



SCIENTIFIC ARTICLES

Genetic heritage as a risk factor enabling childhood obesity

Madalena Cunha^{a,*}, Graça Aparício^a, João Duarte^a, Anabela Pereira^b,
Carlos Albuquerque^a, António Oliveira^c

^aHealth School/Polytechnic Institute of Viseu, Portugal

^bUniversity of Aveiro, Portugal

^cSUB-Moimenta da Beira, Portugal

KEYWORDS

Weight status;
Overweight children;
Overweight mothers;
Metabolic risk

Abstract

Introduction: Nowadays, it is an evidence that maternal obesity is an important predictor of obesity in the descendants, not being consensual if that influence comes from the interaction between genes and facilitators family contexts or both.

Objectives: 1) To determinate the prevalence of the child overweight; 2) to classify the nutritional status and metabolic risk of the progenitors; 3) to analyze the effect of the markers of the family metabolic risk in the expression of the illness in the child.

Material and methods: Descriptive study composed by 1424 children, average age 4.58 years old and their mothers, average age 34.47 years old, living in several parts of Portugal. The children's anthropometric measures were evaluated and classified according to the NCHS referential (CDC, 2000)¹ and of the progenitors by the orientations of the WHO (2000)² and Portugal, DGS (2005).³ Social demographic data was obtained by filling in the Food Frequency Questionnaire adapted from Rito (2007).⁴

Results: The overweight affected 34.3% of the children, (including 17.4% obesity), being the higher values on boys (36.8%) and in 5 year old children (39.5). In 41.9% of the progenitors overweight was noted (12.1% obesity), being higher in mothers with low scholarship, low income, older and living in a rural area. The probability of the child to be overweighted was 1.4 times higher when mothers were overweight, and close to 2 times in the relationship mother/daughter. Others enabling factors were revealed, like weight gain above recommended during pregnancy and a higher weight at birth.

Conclusions: Due to the obtained interferences, it is accepted the existence of enabling factors of maternal and child markers in the development of overweight in the child, so that the prevention of child obesity should consider not only the environmental dimension but also the genetic heritage.

© 2013 Elsevier España, S.L. Open access under [CC BY-NC-ND license](#).

MISIJ project funded by FCT - Monitoring health indicators in children and adolescents: Impact of health education - Reference PTDC/CPE-CED/103313/2008- and CI&DETS FCT - PEstOE/CED/UI4016/2011

*Correspondence author.

E-mail: madalenacunhanunes@gmail.com (M. Cunha).

Background

Nowadays, it is acknowledged that overweight in childhood is of multifactorial etiology, contributing a complexity of factors, such as genetic susceptibility, which helps to explain the inter-individual differences, environmental and behavioral factors, related to life styles, being these, facing the evidences, the strongest determinant factors.⁵ However, studies developed with the goal to discriminating the genetic predisposition of the environmental influences, illustrate the joint contribution of both factors in the expression of obesity. There are many reported risk factors as being associated with the development of childhood obesity. These include parent's overweight, weight at birth, social economic factors, physical activity/inactivity, nutritional and dietetic factors (including the beginning of childhood food habits) and other behavioral and psychological causes. Today, it is acknowledged that these enabling factors are related, but the type of relationship is still not much known.⁶

The family history is considered to be an important indicator of the obesity of the descendants, being, however, still difficult to define how much the influence of family comes from the genetic heritage and how much is due to the family sharing of the food ingestion and physical activity habits.^{7,8}

There are, however, evidences, that the genetic predisposition is able to modulate the answer of the organism to the variations of the environmental factors, emphasizing two factors which, interacting, may contribute to double the risk of obesity in young adults, such as obesity in one of the progenitors and its presence in childhood.⁹

The World Health Organization (WHO),⁶ analyzing several studies developed in various countries, pointed out that the level of adiposity in childhood influences the adiposity in adult life, specially if the parents are both overweighted and that the period between pre-conception to about 24 months of age is fundamental to define the health of the individual for his whole life.

This study aimed, (i) to determinate the prevalence of overweight on the child (ii) to classify the nutritional status and metabolic risk of the progenitors; (iii) to analyze the effect of the family metabolic risk markers in the expression of the illness on the child.

Material and methods

Transversal and descriptive study, developed in the Health School/Polytechnic Institute of Viseu-Portugal, in the context of a wider Project (MISIJ – Monitoring of Infant-Juvenile Health Indicators: Impact on Education for Health).

