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Original article

Global relationship between parent and child obesity: a systematic review and meta-analysis

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Background: The growing prevalence of overweight and/or obese children is an important public health problem in both developed and developing countries. Although the association of obesity between parents and their children is well known, its underlying mechanisms are not well established.

Purpose: This meta-analysis examined parent-child (PC) relationships in obesity and identified factors such as world region and country income level that may influence this relationship.

Methods: We identified all related studies published between January 1, 2015 and May 31, 2020 by conducting a literature search using the MeSH terms "obesity," "overweight," "body mass index," "parent," "child," "associate," and "relate" in the PubMed database in English.

Results: The meta-analysis of 23 studies that reported an odds ratio (OR) for parent and child obesity associations found a significant association between parents and children who were overweight or obese (pooled OR, 1.97; 95% confidence interval, 1.85–2.10). A meta-regression analysis was used to examine the sources of interstudy heterogeneity. The association between parent and child obesity was higher in Asia than in Europe and the Middle East and higher in high-income countries than in middle-or low-income countries. In addition, a higher association between parent and child obesity was found when both parents were obese than when only the father or mother was obese. This study from multiple countries indicates a significant PC relationship in weight status that varies according to PC pair type, parent and child weight statuses, world region, and country income level.

Conclusion: These results demonstrate that the risk of childhood obesity is greatly influenced by parental weight status and indicate that parents could play an important role in preventing child obesity.

Key words: Obesity, Child, Parent

Key message

Question: Are parent and child obesity correlated worldwide?

Finding: Overweight and obese status of parents and children were significantly associated worldwide. The association between parent and child obesity was stronger in Asia than in Europe and the Middle East, and in high-income than in middle- and low-income countries.

Meaning: Childhood obesity is highly influenced by parental weight status, indicating that parents could play an important role in its prevention.

Introduction

Childhood obesity (OB) is a growing global health issue. Worldwide, the age-standardized prevalence of OB in adults (18 years and older) has increased 1.5 times since the year 2000, and the crude prevalence in children aged 5 to19 years more than doubled (from 2.9% to 6.8%) by 2016.[1)] The percentage of overweight (OW) children younger than 5 years was estimated to be around 5.6% or 38.3 million in 2019, compared to about 2.9% or 30.3 million in 2000.[1,2)] The prevalence of OW and obese conditions continues to increase in adults and children. In 2016, 39% of adults aged 18 years and over (39% of men and 40% of women) were OW, and about 13% (11% of men and 15% of women) were obese.[3)]

OB is a multifactorial chronic disease influenced by biological, behavioral, and environmental factors.[4)] Childhood-onset OB frequently leads to adult OB and is associated with increased risk of lifestyle-related diseases including diabetes, hypertension, dyslipidemia, and cardiovascular disease, which in turn are associated with a higher chance of premature mortality and disability.[5)] OB can affect a child's immediate health, educational attainment, mental health, and quality of life.

Many studies have described the association between a parent's OW or obese status and that of their child, but the underlying mechanisms are not well established.[6)]

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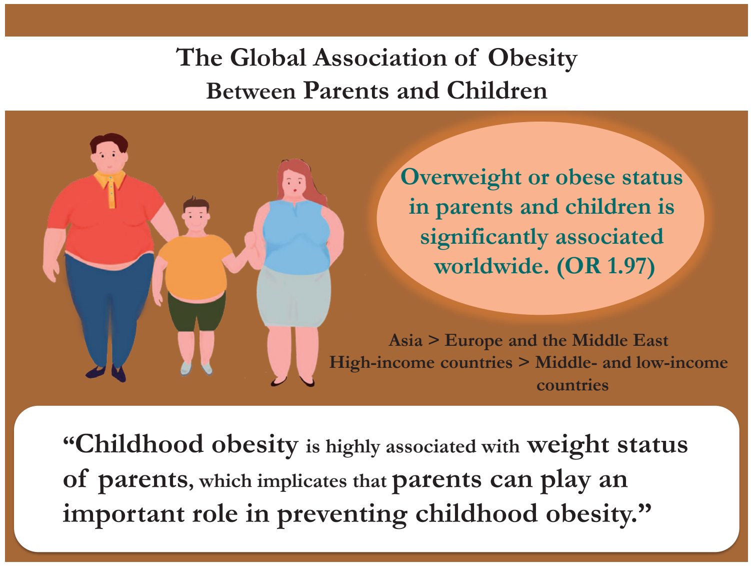

Graphic abstract

It is important to understand the causes and consequences of childhood OB. This paper studied parent-child (PC) OB relationships according to type of PC pair, parent and child weight status, and level of economy in the country. This paper serves as a systematic review that more specifically addresses childhood OB by presenting an overview of the global epidemiology, consequences, and etiopathogenesis relating to parental OB.

Methods

1. Search strategy

Using the MeSH terms obesity, overweight, body mass index (BMI), parent, child, associate, and relate, we searched the PubMed database in English from 1 January 2015 to 31 May 2020 as follows: ((obesity[Title]) OR (overweight[Title])) OR (body mass index[Title])) OR (BMI[Title])) AND (child*[Title])) AND (parent*[Title/Abstract])) AND ((associate*[Title/Abstract]) OR (relate*[Title/Abstract])) AND ("2015/01/01"[Date - Publication] : "2020/05/31"[Date - Publication]). The initial search included 837 articles. We reviewed titles and abstracts and excluded 752 articles that either did not describe parent and child OB relationships, had a total sample size <200, or were review papers. The full text of 85 articles was reviewed, and 23 papers were selected for the final analysis based on the inclusion criteria described below. Fig. 1 shows a flow diagram of the literature search.

2. Inclusion criteria

Articles were included if they met all of the following conditions: (1) both parents' and children's weight statuses were categorized based on BMI; (2) children were between 2–18 years old; (3) total sample size ≥200; (4) results were described as the parent and child OB correlation (odds ratio, OR); and (5) child weight and height were directly measured. The following data were included: authors and publication year, study design, study country, number of participants, age, BMI-based parent and child weight status, and key findings on the parent and child correlation in OB.

