Association between rapid weight gain in early years and subsequent adiposity indices in Portuguese children aged 3 to 5 years

Associação entre o ganho rápido de peso nos primeiros anos de vida e índices de adiposidade subsequentes em crianças portuguesas dos 3 aos 5 anos

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Abstract The present study aimed to evaluate the association of rapid weight gain (RWG) in early years with subsequent measures of adiposity in Portuguese children. We used data from a cross-sectional study of a representative sample of 5359 Portuguese children aged 3 to 5 years in 2009-10. Measures of adiposity

Resumo O presente estudo objetivou avaliar a associação do ganho rápido de peso (RWG) nos primeiros anos de vida com as medidas subsequentes de adiposidade em crianças portuguesas. Foram utilizados dados de um estudo transversal de uma amostra representativa de 5359 crianças portuguesas dos 3 aos 5 anos,

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indices included age-specific body mass index z-score (BAZ) and skinfold (suprailiac, subscapular and triceps) thickness. RWG was defined as the difference between z-scores of weight-for-age and birthweight > 0.67 Standard Deviation. Quantile regression models were used to estimate the difference in the 50th (median) and 90th (upper end) percentiles of each measure by RWG. Rapid weight gain in early years (62.5% of children) was associated with greater levels of BAZ and skinfold thickness measures, both for the median and 90th percentile. For the median, the difference was 1.08 (95% CI: 1.01-1.16) for BAZ, 1.11 mm (95% CI: 0.98-1.25) for suprailiac, 0.99 mm (95% CI: 0.87-1.11) for subscapular and 1.34 mm (95% CI: 1.11-1.57) for triceps skinfolds thickness after the adjustments. The increases in the 90th percentiles of adiposity measures associated with RWG were greater than those in median levels. RWG in childhood was associated with increased levels of adiposity measures, independent of prenatal and childhood factors.

Keywords: Pediatric obesity; weight gain; body weight; skinfold thickness.

observadas em 2009-10. As medidas dos índices de adiposidade incluíram o índice de massa corporal para a idade (BAZ) e a espessura das pregas cutâneas (suprailíaca, subescapular e tricipital). O RWG foi definido como a diferença entre o score-z de peso para idade e peso ao nascimento > 0,67 desvio padrão. Modelos de regressão quantílica foram usados para estimar a diferença nos percentis 50 (mediana) e 90 (extremidade superior) de cada medida por RWG. O ganho rápido de peso nos anos iniciais (62,5% das crianças) foi associado a maiores níveis de BAZ e medidas de pregas cutâneas, tanto para a mediana quanto para o percentil 90. Para a mediana, a diferença foi de 1,08 (IC 95%: 1,01-1,16) para BAZ, 1,11 mm (IC 95%: 0,98-1,25) para a prega suprailíaca, 0,99 mm (IC 95%: 0,87-1,11) para a prega subescapular e 1,34 mm (IC 95%: 1,11-1,57) para prega cutânea tricipital após os ajustes. Os aumentos nos percentis 90 das medidas de adiposidade associados ao RWG foram maiores do que aqueles nos níveis medianos. O RWG na infância foi associado a níveis aumentados de medidas de adiposidade, independente de fatores de risco pré-natais e da infância.

Palavras-chave: Obesidade infantil; ganho de peso; peso corporal; pregas cutâneas.

Introduction

The levels of body mass index (BMI) and overweight/obesity have increased rapidly in recent decades across age groups and in most populations (NCD-RisC, 2017). The worldwide prevalence of overweight and obesity in children aged 0-5 years increased from 30.3 million to 38.9 million between 2000 and 2020 (FAO, 2022). In Portugal, in 2018/19, the prevalence of childhood overweight and obesity remained high at 29.7% and 11.9%, respectively (PORTUGAL, 2021). Childhood obesity tends to persist into adulthood (Reilly and Kelly, 2011) and is associated with a range of adverse health outcomes (NCD-RisC, 2017), including cardiovascular diseases (WHO, 2018). Obesity is a global public health problem (Karnik and Kanekar, 2012).

