Objetivo:** Revisar os principais artigos referentes ao tema desequilíbrio energético e obesidade, a fim de quantificar o excedente energético diário associado ao ganho de peso em crianças e adolescentes.

**Fontes de dados:** Artigos publicados nos últimos dez anos, indexados nas bases de dados eletrônicas Medline (Pubmed) e SciELO-Br. Na base de dados Medline, utilizou-se o descritor “energy gap”, termo que descreve os valores energéticos associados às modificações no peso corporal em indivíduos ou populações. Na base de dados SciELO-Br, utilizaram-se os descritores “obesidade”, “metabolismo energético”, “balanço energético” e “desequilíbrio energético”, devido ao fato de não terem sido encontrados artigos nacionais que discutissem o assunto “energy gap”.

**Síntese dos dados:** Na população infantil, quatro estudos foram realizados e indicam que crianças e adolescentes estão gradualmente ganhando peso devido a um pequeno, mas persistente, balanço energético positivo diário, 70 a 160kcal acima do total calórico adequado para o crescimento. Os valores encontrados sugerem que pequenas modificações nos hábitos diários de alimentação e de atividade física seriam suficientes para evitar futuros ganhos de peso nessa população.

Instituição: Departamento de Pediatria da Faculdade de Ciências Médicas da Universidade Estadual de Campinas (Unicamp), Campinas, SP, Brasil

<sup>1</sup>Mestre em Saúde da Criança e do Adolescente pela Faculdade de Ciências Médicas da Unicamp, Campinas, SP, Brasil

<sup>2</sup>Pós-Doutoranda em Neurociência Motora pela Texas A&M University, Estados Unidos; Professora Doutora do Departamento de Fisioterapia da Universidade do Estado de Santa Catarina (UDESC), Florianópolis, SC, Brasil

<sup>3</sup>Doutora em Pediatria pela Faculdade de Ciências Médicas da Unicamp; Professora do Departamento de Pediatria da Faculdade de Ciências Médicas da Unicamp, Campinas, SP, Brasil

<sup>4</sup>Professor Titular do Departamento de Pediatria da Faculdade de Ciências Médicas da Unicamp, Campinas, SP, Brasil

Endereço para correspondência:

Antônio de Azevedo Barros Filho  
Rua Tessália Vieira de Camargo, 126  
CEP 13083-970  
Caixa Postal 6011 – Campinas/SP  
E-mail: abarros@fcm.unicamp.br

Fonte financiadora: Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq)

Conflito de interesse: nada a declarar

Recebido em: 10/7/2012

Aprovado em: 17/12/2012

**Conclusões:** O ganho gradual de peso pode ser explicado por pequena média diária de balanço energético positivo, de 70 a 160kcal acima do total calórico adequado para o crescimento. O incentivo às pequenas modificações nos hábitos alimentares e de atividades físicas que promovam a redução de 160kcal diárias pode ser uma prática acessível, a fim de barrar o ganho de peso nessa população.

**Palavras-chave:** obesidade; criança; adolescente; metabolismo energético; ingestão de energia; ganho de peso.

## RESUMEN

**Objetivo:** Revisar los principales artículos referentes al tema desequilibrio energético y obesidad, a fin de cuantificar el excedente energético diario asociado a la ganancia de peso en niños y adolescentes.

**Fuentes de datos:** Revisión de artículos publicados en los últimos 10 años, indexados en las bases de datos electrónicas MEDLINE (Pubmed) y SciELO-BR. En la base de datos MEDLINE se utilizó el descriptor *energy gap*, término que describe los valores energéticos asociados a las modificaciones en el peso corporal en individuos o en poblaciones. En la base de datos SciELO-BR se utilizaron los descriptores obesidad, metabolismo energético, balance energético y desequilibrio energético, debido a no haberse encontrado artículos nacionales que discutieran el tema *energy gap*.

**Síntesis de los datos:** En la población infantil, cuatro estudios fueron realizados e indican que niños y adolescentes están gradualmente ganando peso debido a un pequeño pero persistente balance energético positivo diario, 70 a 160kcal por encima del total calórico adecuado para el crecimiento. Los valores encontrados sugieren que pequeñas modificaciones en los hábitos diarios de alimentación y de actividad física serían suficientes para evitar futuras ganancias de peso en esta población.