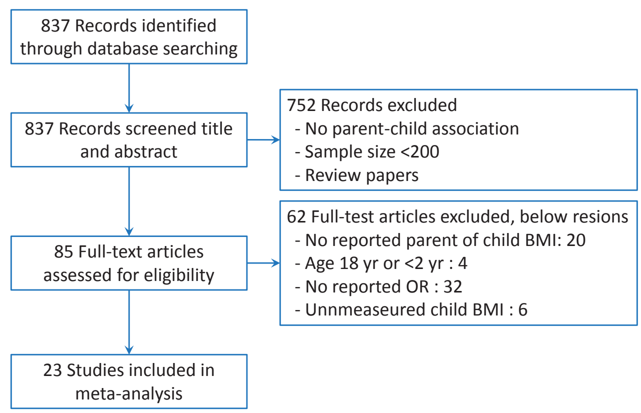

Fig. 1. Flow diagram of the literature search.

3. Exclusion criteria

Articles were excluded if they met any of the following conditions: (1) the parents' or child's weight status was not based on BMI; (2) participants were > 18 or <2 years old; (3) total sample size <200; (4) results for the OB relationship were not described using OR; and (5) parent- or self-reported child weight and height were used.

4. Data extraction

Data were extracted and summarized into a standardized data extraction form base on PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines.[7] Data extracted included first author, publication year, study design, study title, study country, world bank ranking, sample size, PC pair, parent and child weight status, and main results. In total, 102 data points of PC associations in OW and/or OB were collected from the 23 studies. All studies reported ORs, and the meta-analysis was performed on the reported ORs. We included ORs for mutually exclusive specific categories of a PC pair (e.g., father-boy [FB], mother-girl [MG]) as well as general PC pairs.

5. Definitions of OW and obese

The weight statuses of participants were classified as obese, OW, or normal weight, for which BMI cutoffs were used to define weight status across children and adults and throughout articles from different countries. OB is most often defined by the BMI, a mathematical formula of weight-to-height index. BMI (kg/m^2) is calculated as weight (kg) divided by height squared (m^2). In pediatric age groups, OB is diagnosed when BMI is higher than the 95th percentile per age and sex, and BMI over the 85th but less than the 95th percentile for age and sex is considered OW.[8] Because a child's body composition varies with age and sex, a child's weight status is determined using age- and sex-specific percentiles for BMI, different from those used for adults.[9] The International Obesity Task Force (IOTF) has developed an international standard growth chart that allows prevalence to be compared globally.[10] However, many countries use their own country-specific growth charts. Most of the articles classified weight status according to the World Health Organization (WHO) BMI cutoff criteria, with the weight statuses of adults classified as follows: normal weight (BMI<25 kg/m^2), OW (BMI 25–29.9 kg/m^2), and obese (BMI ≥30 kg/m^2).[11]

6. Types of PC pairs and weight status combinations

A total of 9 PC pairs were classified into 3 categories: (1) PC included PC, parent-boy, and parent-girl; (2) father-child (FC) included FC, FB, and father-girl; (3) mother-child (MC) included MC, mother-boy, and MG.

Ten types of PC weight status combinations were used as following: OW-OW, OB-OB, OW and OB (OWOB)-OWOB, OWOB-OB, OWOB-OW, OB-OW, OW-OB, BMI-OB, BMI-OW, and BMI-OWOB.

The most commonly reported combinations of PC weight status (parental weight status–child's weight status) were OW-OW, OB-OB, and OWOB-OB, representing about 54.9 % of the total data points. Of the 23 studies with parents, 6 used information from one parent only.

7. Quality assessment and risk of bias

The risk of bias for each included study was assessed using the RoBANS (Risk of Bias Assessment Tool for Non-randomized Studies).[12] Selection, performance, detection, attrition, and reporting biases were assessed and classified as low, high, and unclear risk of bias. The results of the risk of bias assessment are shown in Fig. 2. There was a high risk of performance biases because the data were obtained through self-reported questionnaire.

8. Statistical analysis

In all studies, 9 PC pairs and 10 PC weight status combinations were used.

We performed a meta-analysis according to the reported 102 ORs from 23 studies. Studies combined in a meta-analysis have differences in design, so we used a random-effects model to account for differences in the underlying study effects, which include a heterogeneity variance parameter. We fitted meta-regression models with random effects and calculated pooled estimates with confidence intervals of effect size for the PC OB correlation. There was significant heterogeneity for the effect size in the PC OB relation (Cochrane Q=2295.87, degrees of freedom [df]=101, P<0.001; I^2=95.6%). The meta-regression analysis was used to determine which factors explained the heterogeneity. We considered child age, type of PC pair, parent and child weight status, world region, and country income level as covariates. Other than the child's age, all other factors were important predictors of the PC association for OB. The differences in pooled OR estimates in the PC OB relationship by PC pair are shown in separate forest plots. All analyses were performed using Stata Release 14.0. Statistical significance was set at P<0.05.

9. Country income level

The countries included in the 23 studies were classified into 3 categories according to level of national income, measured by gross national income per capita (GNI) using the World Bank Atlas method. For the current 2021 fiscal year, low-income economies are defined as those with a GNI per capita of $1,035 or less in 2019; lower middle-income economies are those with a GNI per capita between $1,036 and $4,045; upper middle-income economies are those with a GNI per capita between $4,046 and $12,535; and high-income economies are those with a GNI per capita of $12,536 or more.[13] Of the 24 countries included in the 23 studies, Korea, Spain, USA, Hong Kong (China), Germany, Italy, Australia, Canada, Finland, Portugal, UK, and Japan were classified as high-income countries; China (except Hong Kong), Brazil, Thailand, Turkey, Palestine, Argentina, Iran, Cameroon, Indonesia, Colombia, India, and South Africa were classified as middle-income countries; and Kenya was classified as a low-income country.