Early years are a key risk period for the development of obesity (Gillman, 2010), and there are growing studies confirming an association between early rapid postnatal growth and subsequent higher adiposity measures (Ong and Loos, 2006; Zheng et al., 2018). Recent studies have shown that rapid weight gain (RWG) in early years, defined as a change in weight-for-age > 0.67 standard deviation (Ong et al., 2000), is an important early life risk factor for the development of obesity in the short, medium and long term (Woo Baidal et al., 2016). A meta-analysis showed that children with RWG by two years of age were 3.7 times more likely to become obese in adulthood (Zheng et al., 2018). Furthermore, systematic reviews also found that RWG was related to increased body fat percentage, waist circumference, and waist-to-height ratio (Lucas, 2010). However, most of these studies tend to focus primarily on a single measure of adiposity such as BMI.

The first thousand days of the child's life are a crucial window for prevention and intervention measures for reducing the risk of obesity (Mameli et al., 2016). Therefore, this study aimed to examine the association of RWG in early years with BMI and three skinfold thickness measures in a nationally representative sample of Portuguese children aged three to five years.

Methods

We used the data from a cross-sectional survey, the "Portuguese Prevalence Study of Obesity in Childhood, changes from 2002 to 2007. The Effects of Lifestyle and Environmental Factors". The survey was conducted between March 2009 and January 2010 in public and private kindergartens and primary schools in all districts of Portugal, except the Portuguese archipelagos (Madeira and Azores). The study sample was selected using proportional stratified random sampling according to the number of children in each district. This is a nationally representative survey totaling 17.509 children aged 3 to 10 years. The participation rate was 57.4% (Jago et al., 2012). The study was approved by the Directorate-General for Innovation and Curriculum Development and all participants received information about the research objectives and signed the Informed Consent Form.

Study sample

In this cross-sectional study, children between the ages of 3 and 5 years were included. Children without birthweight, height or weight measurements, or with implausible values were excluded, i.e. standardized weight-for-age index (WAZ) scoring < -6 or > 5, and BMI for age (BAZ) scoring < -5 or > 5 (WHO, 2011). The final eligible sample included 5359 children (Figure 1).

Measures

Trained researchers using standardized procedures performed anthropometric measurements. Height and weight of children were measured to the nearest 0.1 cm and 100 g, with light clothing and without shoes, using a portable stadiometer and a portable electronic scale, respectively. The thickness of the suprailiac skinfold (SSF), subscapular skinfold (SSSF) and triceps skinfold (TSF) (mm) were measured twice with a skinfold caliper and the average of the two readings was used for each skinfold measure (Li et al., 2016). BMI (kg/m^2) was calculated for each child and converted to age- and gender-specific BMI z-score using the WHO Anthro Program (WHO, 2011). Birthweight was reported by parents based on data from the individual card that each child got from the maternity where they were born. In this card, they have all the information concerning the birth.

Exposure and outcome

Rapid weight gain (RWG) as an exposure with the definition of a change in weight-for-age z score > +0.67 (from birth to collection date) is the most frequent and widely accepted definition (Ong et al., 2000). The outcome measures were BMI z-score (BAZ) and three (suprailiac, subscapular and triceps) skinfolds thickness measures.

Confounders

Covariates included the mother's height and weight (for calculating maternal BMI), maternal age, maternal education (low - primary/sub-secondary ≤9 years, middle - secondary 10–12 years, and high - higher education based on the Portuguese Educational System), and duration of breastfeeding (months).

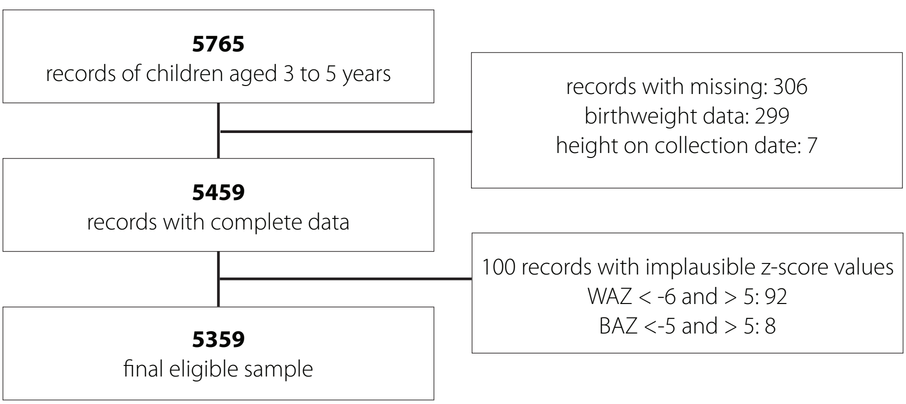

Figure 1. Sample flowchart.