**Conclusión:** La ganancia gradual de peso puede explicarse por pequeño promedio diario de balance energético positivo, de 70 a 160kcal por encima del total calórico adecuado para el crecimiento. El incentivo a las pequeñas modificaciones en los hábitos alimentares y de actividades físicas que promuevan la reducción de 160kcal diarias puede ser una práctica accesible a fin de parar la ganancia de peso en esta población.

**Palabras clave:** obesidad; niño; adolescente; metabolismo energético; ingestión de energía; ganancia de peso.

## Introduction

Obesity is the fastest growing chronic disease in the world, and it has become a pressing concern of public health policies. Epidemiological studies show that since the 70s the number of overweight children in Brazil has tripled, and currently the number of overweight children is larger than of malnourished children<sup>(1,2)</sup>.

The obesogenic environment has favored a persistent state of positive energy balance over the years, which is responsible for the gradual weight gain in children and adults<sup>(3-6)</sup>. The treatment of obesity shows low adherence rates, given the impact of the suggested changes, which reinforces the importance of preventive measures<sup>(3,7)</sup>. In this context, actions that favor the initial stabilization of the population weight, for subsequent weight reduction have been discussed<sup>(7,8)</sup>.

In 2003, Hill *et al*<sup>(9)</sup> were the first authors to propose a method to quantify the excess energy accumulated daily (resulting from the positive difference between the energy intake and energy loss), which is responsible for maintaining the pattern of weight gain in individuals as well as in populations, as depicted in Chart 1. In their study, based on data weight of North American adults from 20 to 40 years, obtained from two national surveys, the authors calculated the distribution of the population's weight gain between 1992 and 2000. The results showed a weight gain from 14 to 16 pounds ( $\approx 6.4$  to  $7.3$ kg) in the eight-year period, which is equivalent to a gradual weight gain from 1.8 to 2.0lb ( $\approx 0.8$  to  $0.9$ kg) per year. Based on this results and on the assumption that each pound (1.0 lbs equals  $\approx 0.454$ kg) of weight gain represents 3.500 excess kcal<sup>(10)</sup>, the mean amount of energy accumulated was 15kcal/day, with 50kcal/day corresponding to the 90th percentile. Also assuming that the energy coming from the diet is stored in the organism with a 50% efficacy, the authors concluded that a daily excess of 100kcal was responsible for maintaining the pattern of weight gain in 90% of the population (50kcal in  $p_{90} \times 50\%$  metabolic efficacy), and that, therefore, if such energy intake was either reduced or spent on physical activity, this could prevent future weight gain in most of the North American population<sup>(9)</sup>.

The value found was called *energy gap*, used in this article as the energetic difference that, related to weight gain in individuals or populations, can be defined as "the difference between energy intake and energy expenditure, resulting in accumulation of

energy”, or “how much extra energy should be spent or how much less energy should be consumed in order to stop the weight gain”<sup>(9)</sup>.

Since the original article by Hill *et al*<sup>(9)</sup> this method has been used in several studies with adults, and the values have usually been low, from 20 to 100kcal/day<sup>(11-15)</sup>. The low values suggest that small changes in the daily habits of eating and physical activity would be sufficient to prevent future weight gain in the adult population<sup>(9)</sup>.

There is consensus that prevention is the best strategy to control the epidemic of obesity in children<sup>(1,5)</sup>. This paper aims to review the articles that quantify the energy gap responsible for excessive weight gain in children.

## Data sources

We searched the electronic databases MEDLINE (PubMed) and Scientific Electronic Library Online (SciELO-Brazil) for the selection and review of articles written in English and Portuguese, published between January 2002 and April 2012.

The search focused on articles that quantified the surplus energy, in calories, that was responsible for weight gain in children and adolescents. For MEDLINE / PubMed we used the term energy gap, which returned 28 publications. Four of these were pediatric studies, and therefore, were selected for analysis and discussion.

As the term *energy gap* has not been used in national articles yet, we used the keywords defined by the Health Descriptors (MeSH) for the search in the SciELO- Brazil database. The mesh terms *obesity* and *child* were used in combination with the following: energy, energy metabolism (also used as energy expenditure) and energy intake. The same search was repeated using the keyword *adolescent* instead of *child*. We also searched terms commonly used in the international literature, but that are not included in the MeSH terms: energy balance and energy imbalance. No articles of interest were found.

