Preventive Medicine 134 (2020) 106024

Contents lists available at ScienceDirect

Preventive Medicine

journal homepage: www.elsevier.com/locate/ypmed

Short Communication

Early life weight patterns and risk of obesity at 5 years: A population-based cohort study

Serena Broccoli[a], Olivera Djuric[a,b,*,**], Laura Bonvicini[a], Anna Maria Davoli[c], Elena Ferrari[c], Francesca Ferrari[a], Maria Elisabeth Street[d], Paolo Giorgi Rossi[a]

[a] Epidemiology Unit, Azienda Unità Sanitaria Locale – IRCCS di Reggio Emilia, Italy
[b] Center for Environmental, Nutritional and Genetic Epidemiology (CREAGEN), Section of Public Health, Department of Biomedical, Metabolic and Neural Sciences, University of Modena and Reggio Emilia, Italy
[c] Primary Care Pediatrician, Azienda Unità Sanitaria Locale – IRCCS di Reggio Emilia, Italy
[d] Division of Paediatric Endocrinology and Diabetology Department of Mother and Child, IRCCS di Reggio Emilia, Italy

ARTICLE INFO

Keywords:
BMI
Weight
Birth weight
Obesity
Overweight

ABSTRACT

Childhood obesity is a major public health problem in industrialized countries. The aim of this study was to estimate the risk of obesity at age 5 based on BMI categories at age 3 and changes in BMI z-score from birth to 3 years of age. In this population-based study BMI data of 5173 children were collected at ages 3 and 5 and were linked to information relative to birth weight. The prevalence of obesity at age 5 was 3.8%. The risk of obesity for children born large for gestational age was 6.5%, while it was 18.6% for children overweight at age 3 and 62% for children who were obese at 3. An increase in BMI z-score from birth to 3 years increases the risk of obesity at age 5 (OR for increase of one standard deviation 2.8%; 95% CI: 2.46–3.20), but adjusting for BMI z-score at age 3, the effect of trajectory disappears (OR 1.08 95% CI: 0.9–1.29). In other words, if one targeted early preventive interventions to 3-year-olds affected by overweight/obesity (only 9.8% of the study cohort), one could possibly address 71% of children potentially affected by obesity at age 5.

1. Introduction

Childhood obesity is a major public health problem in industrialized countries, affecting every third child or adolescent in the United States and Europe (Ogden et al., 2014; Ahrens et al., 2014). The prevalence of childhood obesity has increased since the 1980s, with evident large differences between social classes and countries (Ogden et al., 2002; Frederick et al., 2014). Further, obesity is increasing sharply in every subsequent age group, leading to 50% of adults being affected (Ogden et al., 2002; Frederick et al., 2014).

Biological and epidemiological evidence suggests that obesity in adolescence is influenced by characteristics present in early childhood or even in the prenatal period (Ziauddeen et al., 2018; Ohlendorf et al., 2019). A recent study evaluated the dynamics of weight gain in a large cohort of children aged 0–14 years, showing that one of the most important determinants of obesity in adolescents and young adults is the rapid increase in body mass index (BMI) z-score from the age of 2 to the age of 6 (Geserick et al., 2018). Based on this observation, it should be possible to prevent part of obesity in adolescents and young adults by targeting children aged 2 to 6 in the attempt to avoid a marked increase in BMI percentile in the school age. This represents a possible important point to consider within health system organizations, and in particular within community pediatrics.

Primary care providers and family pediatricians can be an effective point of contact for early prevention of childhood obesity by collaborating with families to determine the level of care needed and by helping to connect families with appropriate resources, thereby complementing and potentially enhancing public health efforts. In the Reggio Emilia province, a network of care has been set up that includes primary prevention, family pediatricians, and specialized outpatient and hospital care. The network was developed according to the national and regional guidelines (Delibera della Regione Emilia-Romagna GPG/2013/783, 2013) and based on the results of locally conducted studies (Davoli et al., 2013; Broccoli et al., 2016). In the present large population-based cohort study we used the data collected within this network to better understand early life growth trajectories and critical age points; specifically, the aim was to estimate the association between birth weight and BMI at 3 years of age and obesity at age 5.