Results

1. General characteristics

The characteristics and findings of the 23 studies are shown in Table 1.[14-36] Most studies were cross-sectional (n=21), with sample sizes of the PC pairs varying from 486 to 42,431.[15,32] Most of the studies included school-aged children (n=20), though 3 focused on preschool children under the age of 5. For income status, 9 studies were conducted in high-income countries, 13 studies were conducted in middle-income countries, and one study included 12 countries from low-income to

Table 1. General characteristics of included studies

Study	Study design	Title	World region/ country	World bank ranking	Sample size	Child age (yr)	Weight related outcomes of parent[a)]	Weight related outcomes of children[b)]	Main results PC relationship in obesity: OR (95% CI)
Cheng et al.,[14)] 2020	Cross-sectional	The associations of specific school-and individual-level characteristics with obesity among primary school children	Beijing, China	Upper middle income	2,201	10±0.41	OWOB	OB IOTF	F (OWOB) C: 2.09 (1.63–2.69) M (OWOB) C: 2.77 (2.12–3.61)
Caixeta and Amato[15)] 2020	Cross-sectional	Factors associated with overweight and abdominal obesity in Brazilian school-aged children: a comprehensive approach	Brazil	Upper middle income	486	6–8	BMI	OWOB CDC reference	MC: 1.05 (1.01–1.10)
Lee et. al.,[16)] 2020	Cross-sectional	Variability in sociodemographic factors and obesity in Korean children: a cross-sectional analysis of Korea National Health and Nutrition Examination survey data (2007–2015)	Korea	High income	14,482	2–18	OW, OB	OB Korean growth chart	M (OW) C (2–6 yr): 2.25 (1.34–3.78) M (OB) C (2–6 yr): 4.67 (2.35–9.26) F (OW) C (2–6 yr): 2.59 (1.70–3.97) F (OB) C (2–6 yr): 6.07 (2.86–12.91) M (OW) C (7–12 yr): 2.47 (1.73–3.52) M (OB) C (7–12 yr): 3.47 (1.89–6.38) F (OW) C (7–12 yr): 2.47 (1.76–3.47) F (OB) C (7–12 yr): 2.25 (1.02–4.98) M (OW) C (13–18 yr): 2.32 (1.52–3.52) M (OB) C (13–18 yr): 3.82 (2.09–6.98) F (OW) C (13–18 yr): 2.07 (1.45–2.98) F (OB) C (13–18 yr): 5.30 (2.78–10.12)
Nonboonyawat et al.,[17)] 2019	Cross-sectional	Prevalence and associates of obesity and overweight among school-age children in rural community	Thailand	Upper middle income	1,749	6–18	BMI	OWOB WHO reference	MC: 1.07 (1.02–1.12) FC: 0.98 (0.93–1.03)
Yardim et al.,[18)] 2019	Cross-sectional	Prevalence of childhood obesity and related parental factors	Ankara, Turkey	Upper middle income	2,066	9–11	OWOB	OW, OB WHO reference	FC (OW): 1.44 (0.97–2.15) FC (OB): 1.94 (1.18–3.18) MC (OW): 1.36 (0.81–2.30) MC (OB): 2.07 (1.13–3.79) PC (OW): 2.05 (1.39–3.02) PC (OB): 3.80 (2.3–6.28)
Al-Lahham et al.,[19)] 2019	Cross-sectional	Prevalence of underweight, overweight and obesity among school-age children and the associated risk factors: a cross sectional study	Palestine	Lower middle income	1,320	6–12	BMI	OW, OB CDC reference	FC (OW): 1.0 (0.92–1.08) FC (OB): 1.09 (0.98–1.22)
Orden et al.,[20)] 2019	Cross-sectional	Short sleep and low milk intake are associated with obesity in a community of school aged children	Argentina	Upper middle income	1,366	6–12	BMI IOTF	OWOB, OW, OB IOTF	FC (OWOB): 1.52 (1.24–1.68) MC (OWOB): 1.65 (1.37–1.98) FC (OW): 1.34 (1.04–1.68) MC (OW): 1.30 (1.06–1.60) FC (OB): 1.48 (1.11–1.99) MC (OB): 1.83 (1.43–2.34)
Ejtahed et al.,[21)] 2018	Cross-sectional	Association of parental obesity with cardiometabolic risk factors in their children: The CASPIAN-V study	Iran	Upper middle income	14,400	7–18	OW, OB	OW, OB Iran reference	P (OW) C (OW): 1.30 (1.17–1.44) P (OB) C (OW): 1.46 (1.29–1.65) P (OW) C (OB): 1.36 (1.18–1.59) P (OB) C (OB): 1.60 (1.35–1.90)
Choukem et al.,[22)] 2017	Cross-sectional	Overweight and obesity in children aged 3-13 years in urban Cameroon: a cross-sectional study of prevalence and association with socioeconomic status	Cameroon	Lower middle income	1,343	3–13	BMI	overweight/ obesity (OWOB) WHO reference	MC: 1.06 (1.02–1.09)
Riaño-Galán et al.,[23)] 2017	Population-based birth cohort study	Proatherogenic lipid profile in early childhood: association with weight status at 4 years and parental obesity	Spain	High income	582	4	OWOB	OWOB IOFT	FC: 3.73 (1.90–7.34) MC: 4.17 (1.76–9.88) PC: 5.10 (2.5–10.40)
Zhao et al.,[24)] 2017	Cross-sectional	Fast food consumption and its associations with obesity and hypertension among children	Beijing, Shanghai, Nanjing, and Xian, China	Upper middle income	1,626	7–16	BMI	OB Chinese school-age BMI reference	MC: 1.11 (1.06–1.17)