This includes 1424 children from 3 to 6 years old, average age 4.58 years old (SD = 0.990), and their mothers, average age 34.47 years old (SD = 5.29), living in several parts of Portugal. The selection of children sample considered as inclusion criteria that was living with their mother and not presenting a base chronic illness, not including the potential overweight.

The children's anthropometric measures were evaluated with weight record, length and Body Mass Index (BMI) percentile for the age and gender and the nutritional status

was classified according to the NCHS referential (CDC, 2000).¹ low-weight < 5; normal weight > 5 < 85; pre-obesity $\geq 85 < 95$; obesity ≥ 95 .

The anthropometry and waste circumference (WC) of the progenitors were evaluated and classified according to the WHO referential (2000)² and of Portugal, DGS (2005).³ The social demographic data was obtained by filling in the parents' Questionnaire of Food Frequency (QFF) adapted from Rito (2007).⁴

In order to analyze the data measures of central trend and dispersion were used and application of inferential measures such as Chi-Square, Odds Ratio e Pearson Correlation, established as level of statistic significance $p = 0.05$. The data was analyzed with the SPSS-*Statistical Package for Social Sciences (Version 21.0 for Windows)* program.

Results

Children nutritional status

The average BMI was 16.708 (12.1-26.0; SD = 1.83), having most of the children normal weight (60.2%), 5.5% low weight, 34.3% overweight (including 17.4% obesity), being this significantly higher in the male gender (36.8%) ($\chi^2 = 31.22$; $p = 0.000$) and in 5 year old children (39.5%) and low weight in 4 year olds (14.0%) ($\chi^2 = 101.301$; $p = 0.000$).

The nutritional status revealed to be dependent of the family income ($\chi^2 = 17.725$; $p = 0.007$), being the children of families with low incomes the ones who presented more obesity and with no relation to the age, residence and mother's scholarship (Tables 1 and 2).

Birth weight

The analyse of the biological characteristics of the child, implicate a retrospective look to some of their predecessors of intra-uterine life, considering the possible influence of these in their present and future life and health. The statistics of the birth weight reveal to the totality of the sample an average value of 3189 gr (820-5210 gr; SD = 509.96). The birth weight was in average higher in the male gender, 3243 gr (SD = 494.9) than in the opposite sex 3129 gr (SD = 502.37), with significant differences, ($t = 4.208$; $p = 0.000$). Being expectable the weight concentration in *Adequate to the Gestational Age* (AIG) to most children, (88.3%), being 7.8% *Light to the Gestational Age* (LGA) and 4.0% *Big for the Gestational Age* (BGA). Most of the BGA children were boys (5,5%) and the LGA 8,8% girls ($\chi^2 = 11.444$; $p = 0.003$) (Table 1).

Mother's nutritional status

The analysis of the maternal nutritional status indicated an average weight of 64.71 kg (SD = 11.54), average stature of 160.85 cm (SD = 6.31), with an average BMI of 25.03 kg/m² and a overweight prevalence of 41.9% (12.1% obesity). This was significantly higher in mothers with low education, low income, in older mothers (≥ 40 years old) and those who living in rural area.

The metabolic risk associated to the mother's WC appeared in 60,8% (including 20.3% with very high risk).