## Summary of the findings

Only four studies have been conducted in children (Table 1). In 2003, Butte & Ellis<sup>(16)</sup> followed the weight gain and the body composition of 337 Hispanic children, mean age 11.9±3.6 years, for one year. Eutrophic children who remained eutrophic after this period gained 9lb (4.1kg) per year, which represented a gain of 75kcal/day (137 for P90). Eutrophic children who became overweight gained 15lb (6.8kg) per year, representing the stocking of 133kcal/day (171 for P90). Overweight children who remained overweight had a mean gain of 16 lb (7.2kg) per year, with a 144kcal/day stocking (251 for P90). Considering a 50% energy efficiency, as proposed by Hill *et al*<sup>(9)</sup>, it would be

Chart 1 - Estimates of the energy gap in adults

<b>Energy Gap in Adults</b>
<p><b>1° step: Evaluation of the rate of weight gain</b></p> <ul style="list-style-type: none"> <li>• If the rate of weight gain of a population is known, it is possible to estimate the rate of energy accumulation, as well as the rate of positive energy balance (energy gap) that originates such weight gain</li> <li>• Weight gain is interpreted as the stocking of fat tissue</li> </ul>
<p><b>2° step: Calculus of the energy accumulation</b></p> <ul style="list-style-type: none"> <li>• The energetic accumulation represents the amount of energy stored in the fat tissue resulting from the weight gain</li> <li>• It is assumed that each pound of weigh corresponds to the accumulation of 3,500kcal. 1lb≈0.454kg=3500kcal</li> </ul>
<p><b>3° step: Calculus of the energy gap</b></p> <ul style="list-style-type: none"> <li>• Whenever the energy intake is greater than the energy loss the energy balance is positive, and this positive fraction (over the neutrality) that causes the energy accumulation is called energy gap</li> <li>• In a mixed diet, nearly 50% of the consumed energy is stored. It is well known that the energy ingested is not 100% stored, due to the metabolic cost related to the process of digestion and assimilation of the nutrients</li> <li>• Assuming a 50% metabolic efficacy, the energy difference corresponds to twice the energy accumulation</li> <li>• For instance: for each extra 100kcal ingested, 50kcal are stored (which means, the energy accumulation of 50kcal corresponds to a 100kcal energy gap, considering a metabolic efficacy of 50%)</li> </ul>

Reference: Hill *et al*, (2003)

**Table 1** - Energy accumulation and energy gap in the samples of children and adolescents from different populations

Author	Country and study design	Characteristics of the sample	Energy gap (kcal/day)
Butte and Ellis <sup>(16)</sup> (2003)	Spain	n=337	342–502
	Cohort study	5–19 years	
Wang <i>et al</i> <sup>(18)</sup> (2006)	U.S.	n=3000	110–165 children
	Cross-sectional study	2–17 years	678–1017 adolescents
Plachta-Danielzik <i>et al</i> <sup>(19)</sup> (2008)	German	n=2057	100–140
	Cohort study	6–14 years	
van den Berg <i>et al</i> <sup>(20)</sup> (2011)	Netherlands	n=2190	69–77kcal
	Cohort study	2–7 years	

necessary a reduction of 342 to 502 kcal/day to stop the weight gain in 90% of the population. The authors also estimated the energy gap based on body composition, using different values of energy efficacy for fat mass (85%) and lean mass (42% for protein stock) and found that the reduction from 204 to 263kcal/day would be necessary to prevent further weight gain<sup>(17)</sup>. Although the values correspond to half of the estimates when a 50% metabolic efficacy is considered, they still represent twice the values stipulated by Hill *et al*<sup>(9)</sup> for adults.

Wang *et al*<sup>(18)</sup> analyzed the data of the National Health and Nutrition Examination Survey (NHANES) cross-sectional study in the periods 1988–94 and 1999–2002 to compare the distribution of the BMI percentiles of two cohorts of North American children and adolescents, who were initially 2–4 and 5–7 year-old. In a fictional scenario, based on the 1988–94 data, the authors built a curve of height and weight gain, considering on optimal growth pattern (in which the energy balance represented the gain weight proportional to the height), and projected this same curve by ten years ahead, assuming that the percentages would remain the same. The hypothetical data were then compared with the actual data from NHANES 1999–2002. The comparison between the actual and simulated scenario showed the distribution of weight gain beyond the values considered normal for the growth process, for further calculation of the energy gap. Assuming a uniform weight gain over the time, and the energy efficacy from 50 to 75%, a lesser energy intake from 110 to 165kcal/day could have prevented the weight gain in most of the pediatric population. Among overweight adolescents (12 to 17 years old in NHANES 1999–2002), the change proved to be far higher, from 678–1017kcal/day, which resulted in the accumulation of a mean 26.5kg above the normal for growth<sup>(18)</sup>.