Table 1. Continued

Study	Study design	Title	World region/ country	World bank ranking	Sample size	Child age (yr)	Weight related outcomes of parent[a]	Weight related outcomes of children[b]	Main results PC relationship in obesity: OR (95% CI)
Salahuddin et al.,[25] 2017	Cross-sectional	Predictors of severe obesity in low-income, predominantly Hispanic/Latino children: the Texas childhood obesity research demonstration study	Texas, USA	High income	517	2–12	severe obesity (BMI>35 kg/m^2)	severe obesity (BMI≥120% of 95th percentile) CDC reference	MC (2–5 yr): 2.67 (1.10–6.47) MC (6–8 yr): 1.58 (0.74–3.35) MC (7–12 yr): 4.12 (1.84–9.23)
Wang et al.,[26] 2017	Cross-sectional	Prevalence of overweight in Hong Kong Chinese children: Its associations with family, early-life development and behaviors-related factors	Hong Kong, China	High income	894	9–12	OWOB (BMI≥25 kg/m^2)	OW IOTF	FC: 1.72 (1.18–2.52) MC: 3.19 (1.94–5.22)
Bahreynian et al.,[27] 2017	Cross-sectional	Association between obesity and parental weight status in children and adolescents	Iran	Upper middle income	23,043	6–18	OW, OB	OB WHO reference	P (OW) B: 1.67 (1.48–1.88) P (OB) B: 2.55 (2.23–2.92) P (OW) G: 2.02 (1.79–2.27) P (OB) G: 3.46 (3.04–3.94)
Schüle et al.,[28] 2016	Cross-sectional	Neighborhood socioeconomic context, individual socioeconomic position, and overweight in young children: a multilevel study in a large German city	Germany	High income	3,499	5–7	OW, OB	OW IOTF	M (OW) C: 2.44 (1.93–3.08) M (OB) C: 3.08 (2.19–4.34)
Parrino et al.,[29] 2016	Cross-sectional	Influence of early-life and parental factors on childhood overweight and obesity	Sicily, Italy	High income	1,521	9–14	OWOB	OWOB IOTF	MC: 2.33 (1.80–3.01) FC: 1.68 (1.30–2.17)
Rachmi et al.,[30] 2016	Cross-sectional	Stunting, underweight and overweight in children aged 2.0–4.9 years in Indonesia: Prevalence trends and associated risk factors	Indonesia	Upper middle income	4,101	2–4.9	OWOB	OWOB WHO reference	MC: 1.88 (1.24–2.87) FC: 1.49 (0.09–2.38)
Muthuri et al.,[31] 2016	Cross-sectional	Relationships between parental education and overweight with childhood overweight and physical activity in 9–11-year-old children: results from a 12-country study	12-country study		4,752	9–11	OW	OW WHO reference	
			Australia	High income					FC (Australia): 1.36 (0.84–2.20) MC (Australia): 2.60 (1.66–4.05)
			Brazil	Upper middle income					FC (Brazil): 2.01 (1.20–3.34) MC (Brazil): 2.40 (1.53–3.76)
			Canada	High income					FC (Canada): 1.35 (0.87–2.10) MC (Canada): 2.36 (1.53–3.63)
			China	Upper middle income					FC (China): 3.17 (2.13–4.70) MC (China): 1.55 (1.01–2.39)
			Colombia	Upper middle income					FC (Colombia): 2.20 (1.46–3.31) MC (Colombia): 2.05 (1.38–3.05)
			Finland	High income					FC (Finland): 1.65 (1.01–2.69) MC (Finland): 2.78 (1.75–4.43)
			India	Lower middle income					FC (India): 2.43 (1.60–3.69) MC (India): 2.16 (1.44–3.25)
			Kenya	lower income					FC (Kenyra): 3.53 (1.73–7.20) MC (Kenyra): 1.37 (0.71–2.64)
			Portugal	High income					FC (Portugal): 1.45 (1.01–2.08) MC (Portugal): 1.52 (1.06–2.16)
			South Africa	Upper middle income					FC (South Africa): 1.23 (0.50–2.73) MC (South Africa): 2.22 (0.98–5.03)
			UK	High income					FC (UK): 1.54 (0.87–2.73) MC (UK): 2.34 (1.38–3.96)
			USA	High income					FC (USA): 1.65 (0.87–2.73) MC (USA): 2.92 (1.80–4.72)

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Table 1. Continued

Study	Study design	Title	World region/ country	World bank ranking	Sample size	Child age (yr)	Weight related outcomes of parent[a)]	Weight related outcomes of children[b)]	Main results PC relationship in obesity: OR (95% CI)
Lombardo et al.,[32)] 2015	Cross-sectional	Severe obesity prevalence in 8- to 9-year-old Italian children: a large population-based study	Italy	High income	42,431	8–9	OW, OB	Severe obese WHO reference (BMI>3 SD)	P (OW) C: 5.28 (4.17–6.70) P (OB) C: 16.25 (11.58–22.82) P (OW) B: 5.13 (3.90–6.73) P (OB) B: 13.13 (8.67–19.89) P (OW) G: 5.77 (3.44–9.68) P (OB) G: 24.3 (13.07–45.15)
Parikka et al.,[33)] 2015	Cross-sectional	Associations between parental BMI, socioeconomic factors, family structure and overweight in Finnish children: a path model approach	Finland	High income	2,573	3–8	BMI	OW IOTF	MB (3–8 yr): 1.12 (1.08–1.16) MG (3–8 yr): 1.09 (1.06–1.12) FB (3–8 yr): 1.14 (1.10–1.2) FG (3–8 yr): 1.11 (1.06–1.15)
					1,836	11–16			MB (11–16 yr): 1.10 (1.06–1.15) MG (11–16 yr): 1.10 (1.06–1.14) FB (11–16 yr): 1.13 (1.08–1.19) FG (11–16 yr): 1.08 (1.03–1.13)
Kachi et al.,[34)] 2015	Cross-sectional	Socioeconomic status and overweight: A population-based cross-sectional study of Japanese children and adolescents	Japan	High income	397 397	6–11 12–18	OWOB (BMI≥25 kg/m^2)	OW IOTF	MC (6–11 yr): 2.72 (1.30–5.71) MC (12–18 yr): 3.47 (1.49–8.07)
Zong et al.,[35)] 2015	Population-based, 1:1 matched case-control design	Family-related risk factors of obesity among preschool children	China	Upper middle income	1,844	3–4	OWOB (BMI≥24 kg/m^2)	OB IOTF	FC (1996): 2.33 (1.28–4.23) MC (1996): 2.49 (1.31–4.76)
					3,298				FC (2006): 2.12 (1.63–2.76) MC (2006): 1.52 (1.09–2.15)
Wan et al.,[36)] 2015	Cross-sectional	Is parental body weight related with their children's overweight and obesity in Gao Hang Town, Shanghai	Shanghai, China	Upper middle income	2,025	7–13	OWOB (BMI≥24 kg/m^2) Chinese adult BMI reference	OWOB Chinese school-age BMI reference	FC: 2.26 (1.78–2.86) MC: 2.17 (1.87–3.92) PC: 4.36 (3.16–6.01)

OR, odds ratio; CI, confidence interval; OWOB, overweight and obese; IOTF, International Obesity Task Force; F, father; M, mother; C, child; BMI, body mass index; FB, father-boy; FC, father-child; FG, father-girl; MB, mother-boy; MC, mother-child; MG, mother-girl; PC, parent-child; OW, overweight; OB, obesity; CDC, Centers for Disease Control and Prevention; WHO, World Health Organization; SD, standard deviation.
[a)]Most studies used the World Health Organization (WHO) definition of overweight (BMI 25–29.9 kg/m^2), obesity (BMI≥30 kg/m^2), underweight (BMI<18.5 kg/m^2), and OWOB (BMI≥25 kg/m^2) for parents. Other definitions are presented in the table. [b)]In children, most studies used the International Obesity Task Force definition or the WHO definition. All definitions are indicated in the table.

high-income countries. Most studies used the WHO definition for parental weight status. In pediatric cases, the IOTF definition or WHO definition was used for child weight status. PC pairs and weight status combinations depend on study purpose, but OW or OWOB was more often used as the weight status for parents and children than was OB (number of data points for parents, OWOB=32, OW=32, BMI=21, and OB=17; for children, OW=45, OB=40, and OWOB=17). The OR of reported PC OB associations ranged from 0.98 to 24.3.