Statistical analysis

They were summarized using mean values (standard deviation) for continuous variables and frequencies for categorical variables. Their differences by RWG group were tested using t-student and chi-square tests, respectively. As the distributions of adiposity measures were skewed (Yu et al., 2003), we applied quantile regression models to examine whether RWG was associated with the median (50th percentile) and upper end (90th percentile) of the adiposity measures (Koenker, 2005). The differences (95% Confidence Interval) in median and 90th percentiles for each adiposity measure between children with and without RWG were estimated. We first fitted an unadjusted model (Model 1), then adjusted for maternal BMI, maternal age, and birthweight (Model 2), and further for maternal education and duration of breastfeeding (Model 3). Data were analyzed using the software STATA (v14).

Results

This study includes 5359 children from 3 to 5 years, being 50.46% (n = 2704) boys and 49.54% (n = 2655) girls. The children had a mean birth weight of 3207.87g. The children's mothers had a mean age of 34 years.

There was a high proportion of children who experienced RWG (62.5%). They had a lower mean birthweight than those who did not. There was no difference in mean maternal BMI, maternal age, maternal education, and duration of

Table 1. Mean, standard deviation and frequency (%) for maternal and child characteristics of Portuguese children according to rapid weight gain (RWG). Portugal, 2009 -10 (n = 5359).

Variables	*n*†	RWG		
		No	Yes	P value*
	5359	2007 (37.5%)	3352 (62.6%)	
Maternal BMI (kg)	4979	23.9 (3.8)	23.8 (3.8)	0.246
Maternal age (year)	5281	34.6 (4.9)	34.5 (5.1)	0.315
Birthweight (g)	5359	3472.6 (433.2)	3049.4 (466.6)	<0.001
Breastfeeding (months)	4579	5.33 (0.12)	5.08 (0.09)	0.099
Maternal education	5263	1972 (37.5%)	3291 (62.5%)	0.362
Low education	2115	811 (38.4%)	1304 (61.7%)	
Middle education	1093	391 (35.8%)	702 (64.2%)	
High education	2055	770 (37.5%)	1285 (62.5%)	

* $p < 0.05$ for difference between RWG and non-RWG groups (t-test for continuous variables and chi-square test for categorical variables).
† Children (3 - 5 years) with adiposity measures.

breastfeeding between those with and without RWG (p>0.05) (Table 1).

RWG was associated with increased levels of all adiposity measures (BAZ, SSF, SSSF, TSF) at both the 50th and 90th percentiles. The differences in mean adiposity measure by the RWG group increased after adjusting for maternal BMI, maternal age, and birthweight, and maintained when further adjusting for maternal education and breastfeeding duration (Figures 2 and 3). The adjusted difference (model 3) in median BAZ was 1.08 z-score (95% CI: 1.01-1.16). The respective difference in skinfold thickness was 1.11 mm (0.98-1.25) for SSF, 0.99 mm (0.87-1.11) for SSSF, and 1.34 mm (1.11-1.57) for TSF (Figure 2).

RWG was also associated with the upper end of the distribution (90th percentile) for each adiposity measure. The adjusted difference (model 3) was 1.47 (1.34-1.60) for BAZ, and for the SSF, SSSF, and TSF measures was 2.89 mm (2.43-3.35), 2.34 mm (1.94-2.74), and 2.37 mm (1.93-2.81), respectively. The difference by RWG was greater in the 90th percentile than the median (Figure 3).

Discussion

The present study showed that children with RWG had greater levels of adiposity of several adiposity indices (e.g., BAZ, SSF, SSSF, TSF), both in median and upper end of distributions after adjusting for prenatal and childhood factors. These differences were consistently greater in the 90th than the 50th percentile, indicat-

Outcomes	Models	β (95% CI)
BAZ	Model 1	0.71 (0.64-0.77)
	Model 2	1.07 (1.01-1.14)
	Model 3	1.08 (1.01-1.16)
SSF	Model 1	0.86 (0.75-0.96)
	Model 2	1.08 (0.96-1.20)
	Model 3	1.11 (0.98-1.25)
SSSF	Model 1	0.75 (0.62-0.83)
	Model 2	0.96 (0.85-1.07)
	Model 3	0.99 (0.87-1.11)
TSF	Model 1	1.02 (0.83-1.20)
	Model 2	1.34 (1.12-1.55)
	Model 3	1.34 (1.11-1.57)