Plachta-Danielzik *et al*<sup>(19)</sup> examined the distribution of adequate and excessive energy intake in 2057 initially eutrophic children, considering the impact of age and gender on the body composition of the individuals. They used the four-year longitudinal study entitled *Kiel Obesity Prevention Study – KOPS* - database for this analysis. The energy gap was calculated for the children who remained within the proper weight range and for those who became overweight during the study period. The subjects were divided into two groups for analysis: 6–10 and 10–14 years old. Among the eutrophic children, the average energy gap (kcal/day) in the 6–10 years old age group was 26.8 for the girls and 21.1 for the boys. Considering the energy gap at the 90th percentile (incidental overweight), the values increased to 58.1 and 46.0, respectively. In the 10–14 years old age group, the values for eutrophic children were 46.4 and 32.5 for girls and boys and 72.0 and 53.2, respectively, in incidental overweight children. Assuming the metabolic efficacy of 50–60%, the authors concluded that, although there were variations in the energy gap between the genders in the observed period, lesser 100 to 140kcal intake a day could prevent excessive weight gain in normal children<sup>(19)</sup>.

In 2011, van den Berg *et al*<sup>(20)</sup> published the results of a 4 years follow-up of 2,190 Dutch children who participated in the *Dutch Prevention and Incidence of Asthma and Mite Allergy (PIAMA)* cohort study. The researchers used the data on weight and height, annually reported by the parents, to calculate the z-scores of BMI and assess the anthropometric changes that occurred from the initial age of 2 years to the last age of 5–7 years. For analysis, children were divided into four groups: children who were eutrophic at the age of 2 and remained eutrophic at 5–7 years; eutrophic children who became overweight, overweight children at both ages and overweight children who became eutrophic in this same

time interval. Initially eutrophic children who remained eutrophic gained 8.5kg, versus 13.3kg for normal weight children who became overweight at the end of the study. The energy gap was calculated as the positive difference between overweight and normal weight children, assuming the energy efficacy of 50%. The energy gap found, which was responsible for the excessive weight gain in most of the overweight children at 5–7 years, was 69–77kcal/day<sup>(20)</sup>.

## Discussion

In the analyzed studies, the estimated energetic gap ranged from 69 to 1.017kcal/day. This variation was greater than that found for adults, from 20 to 100kcal/day.

As with adults, different values among the studies are to be expected, because the rates of weight gain show a singular distribution in each population. However, to estimate the energy gap among children, compared to the adults, some adjustments must be made. It is necessary to consider that the energy imbalance is already expected due to the extra energy costs required for the intense anabolic process of growth, which implies in persistent positive energy balance. It should, therefore, separate the characteristic energy accumulation for growth and the excessive energy intake<sup>(18,21,22)</sup>. During the stage of growth and development, differences in the body composition and in the degree of energy accumulation by age, height, gender, ethnicity and pubertal stage are usually expected<sup>(21,23)</sup>.

In the study by Butte & Ellis<sup>(16)</sup>, the authors did not consider the energy intake necessary for proper growth (75 extra kcal/day for normal children who remain eutrophic), resulting in the overestimation of the energy gap. Wang *et al*<sup>(18)</sup> considered the extra energy necessary for normal growth, but this study was limited by its cross sectional design. The long-term prospective studies performed by Plachta-Danielzik *et al*<sup>(19)</sup> and van den Berg *et al*<sup>(20)</sup> took into consideration the limitations of the prior studies, and were able to provide more accurate estimates of the energy gap. In the study of Plachta-Danielzik *et al*<sup>(19)</sup> the differences between the genders and developmental stages were also considered.

Despite the difficulties in data comparison due to the differences in the study design, hypothesis and methods, if the north American adolescents evaluated by Wang *et al*<sup>(18)</sup>, who had a weight gain 5–6 times the average of the U.S. population were excluded, the energy gap ranges from 70 to 165kcal/day, which suggests that the mean weight gain of the pediatric population could also be explained by a small

mean daily positive energy balance, as observed in adults. Thus, the stimulus to small changes in the eating habits and physical activity seems to be a practice also applicable to this population.