Table 2 shows PC OB associations. Most of the 23 studies showed a positive association in OB (87.3%). Of all the PC pairs, 10 FC pairs (26.3%) and 3 MC pairs (6.5%) showed no significant association between parent and child OB.

Most of the world regions showed a positive association between parent and child OB, but there was no significant association between parent and child OB in 3 data points from North America (42.9%) and in 3 data points from Africa (60%). According to country income level, 4 data points from high-income countries (7.7%) and 9 data points from middle- or low-income countries (17.6%) showed no significant association between parent and child OB.

2. Meta-analysis of parent and child association in OB

A meta-analysis based on data points from 23 studies found that parent and child OW or obese statuses were significantly associated (pooled OR, 1.97; 95% CI, 1.85–2.10) (Table 2). However, there was considerable heterogeneity (Q=2295.87, df=101, P<0.001).

Table 3 shows a meta-regression model predicting the parent and child OB association by child age, PC pair, parent and child weight status, world region, and country income level. The final meta-regression model was as follows:

log(OR of parent and child association in OB) = 1.75 + 0.06 × child age – 0.92 × FC pair – 0.92 × MC pair + 0.55 × parental OB + 0.35 × parental OWOB + 0.22 × child OB – 0.06 × child OWOB – 0.83 × Europe – 0.73 × North America – 0.38 × Latin America – 1.45 × Middle East – 0.39 × Africa + 0.43 × country income level.

This study showed that type of PC pair, parent and child weight statuses, world region, and country's income level were

Table 2. Association between and pooled estimates of parental and child obesity by parent-child pair type, weight status, world region, and country income level

Variable	Total data	Not significant association	Positive association	Pooled OR (95% CI)	I^2
Total data	102	13 (12.7)	89 (87.3)	1.97 (1.85–2.10)	95.6%
Parent pair	102				
Parents	18	0 (0)	18 (100)	3.53 (2.68–4.65)	97.4%
Father	38	10 (26.3)	28 (73.7)	1.58 (1.46–1.71)	89.1%
Mother	46	3 (6.5)	43 (93.5)	1.65 (1.54–1.76)	90.7%
Parental weight status	81				
OW	32	6 (18.8)	26 (81.3)	2.18 (1.90–2.49)	85.9%
OWOB	32	3 (9.4)	29 (90.6)	2.29 (2.02–2.60)	56.8%
OB	17	1 (5.9)	16 (94.1)	4.07 (2.89–5.74)	95.7%
Child weight status	102				
OW	45	8 (17.8)	37 (82.2)	2.84 (2.34–3.45)	86.8%
OWOB	17	3 (17.6)	14 (82.4)	1.44 (1.36–1.52)	94.5%
OB	40	2 (5)	38 (95)	1.64 (1.45–1.84)	96.5%
World regions	102				
Asia and pacific	36	2 (5.6)	34 (94.4)	2.24 (1.96–2.56)	93.2%
Europe	33	3 (9.1)	30 (90.9)	2.11 (1.91–2.32)	96.9%
Middle East	10	2 (20)	8 (80)	1.63 (1.28–2.08)	97.7%
North America	7	3 (42.9)	4 (57.1)	2.13 (1.60–2.83)	40.8%
Latin America	11	0 (0)	11 (100)	1.60 (1.33–1.94)	89.7%
Africa	5	3 (60)	2 (40)	1.60 (0.99–2.58)	72.8%
Country income level	102				
High	52	4 (7.7)	48 (92.3)	2.29 (2.10–2.51)	95.9%
Middle	49	8 (16.3)	41 (83.7)	1.73 (1.58–1.90)[a]	95.4%
Low	2	1 (50)	1 (50)		

OR, odds ratio; CI, confidence interval; OW, overweight; OWOB, overweight and obese; OB, obesity.
[a]Middle- and low-income country pooled OR (95% CI).

important predictors of the PC OB associations.

This study found that the association between the child's weight status and that of both parents was stronger than that of either the father or mother alone (father β±standard error [SE]: -0.94±0.14, P<0.001; mother β±SE: -0.93±0.14, P<0.001).

This study also showed that OW status was associated more weakly with PC OB than with OB or OWOB (OB: β±SE: 0.55±0.12, P<0.001; OWOB β±SE: 0.29±0.12, P=0.022).

According to world region, Asia had a higher PC OB relation than did Europe or the Middle East (Europe β±SE: -0.26±0.11, P=0.026; Middle East β±SE: -0.95±0.17, P< 0.001). Furthermore, this study showed that high-income countries (β±SE: 0.36±0.12, P=0.004) had a stronger PC OB relationship than middle- or low-income countries.

Pooled OR varied according to PC pair by country income, weight status, and world region as follows: (1) PC pairs by country income-pooled OR: 8.74 (95% CI, 5.54–13.78) at PC pairs in high-income regions, 2.08 (95% CI, 1.67–2.59) at PC pairs in middle- and low-income regions, 1.44 (95% CI, 1.31–1.58) at FC pairs in high-income regions, 1.69 (95% CI, 1.44–1.99) at FC pairs in middle- and low-income regions, 1.19 (95% CI, 1.72–2.11) at MC pairs in high-income regions, and 1.47 (95% CI, 1.34–1.61) at MC pairs in middle- and low-income regions (Figs. 3–5), (2) parental weight status–pooled OR: 4.07 (95% CI, 2.89–5.74) in OB, 2.18 (95% CI, 1.90–2.49) in OW, and 2.29 (95% CI, 2.02–2.60) in OWOB; (3) child's weight status–pooled OR: 1.64 (95% CI, 1.45–1.84) in OB, 2.84 (95% CI, 2.34–3.45) in OW, and 1.44 (95% CI, 1.36–1.52) in OWOB; (4) world region–pooled OR: 2.24 (95% CI, 1.96–2.56) in Asia and Pacific, 2.11 (95% CI, 1.91–2.32) in Europe, 2.13 (95% CI, 1.60–2.83) in North America, 1.60 (95% CI, 1.33–1.94) in Latin America, 1.63 (95% CI, 1.28–2.08) in the Middle East, and 1.60 (95% CI, 0.99–2.58) in Africa; (5) country income level–pooled OR: 2.29 (95% CI, 2.10–2.51) in high-income and 1.73 (95% CI, 1.58–1.90) in middle- and low-income countries. The results are shown in Table 2.