* Corresponding author at: Servizio Epidemiologia, Direzione Sanitaria-Azienda Unità Sanitaria Locale-IRCCS di Reggio Emilia, Via Amendola 2, 42122, RE, Italy.
** Corresponding author at: University of Modena and Reggio Emilia, Department of Biomedical, Metabolical and Neurosciences, Modena, Italy.
E-mail addresses: olivera.djuric@ausl.re.it, olivera.duric@unimore.it (O. Djuric).

https://doi.org/10.1016/j.ypmed.2020.106024
Received 23 July 2019; Received in revised form 3 February 2020; Accepted 10 February 2020
Available online 13 February 2020

Table 1
Probability (% and 95% confidence interval) of being underweight, overweight/affected by obesity or affected by obesity at 5-year-old visit according to birth-weight group and BMI group at 3-year-old visit.

	Weight group at 5 years well-child visit																
	Underweight				Normal weight				Overweight and obese				Obese				Total
	N	%	95% CI		N	%	95% CI		N	%	95% CI		N	%	95% CI		N
Birth-weight group																	
SGA	121	19.0	16.0	22.3	463	72.7	69.0	76.1	53	8.3	6.3	10.7	13	2.0	1.1	3.5	637
AGA	451	10.7	9.8	11.7	3212	76.5	75.2	77.8	534	12.7	11.7	13.8	165	3.9	3.4	4.6	4.197
LGA	14	4.5	2.5	7.5	243	78.6	73.6	83.1	52	16.8	12.8	21.5	20	6.5	4.0	9.8	309
Missing	5	16.7			21	70.0			4	13.3			1	3.3			30
Weight group at 3 years																	
Underweight	369	38.1	35.0	41.2	595	61.4	58.2	64.5	5	0.5	0.2	1.2	3	0.3	0.1	0.9	969
Normal weight	219	5.9	5.2	6.7	3131	84.7	83.5	85.8	348	9.4	8.5	10.4	55	1.5	1.1	1.9	3.698
Overweight	2	0.5	0.1	1.8	193	48.6	43.6	53.6	202	50.9	45.8	55.9	74	18.6	14.9	22.8	397
Obese	1	0.9	0.0	5.0	19	17.6	10.9	26.1	88	81.5	72.9	88.3	67	62.0	52.2	71.2	108
Missing	0	0.0			1	100.0			0	0.0			0	0.0			1
Total	591				3939				643				199				5173

2. Materials and methods

2.1. Setting

The Province of Reggio Emilia (RE), located in northern Italy, has a resident population of about 530,000 inhabitants; of these about 80,000 (15.4%) are children aged 0–14 years (demo.istat.it). BMInforma (Bambini Molto In forma or *very fit children*) is an ongoing public health multilevel program based on the application of national and regional guidelines (Delibera della Regione Emilia-Romagna GPG/2013/783, 2013) that encompasses primary and secondary prevention interventions of childhood obesity. As routine monitoring within the program, measurements of children attending regular well-child visits at 3 years and at 5 years are systematically collected.

2.2. Study design

This is a prospective population-based cohort of children born between 1st June 2010 and 31st December 2011 who attended the 3-year-old (accepted age range 2 yr 9mo–3 yr 3mo) and 5-year-old (accepted age range 4 yr 9mo–6 yr 3mo) well-child visits, when systematic BMI and BMI percentile registration was mandatory. The birth certificates for 89.2% of the children were retrieved in order to collect information concerning birth weight and gestational age (Supplementary Figure).