Table 1 Children nutritional status by maternal demographic profile

	Children nutritional status								Chi-square test	
	Underweight		Normal weight		Pre-obesity		Obesity		χ^2	p value
	n	%	n	%	n	%	n	%		
Children demographic profile										
Sex										
Boys	18	2.4	453	60.7	142	19.0	133	17.8	31.220	0.000
Girls	60	8.8	404	59.6	99	14.6	115	17.0		
Total	78	5.5	857	60.2	241	16.9	248	17.4		
Age (years)										
3	7	2.9	152	63.6	44	18.4	36	15.1	101.301	0.000
4	58	14.0	254	61.2	40	9.6	63	15.2		
5	8	1.7	277	57.9	100	20.9	93	19.5		
6	5	1.7	174	59.6	57	19.5	56	19.2		
Birth weight										
Low	9	8.2	73	66.4	14	12.7	14	12.7	14.654	0.023
Adequate	68	5.4	752	60.3	210	16.8	218	17.5		
High	1	1.8	25	44.6	16	28.6	14	25.0		
Mothers demographic profile										
Age (years)										
≤ 25	8	10.3	37	4.3	12	5.0	14	5.6	11.485	0.244
26-32	22	28.2	256	29.9	66	27.4	83	33.5		
33-39	34	43.6	422	49.2	113	46.9	104	41.9		
≥ 40	14	17.9	142	16.6	50	20.7	47	19.0		
School education (years)										
4	6	7.7	53	6.2	13	5.4	14	5.6	8.662	0.469
6/9	27	34.6	276	32.2	78	32.4	93	37.5		
12	24	30.8	278	32.4	82	34.0	90	36.3		
15	21	26.9	250	29.2	68	28.2	51	20.6		
Household income (n = 1280)										
Low (7.8%)	49	6.6	423	57.1	116	15.7	153	20.6	17.725	0.007
Medium (88.2%)	12	4.6	168	64.4	44	16.9	37	14.2		
High (4.0%)	14	5.0	178	64.0	54	19.4	32	11.5		
Home location										
Rural	49	6.0	472	57.8	145	17.8	150	18.4	4.541	0.209
Urban	29	4.8	385	63.3	96	15.8	98	16.1		

The association between the BMI and the mother's WC showed that in 47.6% of the mothers with pre-obesity and 42.3% with obesity there was a high and very high metabolic risk, with statistic relevance ($\chi^2 = 438.136$; $p = 0.000$) (Table 2).

Overweight and child and maternal enabling risk factors

Several studies support the idea that enabling factors, such as the nutritional status of the progenitors, maternal weight gain during pregnancy and the birth weight, can, in a favorable environment, are responsible for the weight gain of the children.¹⁰

Birth weight and overweight of the child

Globally, 88.3% of the children were born with normal weight, 7.8% light and 4.0% big for the gestational age,

being the difference between the genders as significant ($\chi^2 = 11.444$; $p = 0.003$).

From the association between birth weight and the development of overweight, it is noted that from the children with obesity, 25.0% were born BGA and in those with preobesity, 28.6% were equally born BGA. The relation is significant ($\chi^2 = 14.654$; $p = 0.023$), inferring that a higher birth weight, is associated to a higher risk of childhood overweight (Table 1).

Maternal weight at the end of pregnancy and children overweight

The operational definition of the maternal weight gain was based on the evaluation of the BMI in the beginning and end of pregnancy e establishing recommended gain layers to the different cutting points.¹¹

It was noted that in overweight children, 40.4% of the mothers increased above the recommended weight during

Table 2 Mother's nutritional status by demographic profile

Mother's demographic profile	Underweight		Normal weight		Pre-obesity		Obesity		Chi-square test	
	n	%	n	%	n	%	n	%	χ^2	p value
<i>Age (years)</i>										
≤ 25	—	—	31	56.4	17	30.9	7	12.7	10.260	0.330
26-32	6	1.7	203	58.5	100	28.8	38	11.0		
33-39	4	0.8	309	59.1	145	27.7	65	12.4		
≥ 40	2	1.0	93	48.7	71	37.2	25	13.1		
<i>School education (years)</i>										
4	2	3.4	16	27.1	28	47.5	13	22.0	83.940	0.000
6/9	3	0.9	165	48.0	110	32.0	66	19.2		
12	3	0.8	216	56.0	125	32.4	42	10.9		
15	4	1.2	239	73.1	70	21.4	14	4.3		
<i>Household income (n = 1280)</i>										
Low	5	0.9	286	49.3	189	32.6	100	17.2	52.917	0.000
Medium	3	1.4	137	62.8	62	28.4	16	7.3		
High	3	1.3	169	72.8	50	21.6	10	4.3		
<i>Home location</i>										
Rural	2	0.5	183	49.9	115	31.3	67	18.3	23.862	0.000
Urban	10	1.3	453	60.5	218	29.1	68	9.1		
<i>Metabolic risk related to WC</i>										
Without risk (39.2%)	10	2.3	361	82.6	63	14.4	3	0.7	438.136	0.000
High risk (40.5%)	1	0.2	253	56.0	162	35.8	36	8.0		
Very high risk (20.3%)	1	1.1	22	9.7	108	47.6	96	42.3		
Total	12	1.1	636	57.0	333	29.8	135	12.1		

pregnancy, 28.9% below and in 36.2% the weight gain was the recommended, with statistic significance to the global of the sample ($\chi^2 = 12.563$; $p = 0.002$), located (adjusted residual) in children with overweight, whose mothers had a pregnancy weight gain above recommended and in a particular manner in the girls (39.1%) ($\chi^2 = 9.554$; 0.008), explaining this 1.98% of the variability of child overweight ($r = 0.141$; $p = 0.000$) (Table 3).

