Birth order and number of siblings and their association with overweight and obesity: a systematic review and meta-analysis

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Context: *The effect of both birth order and number of siblings on overweight and/or obesity has not been determined. Birth order and sibsize have been mathematically coupled to overweight and/or obesity, but thus far their respective effects have been estimated separately.* ***Objective***: *The aim of this systematic review was to evaluate the effects of both birth order and number of siblings on the risk of overweight/obesity.* ***Data Sources***: *The electronic databases MEDLINE, Social Science, SocINDEX, PsycINFO, CINAHL Plus, and Academic Search Complete were searched systematically.* ***Study Selection***: *Titles and abstracts of 1698 records were examined. After 1504 records were excluded, 2 authors independently assessed the full text of all remaining papers (n = 194); disagreements were resolved by discussion.* ***Data Extraction***: *A standardized form for assessment of study quality and evidence synthesis was used to extract data from the included studies.* ***Results***: *Twenty studies were included in the systematic review, 14 of which were included in the meta-analysis. Meta-analyses showed that lower (vs higher) birth order and smaller (vs greater) number of siblings were associated with overweight and/or obesity, with ORs of 1.47 (95%CI, 1.12–1.93) and 1.46 (95%CI, 1.17–1.84), respectively. However, among the 9 studies that attempted to separate the effects of birth order and number of siblings in the same analysis, a higher risk of overweight/obesity was consistently found among individuals without siblings than among those with 1 or more siblings, rather than among firstborns more generally.* ***Conclusion***: *The results show that both lower birth order and lower number of siblings are associated with risk of overweight/obesity, which suggests that only children are at a slightly increased risk of overweight/obesity.* ***Systematic Review Registration***: *PROSPERO registration number CRD42014015135.*

INTRODUCTION

Obesity is widely recognized as a global public health challenge.[1] The causes of obesity are numerous and include early life factors.[2] Several studies have investigated the influence of birth order and/or number of siblings (ie, sibsize) on overweight or obesity, but the results have been inconsistent.[3–10] Though most studies

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estimate the respective effects of birth order and sibsize separately,[9,11–13] these 2 factors are mathematically linked (ie, a person's birth order is proportional to the number of his or her older siblings). Thus, the effects of birth order could be easily confused with the effects of sibsize, and vice versa. This is not a trivial distinction, as the former is thought to reflect physiological mechanisms linking fetal development with later risk of obesity,[14] while the latter is thought to reflect social and psychological mechanisms.[15] Lower-birth-order infants tend to be smaller at birth compared with later-born infants[16–18] and more likely to undergo catch-up growth.[19] Only children may have reduced opportunities for physical activity[15] and may spend more time watching television than children with siblings.[20] Furthermore, compared with only children, children with siblings may experience a decreased availability of food, resulting in a reduced risk of overweight.[21]

Since birth order and sibsize are mathematically coupled, it is not easy to estimate their respective conditional effects on overweight/obesity, with each factor adjusted for the other. In a previous study, an attempt was made to separate these effects by splitting the number of siblings into younger and older categories and then comparing models that included both younger and older siblings with a model that included just the total number of siblings. The results showed that, relative to the association with overweight/obesity, total number of siblings was more important than birth order.[4]

Considering the worldwide reduction in fertility rates[22] and the increasing number of couples choosing to have only 1 child,[23] it is necessary to examine the effect of these demographic changes on overweight and obesity in a more systematic manner. Thus, this systematic review and meta-analysis aimed to assess the effects of both number of siblings and birth order on the risk of overweight and obesity.

METHODS

The following electronic databases were searched: MEDLINE (1950–2015), Social Science (1964–2015), SocINDEX (1895–2015), PsycINFO (1887–2015), CINAHL Plus (1982–2015), and Academic Search Complete (1887–2015). All articles published by July 2015 were included in the search, irrespective of language, year of publication, study design, or age of the participants.

The following terms were used in the search: (body composition OR "fat mass" OR "fat free mass" OR "body fat" OR adipose OR adiposity OR overweight OR obesity) AND (birth order OR firstborn OR "first born" OR "only child" OR "sib size" OR sibling OR "family structure" OR "birth interval"). The PICO criteria are shown in Table 1.