2.3. Outcome and exposures

The main outcome of this study was obesity at age 5 based on the International Obesity Task Force (IOTF) BMI cut-offs (Cole et al., 2000). We explored the following exposures as determinants of obesity at age 5: (a) birth-weight groups, classified as small for gestational age (SGA), appropriate for gestational age (AGA) and large for gestational age (LGA) (Kramer et al., 2001); (b) age 3 BMI groups, classified as underweight, normal weight, overweight and obese according to IOTF (Cole et al., 2000); (c) changes from birth weight for gestational age to 3 yr BMI group. We also considered differences in birth weight z-score to 3 yr BMI z-score, computed using age- and sex-specific distribution parameters of the Centers for Disease Control and Prevention (CDC) growth charts (Kuczmarski et al., 2000). Preterm birth was defined, according to World Health Organization (WHO) definition, as babies born alive before 37 weeks of pregnancy are completed.

2.4. Statistical analysis

The prevalence of obesity in 5-year-old well-child visits and relative 95% confidence intervals, computed according to binomial exact distribution, are presented based on the weight group at birth (Kramer et al., 2001) and BMI group at age 3 (Cole et al., 2000). Sensitivity of overweight/obesity at age 3 for being obese at age 5 was calculated as the proportion of children obese at 5 years who were also overweight/obese at 3 years and all children obese at 5 years, while the positive predictive value (PPV) was calculated as a proportion of children obese at 5 years who were also overweight/obese at 3 years and children overweight/obese at 3 years. Logistic regression models were used to estimate the association between obesity at 5 years and change in z-score from birth to 3 years and the effect change when adjusting for BMI z-score at 3 years. Data analysis was performed using Stata statistical software, version 13.0.

3. Results

Overall, 5173 children were included in the analyses: 2590 (50.1%) males and 2583 (49.9%) females, born between 1 June 2010 and 31 December 2011, for whom information at birth, 3-year-old and 5-year-old well-child visits were available (Supplementary Figure).

The subjects born SGA and born LGA were 12.3% and 6.0%, respectively, of the entire population. The proportion of children affected by obesity was 2.1% at the 3-year-old visit (9.8% overweight/obese) and 3.8% at the 5-year-old visit (16.3% overweight/obese).

The probability of being affected by obesity at the 5-year-old visit was lower for subjects born SGA and higher for subjects born AGA and LGA (2%, 3.9% and 6.54%, respectively) (Table 1). The probability of being affected by overweight/obesity at age 5 increased in a similar fashion (by 8.3%, 12.7% and 16,8%, respectively). However, the risk of being underweight at age 5 was higher in the subjects born SGA than in the children born LGA (19.0% vs. 4.5%, respectively). Only 10% of children affected by obesity at age 5 were born LGA, while 82.9% were born AGA. BMI group at 3 years was strongly associated with obesity at the 5-year-old visit: the risk of being affected by obesity at age 5 for children who were already affected at age 3 was 62%. Sensitivity of overweight/obesity at age 3 for being obese at age 5 was 70.9% [(74 + 67)/199] and PPV was 27.9% [(74 + 67)/(397 + 108)].

An increase in weight group from birth to 3 years was associated with being affected by obesity at 5 years only when not adjusted for the BMI z-score at the 3-year-old visit. In fact, an increase in z-score from birth to 3 years increased the risk of being affected by obesity at the 5-year-old visit (OR for increase of one standard deviation 2.8 95% CI: 2.46; 3.20), but when we adjusted for BMI z-score at age 3, the effect of the trajectory disappeared (OR 1.08 95% CI: 0.90; 1.29). Consistently, 3-year-old children affected by obesity, regardless of their previous trajectory, had a similar risk of obesity at age 5: 54.5%, 65.1% and 50%, respectively, for those with stable trajectory (LGA → obese at