The Asia and Pacific region had stronger PC OB relationships compared to other regions. According to country income level, high-income countries were much more likely to report higher parent and child OB relationships than were middle- or low-income countries.

3. Publication bias

A funnel plot was used to assess publication bias in the studies evaluating relation between parent and child OB. The funnel plot showed asymmetry, and Egger's test showed significant publication bias (intercept = -0.23; 95% CI, -0.34 to -0.12, z = -3.94, P<0.0001) (Supplementary materials). Therefore, we cannot exclude potential publication bias. Trim and fill methods are used to correct for publication bias in meta-analysis.[37] Using

Table 3. Results of meta-regression: factors related with the parent-child association in obesity based on reported odds ratio of 23 studies

Variable	β	SE	*P* value
Child age			
<5 yr	0.07	0.17	0.689
Included school-age	Reference		
Type of parent-child pairs			
Parents	Reference		
Father	-0.94	0.14	**<0.001**
Mother	-0.93	0.14	**<0.001**
Parental weight status studied			
Overweight	Reference		
Obesity	0.55	0.10	**<0.001**
OWOB	0.29	0.12	**0.022**
Child weight status studied			
Overweight	Reference		
Obesity	0.18	0.10	0.066
OWOB	0.29	0.12	0.435
Country region			
Asia & Pacific	Reference		
Europe	-0.26	0.11	**0.026**
North America	-0.16	0.19	0.386
Latin America	0.13	0.15	0.400
Middle East	-0.95	0.17	**<0.001**
Africa	-0.11	0.22	0.641
Country economic development			
High	0.36	0.12	**0.004**
Middle & low	Reference		

SE, standard error; OWOB, overweight and obese.
The outcome variable used in the meta-regression model was the odds ratio. A Stata Metareg command was used with the dummy variables of type of parent-child pair, parental and child weight status, country region, and categorical variables of child age and country income level.
Boldface indicates a statistically significant difference with $P<0.05$.

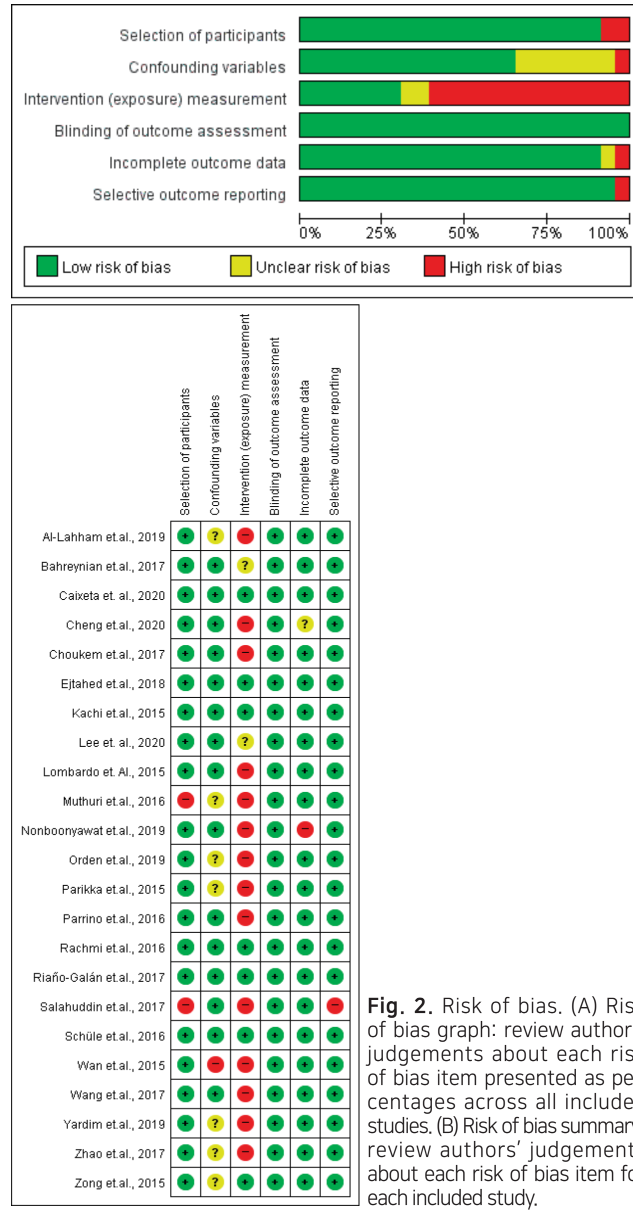

Fig. 2. Risk of bias. (A) Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies. (B) Risk of bias summary: review authors' judgements about each risk of bias item for each included study.

a trim and fill method, 47 prediction studies with results lower than the mean were excluded from analyses. Had these missing predictive studies been included in the meta-analysis, the pooled OR would have decreased to 1.30 (95% CI, 1.13–1.51). But, the corrected effect estimates (pooled OR, 1.30; 95% CI, 1.13–1.51) did not differ in direction, size, or statistical significance of the effect estimates before correction (pooled OR, 1.97; 95% CI, 1.85–2.10).