Original studies that evaluated both birth order and number of siblings and their respective associations with body composition, overweight, and/or obesity were included. Studies that considered only birth order and/or number of siblings as confounders of other estimates and thus did not explicitly report the association of either factor with body composition, overweight, and/or obesity were excluded from the meta-analysis. Reference lists and other sources of information for inclusion of additional studies were also surveyed, although no additional references were found.

This systematic review and meta-analysis was registered with the International Prospective Register of Systematic Reviews (PROSPERO; registration number CRD42014015135).

Study selection and data extraction

Record lists from the searches of electronic databases were combined into a single library using Endnote X7 (Clarivate Analytics, Philadelphia, PA), and duplicates were removed. One author (F.O.M.) examined each remaining title and abstract to remove obviously irrelevant reports. The full text of all remaining items was assessed independently by 2 authors (F.O.M. and D.L.D.). Studies with samples that included twins, patients who were hospitalized and under treatment at the time of measurement, or individuals who showed evidence of any following conditions were excluded: chromosomal or other major genetic abnormalities; congenital malformations or dysmorphic features; cardiac, respiratory, gastrointestinal, or other systemic diseases; severe brain disease or neurological disorders; endocrine disorders; or other acute or serious illnesses. The lists compiled by the 2 authors (F.O.M. and D.L.D.) were compared, and disagreements were resolved by discussion.

A standardized form for assessment of study quality and evidence synthesis was used to extract the following data from the included studies: study design, sample size, characteristics of participants, exposure and outcome measures, categorization of birth order and number of siblings, measures of association, and adjustment for confounders.

Studies reporting odds ratios (ORs) or differences in means as measures of association or studies reporting other estimates that could be transformed into these measures, such as a prevalence ratio, were included in a quantitative meta-analysis. The systematic review also assessed the different methods that were used to analyze both birth order and number of siblings, since these variables are linked.

Table 1 **PICO criteria for inclusion and exclusion of studies**

Criteria	Description
Population	Children, adolescents, and adults
Intervention	Birth order and number of siblings
Comparison group	None
Outcomes	Overweight and obesity

To evaluate the quality of selected articles, the checklist adapted from Downs and Black[24] was applied (see Table S1 in the Supporting Information online). The final score was obtained by dividing the total score of each study by the maximum possible score (some studies did not answer all the questions because of their design). The results were reported in tertiles (low quality, average quality, high quality).

Authors of 5 studies were contacted for required information that could not be extracted from their papers[3,11,12,25,26]; 3 responded,[12,25,26] but only 1 provided additional estimates.[25]

Statistical analysis

Separate meta-analyses for each exposure of interest—birth order and number of siblings—were performed using a random-effects model to pool the estimates. The I^2 statistic was used to evaluate heterogeneity between the studies.

Studies presenting results stratified by gender were included twice, each as an independent one. Meta-regression was used to evaluate the contribution of covariates (sex, birth order category, number of siblings category, outcome, adjustment, sample age, sample size, study design, study continent) to the heterogeneity between studies,[27] estimating the adjusted R^2 in each model. The analyses were performed using Stata version 12.0 (StataCorp Software, College Station, TX).

RESULTS

A total of 2142 studies were identified. After removing duplicates and eliminating 1504 records on the basis of titles and abstracts, 194 full-text articles were selected. From these, 174 articles were eliminated because of methodological issues (94 did not assess the exposures of interest; 68 did not evaluate the association with outcomes of interest; and 12 included specific population subgroups). The remaining 20 studies were included in the systematic review, 14 of which were included in the meta-analysis (Figure 1). All papers evaluated the influence of birth order and number of siblings on body composition, overweight, and/or obesity. A summary of the included studies is presented in Table 2[3,5–13,25,26,28–35]; specific details can be found in Table S2 in the Supporting Information online.