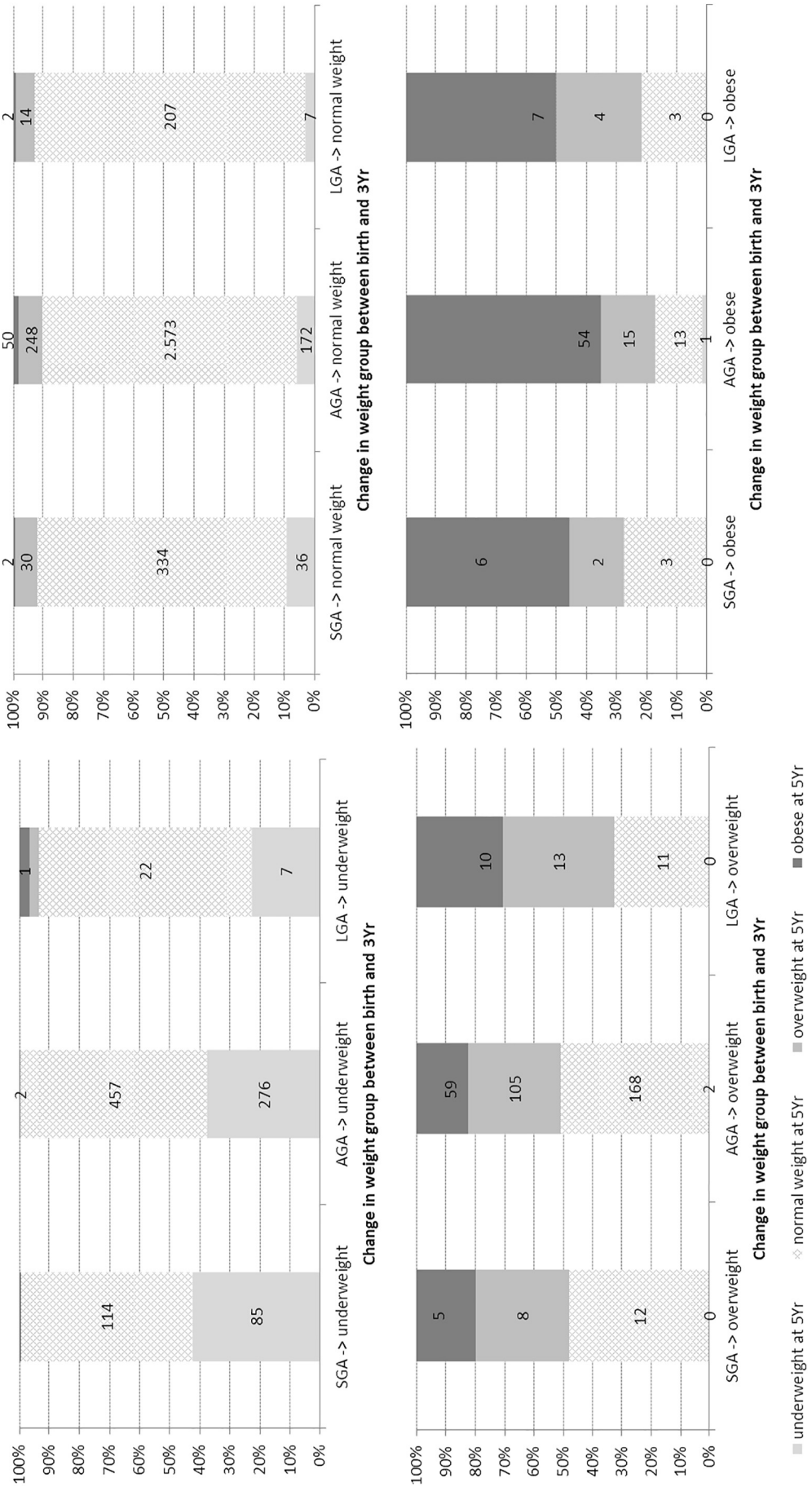

Fig. 1. Percentage of children in each BMI group at 5-year-old visit according to change in weight group between birth and 3-year-old visits.

3 yr), moderate increase (AGA → obese at 3 yr), and strong increase (SGA → obese at 3 yr) (Fig. 1). If we also consider the trajectories leading to being overweight at 3 years, we observed an inverse trend for the risk of being affected by obesity at 5 years: 20%, 17.7% and 29.4% for those with stable (LGA → overweight at 3 yr), moderate increase (AGA → overweight at 3 yr), and strong increase trajectory (SGA → overweight at 3 yr), respectively (Fig. 1). Analysis restricted to term birth children yielded similar results.