Maternal weight and metabolic risk and overweight of the child

Having done the relationship between the BMI of the progenitors and the same indicator of the child, the odds ratios indicated in a significant manner that the probability of the children to be overweighted was 1.4 times higher if the mother was overweighted (OR = 1.443; IC 95% = 1.120-1.860).

Some studies revealed a greater association between the values of the mother's overweight and particularly the daughters, so that relationship was studied. It was revealed that the probability of the female children to being overweighted was close to 2 times higher in the mother/daughter relationship (OR = 1.635; IC 95% = 1.120-2.388), with statistic significance, ($\chi^2 = 6.529$; $p = 0.007$), being this risk reduced concerning boys, although without statistic significance (OR = 1.304; IC 95% = 0.925-1.838) ($\chi^2 = 2.305$; $p = 0.076$).

It was considered to be pertinent to evaluate the existence of a significant relationship between the WC of the mothers and the children overweight, noting also a probability of 1.3 times higher of the children to have

overweight if the mother presented high WC (OR = 1.304; IC 95% = 1.004-1.693), specially concerning daughters (OR = 1.477; CI 95% = 1.000-2.188), revealing statistic significance in the mother/daughter relationship ($\chi^2 = 3.805$; $p = 0.031$) (Table 3).

Synthetically, it was revealed as child and maternal risk factors enabling of overweight of preschool children, being male, maternal weight gain during pregnancy above recommended, higher birth weight, metabolic maternal risk (maternal overweight and high maternal waste circumference) specially in the mother/daughter relationship.

Discussion

The prevalence of overweight in Portugal, specially in preschool children justifies the pertinence of the analysis of child and maternal risk factors enabling this problem in this stage of the vital cycle, that support the decision making in the definition of strategies to its prevention.

This study aimed to classify the nutritional status of the children and their progenitors, analyzing the effect of the family metabolic risk markers in the expression of the illness in the child.

In the confrontation between the results of this study and those of other authors, we take into consideration the produced inferences, because the respective diversity of the measurement instruments used, the different sampling amplitudes and methodology strategies, which are example the use of self-reported data by the mothers concerning the

Table 3 Relationship between weight and metabolic risk related to mother's WC and child weight

	Male				Female				Total			
	Overweight		No Overweight		Overweight		No Overweight		Overweight		No Overweight	
	n	%	n	%	n	%	n	%	n	%	n	%
<i>Child nutritional status</i>												
Gain in pregnancy												
Recomended	99	38.2	160	61.8	76	33.8	149	66.2	175	36.2	309	63.8
Below recomended	87	32.5	181	67.5	60	24.9	181	75.1	147	28.9	362	71.1
Above recomended	67	41.6	94	58.4	61	39.1	95	60.9	128	40.4	189	59.6
<i>Mother BMI (n = 1116)</i>												
Overweight (468)	95	46.3	151	39.8	77	50.3	145	38.3	172	36.8	296	63.2
Normal weight(648)	110	53.7	228	60.2	76	49.7	234	61.7	186	28.7	462	71.3
<i>Metabolic risk (WC)</i>												
With metabolic risk	131	63.9	228	60.2	102	66.7	218	57.5	233	34.3	446	65.7
Without risk	74	36.5	151	39.8	51	33.3	161	42.5	125	28.6	312	71.4

maternal weight gain during pregnancy and the child birth weight. As other limitations we included the non random character on the children's selection.

The investigation indicated that from the studied children 34.3% presented overweight (including 17.4% obesity), which is globally higher to what is reported in Portugal to this age group, but may suggest on the other hand, not only its increment but also the regional variations of the problem. Studies developed in the same age group in Beira Interior¹² found globally a overweight prevalence of 27.7% (12% obesity), while after that, in the EPObIA study¹³ representative at a regional level, the prevalence was 35.5% (13% obesity) (cut-offs WHO 2006 and 2007),¹⁴ having the authors noted a trend of greater prevalence in children of the north of Portugal (39.3%). In the center region in 2011¹⁵ it was identified 31.3% of overweight (12.4% obesity). Several studies show the extension of the problem in this age group, which magnitude reveals to be worrying because it is transversal to the several regions of the Portuguese continent.