It is important to consider that the new weight standard attained by the child is accompanied by changes in the body composition that cause both increased fat mass and lean body mass, and a consequent increase in the resting metabolic rate (RMR), in the energy expenditure during physical activities and in the total daily energy expenditure. Thus, the increase in the energy intake is always accompanied by an increase in the total daily energy expenditure, which continues until a new energy balance is reached. This suggests that, despite the increased energy requirements after weight gain, the individuals keep consuming slightly more energy than they expend<sup>(22,24-26)</sup>.

## Practical application

If a daily reduction of 160kcal was adopted to prevent weight gain in children, this would represent rather simple changes in the children's routine. Taking as example the exclusion of industrialized foods, it would be the equivalent to the exclusion of a small pack (45g) of potato chips, or two cookies. The energy expenditure of the same amount of calories, calculated for a 40kg child, corresponds to 1 hour and 15 minutes walk at 5km/h (moderate pace) on level ground, or 1 h of activities such as football, basketball or swimming. Assuming the same reduction of 160kcal per day was combined between energy intake and loss, this could be accomplished, for example, with the substitution of whole milk by skimmed milk (less 50kcal in a 240mL portion), plus the replacement of a pack of industrialized potato chips by a slice (30g) of plain cake (less 50kcal) and a 30 minutes walk in the same intensity as described<sup>(27,28)</sup>. Note that, because there is no consensus on energy expenditure in terms of calories loss and the metabolic equivalent of the activities performed by children and adolescents, these estimates were based on adult values, which tend to underestimate the energy expenditure in this population<sup>(29,30)</sup>.

Regardless the importance of each factor — ie, energy consumption or energy expenditure — in the equation of energy imbalance, in an environment where the poor quality diet and sedentary lifestyle are global characteristics among all age groups<sup>(1,31)</sup>, changes in both habits are indisputable and necessary for the reversal of this epidemic picture.

Using such approach, public health organizations in the U.S. have adopted the premise that “small changes lead to positive results on health and can effectively stop the weight gain in the population.” Among others, we can cite the *American Diabetes Association* and the *American Heart Association*, in addition to non-profit initiatives such as the *America on the Move* (<https://aom3.americaonthemove.org/default.aspx>), in partnerships with the *American College of Sports Medicine*, and the *United States Department of Agriculture (USDA)*<sup>(17)</sup>.

## Conclusions

The continuous growing weight among children indicates that, in spite of the increased energy requirements after weight gain, individuals keep consuming slightly more energy than they expend. These studies suggest that children have been gradually putting on weight due to a small but persistent daily positive energy gap, from 70 to 160kcal above the necessary for the growth process.