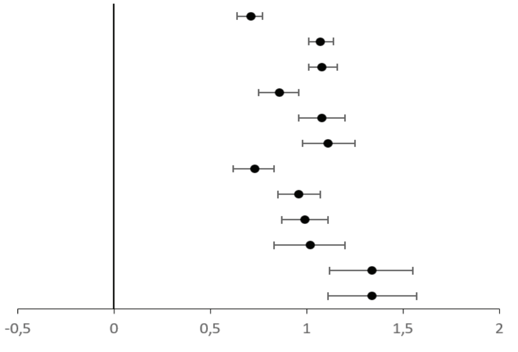

Figure 2. Difference (95% CI) in 50th percentile (median) of adiposity indices by the presence of rapid weight gain (RWG), without and with adjustments*. Portugal, 2009 -10 (n = 5359).

* Estimated from quantile regression. Model 1 unadjusted. Model 2 adjusted for maternal BMI, maternal age and birthweight. Model 3 includes all variables in Model 2, plus breastfeeding and maternal education. Acronyms: 95% CI: 95% Confidence Interval; BAZ: BMI z-score; SSF: suprailiac skinfold; SSSF: subscapular skinfold; TSF: triceps skinfold.

Outcomes	Models	β (95% CI)
BAZ	Model 1	1.23 (1.11-1.34)
	Model 2	1.45 (1.33-1.58)
	Model 3	1.47 (1.34-1.60)
SSF	Model 1	2.70 (2.28-3.11)
	Model 2	2.83 (2.38-3.28)
	Model 3	2.89 (2.43-3.35)
SSSF	Model 1	2.30 (1.90-2.69)
	Model 2	2.44 (1.98-2.90)
	Model 3	2.34 (1.94-2.74)
TSF	Model 1	1.96 (1.61-2.32)
	Model 2	2.38 (1.95-2.81)
	Model 3	2.37 (1.93-2.81)

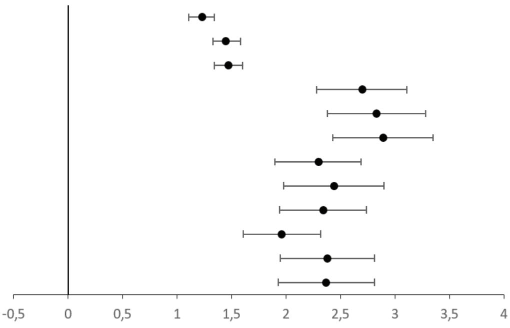

Figure 3. Difference (95% CI) in 90th percentile of adiposity indices by the presence of rapid weight gain (RWG), without and with adjustments*. Portugal, 2009 -10 (n = 5359).

* Estimated from quantile regression. Model 1 unadjusted. Model 2 adjusted for maternal BMI, maternal age and child birthweight. Model 3 includes all variables in Model 2, plus breastfeeding and maternal education. Acronyms: 95% CI: 95% Confidence Interval; BAZ: BMI z-score; SSF: suprailiac skinfold; SSSF: subscapular skinfold; TSF: triceps skinfold.

ing that RWG not only increased the median, but increased more for the extreme high levels of adiposity measures.

A recent systematic review and meta-analysis of populations from countries on five continents showed that RWG by the age of 2 years was associated with increased risk of overweight in childhood and adulthood (Zheng et al., 2018). Our findings are consistent with previous studies (Nanri et al., 2017; Zheng et al., 2018). It has been reported that changes in velocity of weight growth in the early years have long-lasting effects for adipose tissue accumulation (Hooper et al., 2001; Godfrey et al., 2007) and other health outcomes (Godfrey et al., 2010; Hanley et al., 2010; Lillycrop, 2011; van der Haak et al., 2019). Using the same definition of 0.67 standard deviation of the WAZ, Brazilian children showed a 69% and 64% increase in the overweight and obesity risks, respectively (Monteiro et al., 2003).