The prevalence of the maternal overweight was 41.9% (12.1% obesity), results that, although significant, are lower than the ones reported in Portugal,¹⁶ where it was referred a prevalence of women's overweight of 47.8%. That national study still revealed significant correlation between age and the BMI value, increasing in a linear manner with the age of the participants and inversely with the academic degree and income. The same was noted in this study, who show that overweight was significantly higher in mothers with low scholarship, low income, in the older and those living in rural area, showing, as reported in literature, that the least favored population present a greater prevalence of obesity and more need of intervention.

The biological and metabolic mechanisms that rule the development of obesity are not yet completely clarified, however several studies support the idea that the genetic predisposition associated to the weight status of the progenitors would have an enabling role on the increase of the weight role. In the same manner the waste circumference is an indirect evaluation tool of the nutritional status and

the health risk, predictive of the metabolic syndrome and cardiovascular condition, suggesting some evidences the existence of a genetic predisposition in that accumulation of fat in the abdominal region.

In this way, primary studies documented,^{17,18} that parent's obesity, would be an important predictor, independently the birth weight, gestational age and social economic family situation. According to this, we aimed specifically to measure the predictive value of that risk factor, inferring that the markers of family risk, BMI and metabolic maternal risk, have a significant effect on the children weight, discovering that the probability of the children to be overweighed is about 1,4 times higher if the mother is overweighed and 1,3 times higher if the mother has high waste circumference. This risk is even more (about 2 times more) when we see the effect of the overweight of mothers in the nutritional status of the daughters comparing to the sons, assuming this to be an enabling factor to be precociously considered in the planning of child health monitoring interventions.

The systematic revision of *Moreira*¹⁹ showed in an equal manner this risk factor as one of the strongest determinant in the increase of child overweight, specially in the association with maternal obesity.

The results found came close to the ones reported in other studies^{18,20} in which the BMI of the children showed a positive association with the parents' BMI, revealing in the same way, a greater association with the mother's, even when only one progenitor presented overweight, being this probability, in a similar way, more significant to children of the female gender.

Also Donohoe²¹ noted that a child whose progenitor is overweighed, presents 40% of probability of having in the future that same manifestation, increasing to 80% if both parents present a BMI superior or equal to 25 Kg/m².

Nowadays, the risks of the excessive maternal weight gain during pregnancy are well established in the size of the new-born and future health of the child.¹¹

From the association between the obstetric predecessors and the overweight it was discovered that from children

with obesity and pre-obesity 25.0% and 28.6% were born BGA, inferring that to a higher birth weight, it is associated a higher risk of overweight in childhood.

Similar results were reported in several longitudinal and observational studies^{17,22-24} as in the study of Padez et al,²⁰ that took place in a sample of children between 7-9 years old in which the risk of obesity increased facing macrosomic birth weights and mostly on children in which this was superior to 4,000 kg versus 2,500 kg.

These appear in the same way on the study of *Moreira et al*,¹⁹ taken place with children from 6-12 years old, where it was discovered a positive and significant association between the overweight and the maternal weight gain superior than 16 kg at the end of pregnancy, showing the importance of precociously *initiating the prevention of obesity, due to the presumable influence of the fetal metabolic environment in the future nutritional programming. However, contrary results were seen in other investigations.*^{7,25-28}

The results of this study reinforce, in this way, the role of genetic, as a game of probabilities able to modulate the response of the organisms to the variations of the environmental factors, emphasizing those when in interaction, may contribute to the increase of the risk in childhood obesity, such as the weight gain during pregnancy, birth weight and the presence of obesity in the progenitors (mostly on the mother).

Existing agreement concerning the priority need of prevention of this public health problem, facing the complexity of the interventions in declared situations, and of its low effectiveness, it is defended that any interventive planning needs an identification and understanding of the epidemiologic patterns of the problem, pointing out that effective approaches need a mix of orientated interventions to the suitability of the clinical measures aimed to the multi-causality and measures concerning the social-ecological environment, through community actions and social sensitive policies that aim to influence directly the family life style. Take action before the manifestation of the problem gains particular relevance concerning the children's vulnerability.