4. Discussion

In this population-based cohort study, 70.9% of children who were affected by obesity at 5 years were already affected by overweight/obesity at 3 years. Interestingly, 82.9% of the children who were affected by obesity at 5 years were normal weight for gestational age at birth. Therefore, being at least overweight at a previous well child visit is a strong predictor of being affected by obesity at the subsequent visit in preschool children (sensitivity about 71%) and the odds of being affected by obesity at 5 if at least overweight at age 3 is about 28% (PPV). Similar findings of strong correlation between BMI z-score at ages 2/3 and 5/6 were reported by a Spanish longitudinal study (Lurbe et al., 2018), by Geserick et al. (2018), and, with the limitation of the small sample size, by Gittner et al. (2013).

We did not confirm an independent role of increasing trajectories from birth to 3 years on obesity at age 5. Indeed, children with increasing trajectories from birth to 3 years had a higher risk of obesity at 5 years compared to children with a stable trajectory. However, when we stratified by weight groups at age 3, the effect of the trajectory disappeared. This is in line with studies which have analyzed the effect of early BMI on later childhood obesity, showing that trajectories that lead to obesity are similar up to the second (Lei et al., 2015; Glavin et al., 2014) or third year of life, when they start to be distinguishable (Stuart and Panico, 2016). Although a strong association is expected for measurements so close in time, i.e. weight at ages 3 and 5 (Geserick et al., 2018; Ong et al., 2000), more than 50% of the overweight/obese children and 18% of obese children at 3 years have normal weight at 5 year, demonstrating that obesity at this age could be reversible.

As our study stopped follow up just in the middle of the age of adiposity rebound, we could not observe how the trajectories in this critical period influence BMI in puberty and adolescence (Geserick et al., 2018; Kristiansen et al., 2015). Other limitations of the study are birth weight assessment through a retrospective incomplete linkage between a 3-year-old cohort and birth certificates and using BMI for the weight classification, which is an indirect measure of body fat. Furthermore, this study is nested in the BMInforma intervention, a public health intervention targeting all the resident children based on the regional guidelines on childhood obesity prevention. Information campaign interventions for pre-school-aged children are quite standard in schools and in partnerships with municipalities to promote physical activity and are present in most industrialized counties. The results in our study, therefore, could be influenced by the actions taken by our Local Health Authority. Nevertheless, the most specific intervention of screening and counselling for all overweight children is dedicated only to 5-year-old children. Therefore the associations found in the study were not influenced since both the exposures and the outcome had been already assessed prior to offering the intervention. The generalisability of results, however, may be limited only to those countries that have implemented similar interventions. On the other hand, nesting the study in a population-based intervention allowed us to have a cohort, representing almost all the population (90.3% of resident children attended the 5-year-old well-child visit). Also, all measurements were performed by pediatricians and reported in a standardized way.

In conclusion, from a public health perspective, this study shows that if effective obesity prevention interventions are offered to 3-year-old overweight/obese children, who account for only 9.8% of the population, i.e. about 450 children in 2020 in the province of Reggio Emilia, we can possibly target 71% of children potentially threatened by obesity at age 5, i.e. about 120 of the 170 children that would be obese in the absence of the intervention. The impact of such a strategy will clearly depend on the effectiveness of the intervention we can implement.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2020.106024.

Acknowledgement

We thank Jacqueline M. Costa for the English language editing.

Ethical consideration

The study was approved by the Ethical Committee of Area Vasta Emilia Nord – IRST (n. 129818).

Funding sources

The analyses and publication have been partially funded by the European Commission within CoSIE project (Co-creation in Service Innovation in Europe) grant agreement number: 770492 — CoSIE — H2020-SC6-CO-CREATION-2016-2017/H2020-SC6-COCREATION-2017.

Declaration of competing interest

The authors have no conflicts of interest to declare.