In general, large infants tend to be at greater risk of overweight and obesity during adolescence (Lyons-Reid et al., 2021). However, accelerated growth in premature, small for gestational age, or low birthweight infants is associated with a range of long-term deleterious effects (Victora et al., 2001; Martin et al., 2017), including obesity and hypertension (Parsons et al., 1999). Infants born with low birthweight have a higher risk of having increased growth velocity (Gillman et al., 2010). Given that the relationships between extremes of weight (high or low) outcomes associated with adiposity in later life are not consistent, rapid weight gain in children may be an alternative explanation to this controversy.

Some studies have shown that exclusive breastfeeding longer than 6 months and delayed exposure to food formula may protect from increased adiposity throughout adolescence (Cordero et al., 2014). A cohort of Australian children showed that formula-fed children had more accelerated BMI growth trajectories compared to those who were breastfed (Oddy et al., 2014). In the present study, breastfeeding duration was not associated with BAZ or with skinfold thickness values, and the adjustment for breastfeeding did not alter the findings. Lack of information on food consumption patterns before or during breastfeeding (e.g., introduction of formula milk or other weaning foods) may explain the inconsistent findings from previous studies.

Health care in the first years of life provides a foundation for good health in later life, especially the period of the first 1000 days from conception to two years of age. In the context of an ecological model, maternal conditions before and during pregnancy and nutrition in early childhood are crucial to mitigate the burden of diseases in adulthood (Darnton-Hill et al., 2004). It is unclear which period of childhood is most critical for the development of obesity in children with RWG (Ong and Loos, 2006). Although evidence has suggested that the first two years are the period of greatest risk for the development of overweight (Zheng et al., 2018; Li et al., 2020), the age between 2 and 5 years was also indicated (Matos et al., 2011). Thus, this set of studies reinforces the need for careful monitoring of postnatal weight gain in these groups and referral to health professionals responsible for specific assessment and intervention. A comprehensive understanding of the importance of predictors of obesity in children is essential for the development and refinement of strategies aimed at improving maternal and child health care in childhood and other life cycles.

It is noteworthy that our findings are from a large, nationally representative sample of Portuguese children and include multiple measures objectively collected of subcutaneous adipose tissue. Although these measures are correlated, they indicate different aspects of adiposity (e.g., BAZ representing overall adiposity and skinfold thickness, which is a proxy for fat mass). Limitations include the cross-sectional design that does not allow us to assess temporality nor the possibility of exploring trajectories of the anthropometric measures measured. Thus, future investigations using longitudinal data are necessary.

Conclusion

RWG in the early years of life was associated with increased levels of adiposity in children aged 3 to 5 years, especially at the upper end of distributions, independent of prenatal and childhood factors. These results highlight the importance of monitoring the child's weight growth from early years as a potential preventive action for childhood obesity in primary care, as well as, to promote healthy child development and growth, and adulthood.

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Disclosure statement

There are no conflicts of interests.

References

Cordero, M. J. A.; López, A. M. S.; Baños, N. M.; Villar, N. M.; Ruiz, M. E; Rodríguez, E. H. 2014. Lactancia materna como prevención del sobrepeso y la obesidad en el niño y el adolescente; revisión sistemática. *Nutrición Hospitalaria*, 31(2): 606–20. DOI: 10.3305/nh.2015.31.2.8458.

Darnton-Hill, I.; Nishida, C.; James, W. P. 2004. A life course approach to diet, nutrition and the prevention of chronic diseases. *Public Health Nutrition*, 7(1A): 101–21. DOI: 10.1079/phn2003584.

Fund for Agricultural Development, International Fund for Agricultural Development, United Nations International Children's Emergency Fund, World Food Programme and World Health Organization. 2022. *The state of food security and nutrition in the world 2022. Repurposing food and agricultural policies to make healthy diets more affordable*. Rome, FAO. DOI: 10.4060/cc0639en.

Gillman, M. W. 2010. Early infancy as a critical period for development of obesity and related conditions. *Nestle Nutrition Workshop Series Pediatric Program*, 65: 13–24. DOI: 10.1159/000281141.

Godfrey, K. M.; Lillycrop, K. A.; Burdge, G. C.; Gluckman, P. D.; Hanson, M. A. 2007. Epigenetic mechanisms and the mismatch concept of the developmental origins of health and disease. *Pediatric Research*, 61(5 Pt 2): 5R–10R. DOI: 10.1203/pdr.0b013e318045bedb.