What was known about this subject

Are enabling factors of the increase of child obesity the parents overweight (specially the mother), the birth weight (Light and Big to the gestational weight) and the maternal weight gain during pregnancy.

Study's key points

The study shows that in the preschool sample of Portuguese children and their mothers, the children and maternal risk factors enabling of overweight were: gender, maternal weight gain during pregnancy above recommended, higher birth weight, high maternal metabolic risk (overweight and waste circumference) especially in the mother-daughter relationship.

To mislead and to consider these alert signs in prevention, monitoring and precocious intervention, reveals to be a window of opportunity, promoting and health protecting, with high pertinence in the long term.

Conflict of interests

The authors declare that there are no conflicts of interests.

Acknowledgements

Project MISIJ funded by FCT (PTDC/CPE-CED/103313/2008) and CI&DETS FCT (PEstOE/CED/UI4016/2011)

References

- Centers for Diseases Control and Prevention (CDC). National center for health and statistics: clinical growth charts [Internet]. 2000. [Consult. 2008 Jun 4]. retrieved from http://www.cdc.gov/nchs/about/major/nhanes/growthcharts/clinical_charts.htm
- World Health Organization (WHO). Obesity: Preventing and Managing the Global Epidemic. Report of a WHO Consultation on Obesity. Geneva. World Health Organization; 2000.
- Portugal. Ministério da Saúde. Direcção Geral da Saúde. Programa nacional de combate à obesidade. Lisboa: Direcção Geral da Saúde; 2005.
- Rito A. Questionário de frequência alimentar e hábitos saudáveis dirigido a crianças dos 3-7 anos [Internet]; 2007. retrieved from http://www.plataformacontraaobesidade.dgs.pt/ResourcesUser/ObesidadeInfantil/Ferramentas/quest_fqa_para_crianças.pdf
- Guedes EP, Carraro L, Godoy-Matos A, Lopes AC. Obesidade: etiologia. Projecto directrizes. Rio de Janeiro: Sociedade Brasileira de Clínica Médica; 2005.
- Branca F, Nikogosian H, Lobstein T. The challenge of obesity in the WHO European Region and the strategies for response. Geneva: WHO; 2007.
- Ebbeling CB, Pawlak DB, Ludwig DS. Childhood obesity: public-health crisis, common sense cure. *Lancet* [Internet]. 2002;360:473-82. Retrieved from <http://www.allhealth.org/briefingmaterials/lancetobesityrev-393.pdf> DOI: 10.1016/S0140-6736(02)09678-2.
- Wardle J, Carnell S, Haworth CM, Plomin, R. Evidence for a strong genetic influence on childhood adiposity despite the force of the obesogenic environment. *Am J Clin Nutr* [Internet]. 2008;87:398-404. Retrieved from <http://ajcn.nutrition.org/content/87/2/398.full.pdf+html> DOI: 87/2/398 [pii].
- Balaban G, Silva GA. Protective effect of breastfeeding against childhood obesity: review. *J Pediatr* (Rio J). 2007;80:7-16.
- Rego C. Criança "gordinha" herança ou hábito? In: do Carmo I. Gorduchos e Redondinhas. Alfragide: Livros d'Hoje; 2012. p. 17-29.
- Metzger BE, Lowe LP, Dyer AR, Trimble ER, Chaovarindr U, Coustan DR, Sacks DA. Hyperglycemia and adverse pregnancy outcomes: multicenter study research support. *Engl J Med* [Internet]. 2008;358:1991-2002. Retrieved from <http://www.nejm.org/doi/pdf/10.1056/NEJMoa0707943> DOI: 10.1056/NEJMoa0707943
- Duarte E. Estilos de vida familiar e peso excessivo na criança em idade pré-escolar na região da Beira Interior. In do Carmo I, Santos O, Camolas J, Vieira J, eds. Obesidade em Portugal e no Mundo. Lisboa: Faculdade de Medicina da Universidade de Lisboa; 2008. p. 139-59.
- Miranda AC, Santos O, Araújo J, Ramos E, Lopes C, Carreira M, Galvão-Teles A. Prevalência da obesidade infanto-juvenil e perímetros da cintura em Portugal: resultados do EPOBiA. *Revista de Endocrinologia, Diabetes e Obesidade (ENDO)*. 2010; 4:246.
- World Health Organization. WHO child growth standards: growth velocity based on weight, length and head circumferen-