Discussion

The risk of OB can pass from one generation to the next as a result of biological and/or environmental factors. Parents and children share about 50% of their genes, and these genetic factors likely explain some of the observed intergenerational association. In addition, parents and children share a common environment that can correlate with BMI and OB status, such as eating the same meals and engaging in similar physical activities.[6] This meta-analysis demonstrated a significant PC OB relationship (pooled OR, 1.97; 95% CI, 1.85–2.10). Children with OW or obese parents were 1.97 times more likely to be OW or obese than children with healthy-weight parents. Studies performed in many countries have demonstrated many possible reasons for the body weight relationship between parents and their children. Epigenetic mechanisms such as DNA methylation demonstrate how inherited OB-related genes interact with environmental factors, which can lead to development of childhood OB.[38] Epigenetic changes can affect OB-related hormones such as such as leptin, insulin, and ghrelin and are dynamically regulated by nutritional and metabolic status.[39] Leptin plays a role in reducing food intake and decreasing body weight,[40] whereas decreased insulin receptors cause increases in food intake, adiposity, and peripheral insulin resistance,[41] and ghrelin promotes appetite, suppresses energy expenditure, and causes weight gain.[42] Furthermore, family lifestyles are an important risk factor for child OB, and dietary behavior of the parents is

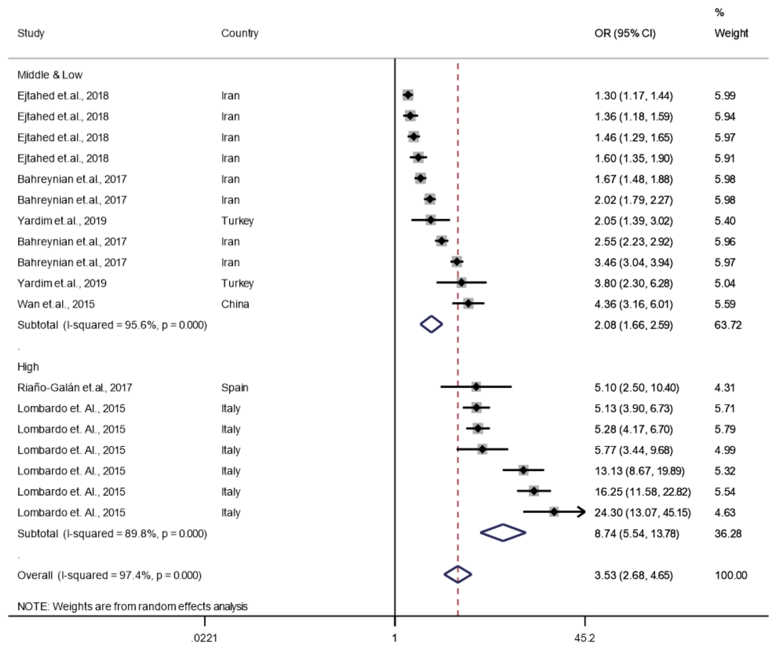

Fig. 3. Meta-analysis results of reported odds ratio (OR) of the correlation between parent and child obesity in 23 studies for parent-child pairs. Pooled estimation with 18 data points from 23 studies. Multiple OR for same studies reflect OR for different subgroups (middle- and low-income country OR: 2.08 [95% CI, 1.66–2.59]; test for heterogeneity: Cochrane Q=229.44 [*df*=10], *P*<0.001; vs. high-income country OR: 8.74 [95% CI, 5.54–13.78]; test for heterogeneity: Cochrane Q=58.74 [*df*=6], *P*<0.001). CI, confidence interval; *df*, degrees of freedom.

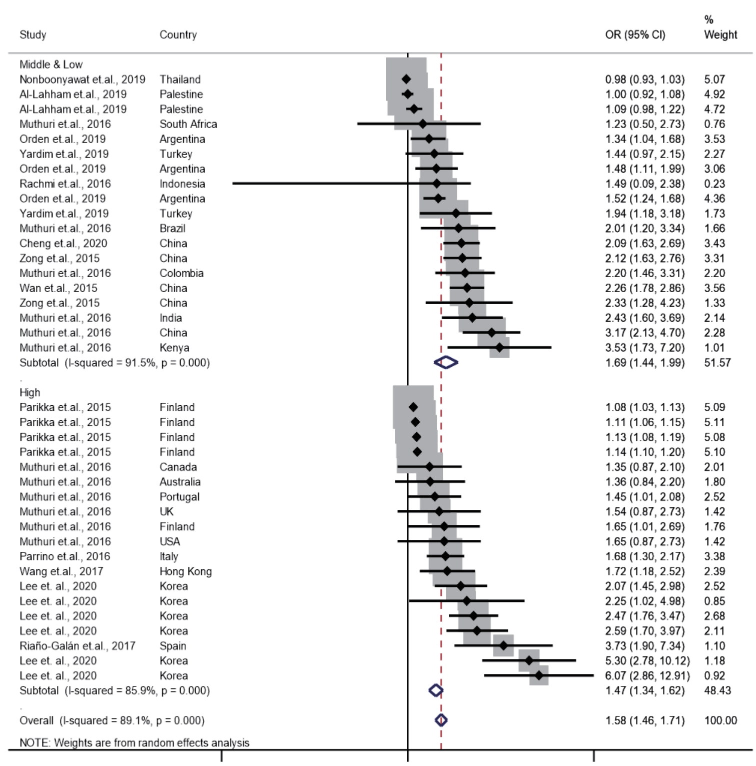

Fig. 4. Meta-analysis results of reported odds ratio (OR) of the correlation between parent and child obesity in 23 studies for the father-child pair. Pooled estimation with 38 data points from 23 studies. Multiple OR for same studies reflect OR for different subgroups (middle- and low-income country OR: 1.69 [95% CI, 1.44–1.99]; test for heterogeneity: Cochrane Q=212.63 [*df*=18], *P*<0.001 vs. high-income country OR: 1.47 [95% CI, 1.34–1.62]; test for heterogeneity: Cochrane Q=128.10 [*df*=18], *P*<0.001). CI, confidence interval; *df*, degrees of freedom.