Godfrey, K. M.; Gluckman, P. D.; Hanson, M. A. 2010. Developmental origins of metabolic disease: life course and intergenerational perspectives. *Trends in Endocrinology and Metabolism*, 21(4): 199–205. DOI:10.1016/j.tem.2009.12.008.

Hanley, B.; Dijane, J.; Fewtrell, M.; Grynberg, A.; Hummel, S.; Junien, C.; Koletzko, B.; Lewis, S.; Renz, H.; Symonds, M.; Gros, M.; Harthoorn, L.; Mace, K.; Samuels, F.; van Der Beek, E. 2010. Metabolic imprinting, programming and epigenetics - a review of present priorities and future opportunities. *British Journal Nutrition*, 104 (Suppl S1): S1–25. DOI: 10.1017/S0007114510003338.

Hooper, L. V.; Wong, M. H.; Thelin, A.; Hansson, L.; Falk, P. G.; Gordon, J. I. 2001. Molecular analysis of commensal host-microbial relationships in the intestine. *Science*, 291(5505): 881–884. DOI: 10.1126/science.291.5505.881.

Jago, R.; Stamatakis, E.; Gama, A.; Carvalhal, I. M.; Nogueira, H.; Rosado, V.; Padez, C. 2012. Parent and child screen-viewing time and home media environment. *American Journal of Preventive Medicine*, 43(2): 150–158. DOI: 10.1016/j.amepre.2012.04.012.

Karnik, S.; Kanekar, A. 2012. Childhood obesity: a global public health crisis. *International Journal Preventive Medicine*, 3(1): 1–7. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3278864/.

Koenker, R. 2005. *Quantile regression*. Cambridge, Cambridge University Press.

Li, L.; Peters, H.; Gama, A.; Carvalhal, M. I.; Nogueira, H. G.; Rosado-Marques, V.; Padez, C. 2016. Maternal smoking in pregnancy association with childhood adiposity and blood pressure. *Pediatric Obesity*, 11(3): 202–209. DOI: 10.1111/ijpo.12046.

Li, Y. F.; Lin, S. J.; Chiang, T. L. 2020. Timing of rapid weight gain and its effect on subsequent overweight or obesity in childhood: findings from a longitudinal birth cohort study. *BMC Pediatrics* [Online], 20: 293. DOI: 10.1186/s12887-020-02184-9.

Lillycrop, K. A. 2011. Effect on maternal diet on the epigenome: implications for human metabolic disease. *Proceedings of the Nutrition Society*, 70(1): 64–72. DOI: 10.1017/S0029665110004027.

Lucas, A. 2010. Growth and later health: a general perspective. *Nestle Nutrition Workshop Series Pediatric Program*, 65: 1–9. DOI: 10.1159/000281107.

Lyons-Reid, J.; Albert, B. B.; Kenealy, T.; Cutfield, W. S. 2021. Birth size and rapid infant weight gain-where does the obesity risk lie? *The Journal of Pediatrics*, 230: 238–243. DOI: 10.1016/j.jpeds.2020.10.078.

Mameli, C.; Mazzantini, S.; Zuccotti, G. V. 2016. Nutrition in the first 1000 days: the origin of childhood obesity. *International Journal Environmental Research and Public Health* [Online], 13(9): 838. DOI: 10.3390/ijerph13090838.

Martin, A.; Connelly, A.; Bland, R. M.; Reilly, J. J. 2017. Health impact of catch-up growth in low-birth weight infants: systematic review, evidence appraisal, and meta-analysis. *Maternal & Child Nutrition* [Online], 13(1): e12297. DOI: 10.1111/mcn.12297.

Matos, S. M. A.; Jesus, S. R.; Saldiva, S. R. D. M.; Prado, M. S.; D'Innocenzo, S.; Assis, A. M. O.; Rodrigues, L.; Barreto, M. 2011. Velocidade de ganho de peso nos primeiros anos de vida e excesso de peso entre 5-11 anos de idade, Salvador, Bahia, Brasil. *Caderno Saúde Pública*, 27(4): 714–722. DOI: 10.1590/S0102-311X2011000400010.

Monteiro, P. O.; Victora, C. G.; Barros, F. C.; Monteiro, L. M. 2003. Birth size, early childhood growth, and adolescent obesity in a Brazilian birth cohort. *International Journal Obesity and Related Metabolic Disorders*, 27(10): 1274–1282. DOI: 10.1038/sj.ijo.0802409.