References

Ahrens, W., Pigeot, I., Pohlabeln, H., et al., 2014. Prevalence of overweight and obesity in European children below the age of 10. Int. J. Obes. 38, S99–107.
Broccoli, S., Davoli, A.M., Bonvicini, L., et al., 2016. Motivational interviewing to treat overweight children: 24-month follow-up of a randomized controlled trial. Pediatrics. 137, e20151979.
Cole, T.J., Bellizzi, M.C., Flegal, K.M., Dietz, W.H., 2000. Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ. 320 (7244), 1240–1243.
Davoli, A.M., Broccoli, S., Bonvicini, L., et al., 2013. Pediatrician-led motivational interviewing to treat overweight children: an RCT. Pediatrics. 132, e1236–e1246.
Delibera della Regione Emilia-Romagna GPG/2013/783 “Modello regionale di presa in carico del bambino sovrappeso e obeso”.
Frederick, C.B., Snellman, K., Putnam, R.D., 2014. Increasing socioeconomic disparities in adolescent obesity. Proc. Natl. Acad. Sci. U. S. A. 111, 1338–1342.
Geserick, M., Vogel, M., Gausche, R., et al., 2018. Acceleration of BMI in early childhood and risk of sustained obesity. N. Engl. J. Med. 379, 1303–1312.
Gittner, L.S., Ludington-Hoe, S.M., Haller, H.S., 2013. Utilising infant growth to predict obesity status at 5 years. J. Paediatr. Child Health 49, 564–574.
Glavin, K., Roelants, M., Strand, B.H., et al., 2014. Important periods of weight development in childhood: a population-based longitudinal study. BMC Public Health 14, 160.
Kramer, M.S., Platt, R.W., Wen, S.W., et al., 2001. A new and improved population-based Canadian reference for birth weight for gestational age. Pediatrics. 108, E35.
Kristiansen, A.L., Bjelland, M., Brantsæter, A.L., et al., 2015. Tracking of body size from birth to 7 years of age and factors associated with maintenance of a high body size from birth to 7 years of age – the Norwegian Mother and Child Cohort study (MoBa). Public Health Nutr. 18, 1746–1755.
Kuczmarski, R.J., Ogden, C.L., Guo, S.S., et al., 2000. CDC growth charts for the United States: methods and development. Vital Health Stat 11 246, 1–190 2002.
Lei, X., Chen, Y., Ye, J., et al., 2015. The optimal postnatal growth trajectory for term small for gestational age babies: a prospective cohort study. J Pediatr. 166 (54–58.e3).
Lurbe, E., Aguilar, F., Álvarez, J., et al., 2018. Determinants of cardiometabolic risk factors in the first decade of life. Hypertension. 71, 437–443.
Ogden, C.L., Flegal, K.M., Carroll, M.D., et al., 2002. Prevalence and trends in overweight among US children and adolescents, 1999–2000. JAMA. 288, 1728.
Ogden, C.L., Carroll, M.D., Kit, B.K., et al., 2014. Prevalence of childhood and adult obesity in the United States, 2011–2012. JAMA. 311, 806.
Ohlendorf, J.M., Robinson, K., Garnier-Villarreal, M., 2019 Jan. The impact of maternal BMI, gestational weight gain, and breastfeeding on early childhood weight: analysis of a statewide WIC dataset. Prev. Med. 118, 210–215.
Ong, K.K., Ahmed, M.L., Emmett, P.M., et al., 2000. Association between postnatal catch-up growth and obesity in childhood: prospective cohort study. BMJ. 320, 967–971.
Stuart, B., Panico, L., 2016. Early-childhood BMI trajectories: evidence from a prospective, nationally representative British cohort study. Nutr Diabetes. 6, e198.
Ziauddeen, N., Roderick, P.J., Macklon, N.S., Alwan, N.A., 2018. Predicting childhood overweight and obesity using maternal and early life risk factors: a systematic review. Obes. Rev. 19 (3), 302–312.