## References

- World Health Organization. WHO forum and technical meeting on population-based prevention strategies for childhood obesity. Geneva: WHO; 2009.
- Brasil - Instituto Brasileiro de Geografia e Estatística. Pesquisa de Orçamentos Familiares - 2008-2009: antropometria e estado nutricional de crianças, adolescentes e adultos no Brasil. Rio de Janeiro: IBGE; 2010.
- Ribeiro Junior HC. A pandemia de obesidade entre os jovens. *Rev Paul Pediatr* 2007;25:304.
- Barros-Filho AA. Obesity: a puzzling disorder. *J Pediatr (Rio J)* 2004;80:1-3.
- Han JC, Lawlor DA, Kimm SY. Childhood obesity. *Lancet* 2010;375:1737-48.
- Enes CC, Slater B. Obesity in adolescence and its main determinants. *Rev Bras Epidemiol* 2010;13:163-71.
- Hill JO. Understanding and addressing the epidemic of obesity: an energy balance perspective. *Endocr Rev* 2006;27:750-61.
- Heymsfield SB. How large is the energy gap that accounts for the obesity epidemic? *Am J Clin Nutr* 2009;89:1717-8.
- Hill JO, Wyatt HR, Reed GW, Peters JC. Obesity and the environment: where do we go from here? *Science* 2003;299:853-5.
- A Healthier You [homepage on the Internet]. Chapter 5: a calorie is a calorie, or is it? [cited 2012 set 18]. Available from: <http://www.health.gov/dietaryguidelines/dga2005/healthieryou/html/chapter5.html>
- Tataranni PA, Harper IT, Snitker S, Del Parigi A, Vozarova B, Bunt J *et al*. Body weight gain in free-living Pima Indians: effect of energy intake vs expenditure. *Int J Obes Relat Metab Disord* 2003;27:1578-83.
- Berg C, Rosengren A, Aires N, Lappas G, Torén K, Thelle D *et al*. Trends in overweight and obesity from 1985 to 2002 in Göteborg, West Sweden. *Int J Obes (Lond)* 2005;29:916-24.
- Brown WJ, Williams L, Ford JH, Ball K, Dobson AJ. Identifying the energy gap: magnitude and determinants of 5-year weight gain in midage women. *Obes Res* 2005;13:1431-41.
- Zhai FY, Wang HJ, Wang ZH, Chen CM. Control the increasing of the prevalence of overweight and obesity by covering the energy gap of Chinese population. *Wei Sheng Yan Jiu* 2006;35:72-6.
- Ebrahimi-Mameghani M, Scott JA, Der G, Lean ME, Burns CM. Changes in weight and waist circumference over 9 years in a Scottish population. *Eur J Clin Nutr* 2008;62:1208-14.
- Butte NF, Ellis KJ. Comment on “Obesity and the environment: where do we go from here?” . *Science* 2003;301:598.
- Hill JO. Can a small-changes approach help address the obesity epidemic? A report of the Joint Task Force of the American Society for Nutrition, Institute of Food Technologists, and International Food Information Council. *Am J Clin Nutr* 2009;89:477-84.
- Wang YC, Gortmaker SL, Sobol AM, Kuntz KM. Estimating the energy gap among US children: a counterfactual approach. *Pediatrics* 2006;118:e1721-33.
- Plachta-Danielzik S, Landsberg B, Bony-Westphal A, Johannsen M, Lange D, Müller MJ. Energy gain and energy gap in normal-weight children: longitudinal data of the KOPS. *Obesity (Silver Spring)* 2008;16:777-83.
- Van den Berg SW, Boer JM, Scholtens S, de Jongste JC, Brunekreef B, Smit HA *et al*. Quantification of the energy gap in young overweight children. The PIAMA birth cohort study. *BMC Public Health* 2011;11:326.
- Institute of Medicine of the National Academies. Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein, and amino acids. Washington: The National Academies Press; 2002.
- Bouchard C. The magnitude of the energy imbalance in obesity is generally underestimated. *Int J Obes (Lond)* 2008;32:879-80.
- Barbosa KB, Franceschini SC, Priore SE. Influence of the stages of sexual maturation in the nutritional status, anthropometrics and corporal composition of adolescents. *Rev Bras Saude Mater Infant* 2006;6:375-82.
- Swinburn BA, Jolley D, Kremer PJ, Salbe AD, Ravussin E. Estimating the effects of energy imbalance on changes in body weight in children. *Am J Clin Nutr* 2006;83:859-63.
- Butte NF, Christiansen E, Sørensen TI. Energy imbalance underlying the development of childhood obesity. *Obesity (Silver Spring)* 2007;15:3056-66.
- Swinburn BA, Sacks G, Lo SK, Westterterp KR, Rush EC, Rosenbaum M *et al*. Estimating the changes in energy flux that characterize the rise in obesity prevalence. *Am J Clin Nutr* 2009;89:1723-8.
- Paoli DS, Abbes PT, Lavrador MS, Escrivão MA, Taddei JA. Prevenção e tratamento da obesidade na infância: atividade física e hábitos alimentares. *Pediatr Mod* 2009;45:165-71.
- Anção MS, Cuppari L, Draibe AS, Sigulem D. NutWin - programa de apoio à nutrição, versão 1.6. São Paulo: Departamento de Informática em Saúde, SPDM, Unifesp/EPM; 2009.
- Harrell JS, McMurray RG, Baggett CD, Pennell ML, Pearce PF, Bangdiwala SI. Energy costs of physical activities in children and adolescents. *Med Sci Sports Exerc* 2005;37:329-36.
- Ainsworth BE, Haskell WL, Whitt MC, Irwin ML, Swartz AM, Strath SJ *et al*. Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc* 2000;32 (Suppl 9):S498-504.
- Stubbs CO, Lee AJ. The obesity epidemic: both energy intake and physical activity contribute. *Med J Aust* 2004;181:489-91.