Nanri, H.; Shirasawa, T.; Ochiai, H.; Nomoto, S.; Hoshino, H.; Kokaze, A. 2017. Rapid weight gain during infancy and early childhood is related to higher anthropometric measurements in preadolescence. *Child: Care, Health and Development*, 43(3): 435–440. DOI: 10.1111/cch.12455.

NCD Risk Factor Collaboration (NCD-RisC). 2017. Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128·9 million children, adolescents, and adults. *Lancet*, 390(10113): 2627–2642. DOI: 10.1016/S0140-6736(17)32129-3.

Oddy, W. H.; Mori, T. A.; Huang, R. C.; Marsh, J. A.; Pennell, C. E.; Chivers, P. T.; Hands B. P.;

Jacoby, P.; Rzehak, P.; Koletzko, B. V.; Beilin, L. 2014. Early infant feeding and adiposity risk: from infancy to adulthood. *Annals of Nutrition and Metabolism*, 64(3-4): 262–270. DOI: 10.1159/000365031.

Ong, K. K. L.; Ahmed, M. L.; Emmett, P. M.; Preece, M. A.; Dunger, D. B. 2000. Association between postnatal catch-up growth and obesity in childhood: prospective cohort study. *British Medical Journal*, 320(7240): 967–971. DOI: 10.1136/bmj.320.7240.967.

Ong, K. K.; Loos, R. J. 2006. Rapid infancy weight gain and subsequent obesity: systematic reviews and hopeful suggestions. *Acta Paediatrica*, 95: 904–908. DOI: 10.1080/08035250600719754.

Parsons, T. J.; Power, C.; Logan, S.; Summerbell, C. D. 1999. Childhood predictors of adult obesity: a systematic review. *International Journal of Obesity*, 23(Suppl 8): S1–107. Available at: https://pubmed.ncbi.nlm.nih.gov/10641588/.

Reilly, J. J.; Kelly, J. 2011. Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: systematic review. *International Journal Obesity*, 35(7): 891–898. DOI: 10.1038/ijo.2010.222.

Rito, A.; Mendes, S.; Baleia, J.; Gregório, M. J. 2021. *Childhood Obesity Surveillance Initiative: COSI Portugal 2019* [Online]. Lisboa, Instituto Nacional de Saúde Doutor Ricardo Jorge, IP. Available at: http://repositorio.insa.pt/bitstream/10400.18/7783/1/COSI_Portugal_2019_out2021.pdf.

van der Haak, N.; Wood, K.; Sweeney, A.; Munn, Z. 2019. Risk of metabolic consequences of rapid weight gain and catch-up growth in the first two years of life: a systematic review protocol. *JBI Database of Systematic Reviews and Implementation Reports*, 17(1): 10–15. DOI: 10.11124/JBISRIR-2017-003451.

Victora, C. G.; Barros, F. C.; Horta, B. L.; Martorell, R. 2001. Short-term benefits of catch-up growth for small-for-gestational-age infants. *International Journal Epidemiology*, 30(6): 1325–1330. DOI: 10.1093/ije/30.6.1325.

Woo Baidal, J. A.; Locks, L. M.; Cheng, E. R.; Blake-Lamb, T. L.; Perkins, M. E.; Taveras, E. M. 2016. Risk factors for childhood obesity in the first 1,000 days: a systematic review. *American Journal of Preventive Medicine*, 50(6): 761–779. DOI: 10.1016/j.amepre.2015.11.012.

World Health Organization. 2011. *WHO Anthro Survey Analyser* [Online]. [Geneva], World Health Organization. Available at: https://www.who.int/tools/child-growth-standards/software.

World Health Organization. 2018. *Obesity and overweight* [Online]. [Geneva], World Health Organization. [Consultado em 27-01-2023]. Available at: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight.

Yu, K.; Lu, Z.; Stander, J. 2003. Quantile regression: applications and current research areas. *Journal of the Royal Statistical Society: Series D* (The Statistician), 52(3): 331–350. DOI: 10.1111/1467-9884.00363.

Zheng, M.; Lamb, K. E.; Grimes, C.; Laws, R.; Bolton, K.; Ong, K. K.; Campbell, K. 2018. Rapid weight gain during infancy and subsequent adiposity: a systematic review and meta-analysis of evidence. *Obesity Review*, 19(3): 321–332. DOI: 10.1111/obr.12632.