- ce: methods and development. Geneva: Multicentre Growth Reference Study Group, World Health Organization; 2009.
15. Aparício G, Cunha M, Duarte J, Pereira A. Olhar dos pais sobre o estado nutricional das crianças pré-escolares. *Millenium*. 2011;40:99-113.
 16. Do Carmo I, Dos Santos O, Camolas J, Vieira J, Carreira M, Medina L, Galvão-Teles A. Overweight and obesity in Portugal: national prevalence in 2003-2005. *Obes Rev* [Internet]. 2008; 9:11-9. Retrieved from <http://onlinelibrary.wiley.com/doi/10.1111/j.1467-789X.2007.00422.x/pdf> DOI: 10.1111/j.1467-789X.2007.00422.x
 17. Whitaker RC, Dietz WH. Role of the prenatal environment in the development of obesity. *J Pediatr* [Internet]. 1998;132: 768-76. Retrieved from <http://www.sciencedirect.com/science/article/pii/S0022347698703026#> DOI: S0022-3476(98)70302-6 [pii].
 18. Danielzik S, Langnase K, Mast M, Spethmann C, Muller MJ. Impact of parental BMI on the manifestation of overweight 5-7 year old children. *Eur J Nutr* [Internet]. 2002;41:132-8. Retrieved from <http://link.springer.com/content/pdf/10.1007%2Fs00394-002-0367-1> DOI: 10.1007/s00394-002-0367-1.
 19. Moreira P, Padez C, Mourao-Carvalho I, Rosado V. Maternal weight gain during pregnancy and overweight in Portuguese children. [Research Support, Non-U.S. Gov't]. *Int J Obes (Lond)*. 2007;31:608-614. doi: 10.1038/sj.ijo.0803582.
 20. Padez C, Mourao I, Moreira P, Rosado V. Prevalence and risk factors for overweight and obesity in Portuguese children. *Acta Paediatr* [Internet]. 2005;94:1550-7. Retrieved from <http://onlinelibrary.wiley.com/doi/10.1080/08035250510042924/pdf> DOI: Q007460666W43228 [pii] 10.1080/08035250510042924.
 21. Donohoe M. Weighty matters: public health aspects of the obesity epidemic: part I - causes and health and economic consequences of obesity. *Medscape Ob/Gyn & Women's Health* [Internet]. 2007 Dez., 11. Retrieved from <http://www.medscape.com/viewarticle/566056>
 22. Fall CH, Barker DJ, Osmond C, Winter PD, Clark PM, Hales CN. Relation of infant feeding to adult serum cholesterol concentration and death from ischaemic heart disease. *BMJ*. 1992;304:801-5.
 23. Barker DJ. Fetal origins of coronary heart disease. *BMJ*. 1995; 311:171-4.
 24. Ravelli AC, Van Der Meulen JH, Osmond C, Barker DJ, Bleker OP. Obesity at the age of 50 y in men and women exposed to famine prenatally. *Am J Clin Nutr*. 1999;70:811-6.
 25. Pettitt DJ, Baird HR, Aleck KA, Bennett PH, Knowler WC. Excessive obesity in offspring of Pima Indian women with diabetes during pregnancy. *N Engl J Med* [Internet]. 1983;308: 242-5. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/6848933> DOI: 10.1056/NEJM198302033080502.
 26. Whitaker RC, Wright JA, Pepe MS, Seidel KD, Dietz WH. Predicting obesity in young adulthood from childhood and parental obesity. *N Engl J Med* [Internet]. 1997;337:869-73. Retrieved from <http://www.nejm.org/doi/pdf/10.1056/NEJM199709253371301> DOI: 10.1056/NEJM199709253371301.
 27. Dietz WH. Critical periods in childhood for the development of obesity. *Am J Clin Nutr* [Internet]. 1994;59:955-9. Retrieved from <http://ajcn.nutrition.org/content/59/5/955.full.pdf+html>
 28. Dietz WH. Periods of risk in childhood for the development of adult obesity: what do we need to learn?. *J Nutr* [Internet]. 1997;127:1884S-6S. Retrieved from <http://jn.nutrition.org/content/127/9/1884S.full.pdf+html>