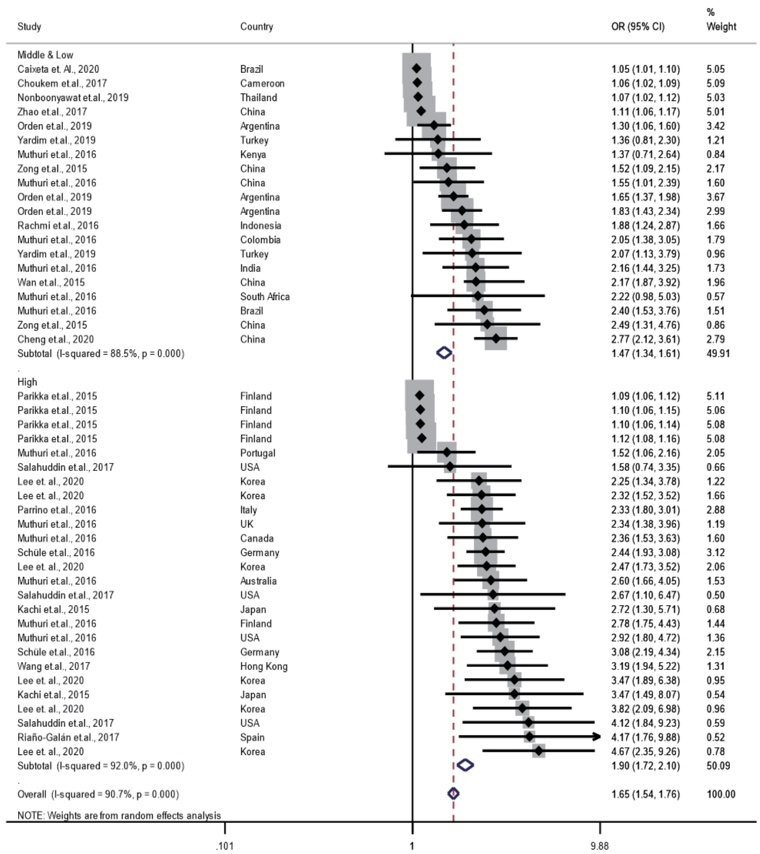

Fig. 5. Meta-analysis results of reported odds ratio (OR) of the correlation between parent and child obesity in 23 studies for the mother-child pair. Pooled estimation with 46 data points from 23 studies. Multiple OR for same studies reflect OR for different subgroups (middle- and low-income country OR: 1.47 [95% CI, 1.34–1.61]; test for heterogeneity: Cochrane Q=165.63 [*df*=19], *P*<0.001 vs. high-income country OR: 1.90 [95% CI, 1.72–2.10]; test for heterogeneity: Cochrane Q=313.66 [*df*=25], *P*<0.001). CI, confidence interval; *df*, degrees of freedom.

likely to determine a child's dietary patterns.[43)]

Meta-regression analysis showed that PC OB association varied by parent and child pair (PC, FC, or MC), country income level, parent and child weight statuses (obese, OW, OWOB), and world region. The study showed that the OB relationship is stronger between PC pairs than between FC or MC pairs, meaning that children are more likely to be obese if both parents are OW or obese compared to children with only one parent (mother or father) who is OW or obese. These findings are consistent with a previous meta-analysis study and might be explained by a double genetic burden from having 2 OW or obese parents or as a result of a common family environment that is more likely to promote unhealthy weight gain in the family.[44)] This study did not reveal any significant differences in OB between FC and MC pairs, but previous studies showed that maternal OW and OB status influenced childhood OB more than paternal OW and OB status.[45,46)] Previous studies have shown that maternal OB is a more potent determinant of postpartum infant BMI growth and an indicator of OB risk, whereas paternal effects may appear later, possibly between 3 and 4 years of age.[45)] In early childhood, eating habits may be predominantly shaped by the mother, which could be a factor in the differences previously shown between maternal and paternal OB. This meta-analysis did not include infants or children under 2 years of age, however, which may explain why no differences were observed between maternal and paternal OB.

According to country income level, our study showed that high-income countries were much more likely to report strong parent and child OB relationships than were middle- or low-income countries. These "OB-causing" changes (such as economic growth, industrialization, mechanized transport, urbanization, and increased availability of abundant, inexpensive, and often undernourished foods) have been taking place in high-income countries since the beginning of the 20th century and are accelerating currently in low- and middle-income countries.[47)] As multiple generations are exposed to high-risk environments, it is possible that intergenerational similarities in dietary habits and activity patterns are higher in high-income countries, while rapid generational transitions in diet and activity patterns persist in middle-income countries.[44)] In high-income countries, the risk of childhood OB is greatest among lower socioeconomic groups.[48)] Considering not only country income level but also family income, the United States (US) and Europe (high-income countries) could directly link wealth to OB by the middle of the

20th century.[47] It was previously found that the richer was an individual, the more likely they were to be OW. Perhaps due to the abundance of inexpensive and highly available food as well as social changes, this association has been reversed in the present. Wealth in the US now tends to be inversely correlated with OB, and those are at or below the poverty line have the highest rates of OB.[49]

This study showed that Asia had higher PC OB relationships compared to Europe or the Middle East. A previous study showed that the overall prevalence of OW, including obese, school children in European countries was estimated at 20.5%, where 15.6% were OW and 4.9% were obese.[50] The prevalence of OW and/or obese status was 24.5% in Eastern Asia countries and 11.9% in the Western Asia regions, where the overall prevalence of OB and OW status were 5.8% and 11.2% in Asian children and 8.6% and 14.6% in adolescents, respectively.[51] Unlike the western societies that are promoting "individualism," the Asian society is "collectivistic" in that it promotes interdependence and co-operation, with families at the center of this social structure.[52] Thus, Asian families tend to be more involved in care of one another and more involved in each other's lives. In Asian regions, the higher association between parental and child OB can be explained by the high OB rate in Asia coupled with the collectivistic family culture.

There are some limitations to this study. First, different cutoff points (IOTF, Centers for Disease Control and Prevention, WHO, and country reference) were used to compared OB status in this meta-analysis, so it is difficult to directly compare across studies. Second, this study did not investigate the effects of family socioeconomic status, because published studies either did not include socioeconomic status factors or analyzed different socioeconomic status variables. Third, most of the included studies (21 of 23) were cross-sectional. Forth, the funnel plot presented an asymmetry, so publication bias cannot be fully excluded. In this study, asymmetry funnel plot with the scatter diagram is asymmetrical at the left lower bottom. This asymmetry indicates that smaller studies with negative findings are not published or not identified by the authors.

Further study should use longitudinal data to examine the parent and child relationships in OB and the related risk factors, including those related to family socioeconomic status such as family income, parental education level, and residential area.

The risk of childhood OB is greatly influenced by parental weight status. Most of the included studies reported a positive association between parent and child OB, and this relationship varied depended on type of PC pair, parent and child weight statuses, world region, and national income level. Children with OW or obese parents are more likely to be OW or obese than those with parents of normal weight. Pediatric OB is a complex disorder due to environmental, biopsychosocial, genetic, and epigenetic factors. Further study is needed to uncover the biological and social factors of the PC OB relationship.

Footnotes

Supplementary material: Supplementary material can be found via https://doi.org/10.3345/cep.2020.01620

Conflicts of interest: No potential conflict of interest relevant to this article was reported.

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