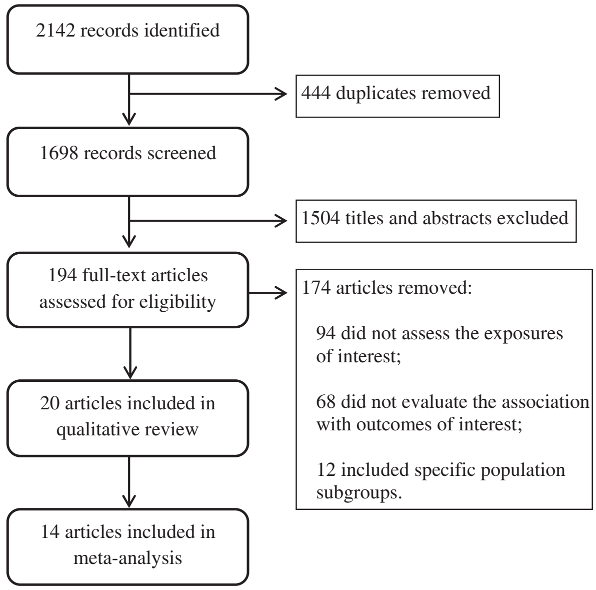

Figure 1 **Flow diagram of the literature search process.**

Of the 20 studies included in the systematic review, 7 were performed in Asia,[5,10,11,13,29,34,35] 7 in Europe,[7–9,28,30,31,33] 5 in the Americas,[3,6,12,25,26] and 1 in Africa.[32] Most of the studies were conducted in adolescents,[3,5,7,12,13,28,29,32,34] 5 in children,[6,8,10,25,30] 5 in adults,[9,11,26,31,35] and 1 in both children and adolescents.[33]

Fifteen studies were of cross-sectional design[5,8–11,13,25,28–35] and the remaining 5 of longitudinal design.[3,6,7,12,26] Only 4 studies reported outcomes as continuous variables,[3,9,11,28] while 16 reported outcomes as categorical variables[5–8,10,12,13,25,26,29–35]; 1 study reported outcomes as both continuous and categorical variables.[3] Of the 17 studies that analyzed categorical variables, 6 evaluated overweight and obesity,[8,25,29,33–35] 5 assessed overweight only,[5,6,10,13,32] and 6 evaluated obesity only.[3,7,12,26,30,31] The 4 studies that analyzed continuous variables assessed fat mass,[11] fat-free mass,[11] and body mass index (BMI).[3,9,11,28] In the longitudinal studies, the outcomes were assessed at the last follow-up.

Birth order

Fourteen studies were included in the meta-analysis, providing 15 estimates of the OR of the association of birth order with overweight and/or obesity and 3 linear regression coefficients that described the association with continuously measured BMI. For those studies that estimated ORs, 6 showed higher odds of overweight/obesity among individuals with lower birth order,[7,8,10,13,25,34] while 1 reported the opposite, ie, a positive association.[33] The remaining 8 found no

Table 2 **Summary of studies included in the systematic review**

References	Study design	Sample size	Age group	Outcome	BO × NS[a]	Method of evaluation	Association[b]
Baecke et al. (1983)[9]	Cross-sectional	3857	Adults	BMI	No	NA	No
Bamidele et al. (2011)[32]	Cross-sectional	497	Adolescents	OW	No	NA	No
Chen & Escarce (2014)[3]	Cohort	NG	Adolescents	BMI	Yes	Adjusted analysis for BO	Yes, BO
Chen & Escarce (2014)[3]	Cohort	NG	Adolescents	OB	Yes	Stratified analysis by BO	Yes, NS
Ghosh & Bandyopadhyay (2006)[11,c]	Cross-sectional	171	Adults	BMI	No	NA	Yes
Ghosh & Bandyopadhyay (2006)[11,c]	Cross-sectional	171	Adults	FM	No	NA	Yes
Ghosh & Bandyopadhyay (2006)[11,c]	Cross-sectional	171	Adults	FFM	No	NA	Yes
Haugaard et al. (2013)[7]	Cohort	29 327	Adolescents	OB	Yes	Only child and firstborn categories were compared	Yes
Hesketh et al. (2003)[5]	Cross-sectional	4197	Adolescents	OW	No	NA	No
Juresa et al. (2012)[8]	Cross-sectional	960	Children	OW + OB	No	NA	Yes
Koziel & Kolodziej (2001)[28,c,d]	Cross-sectional	1026	Adolescents	BMI	Yes	Stratified analysis by NS	Yes, BO
Martin & Burnett (2007)[12,c,e]	Cohort	2955	Adolescents	OB	No	NA	Yes, NS
Martinovic et al. (2015)[33]	Cross-sectional	4097	Children and adolescents	OW + OB	Yes	Only child and firstborn were evaluated in the same category	Yes
Mosli et al. (2015)[25]	Cross-sectional	273	Children	OW + OB	Yes	Only child category was compared with BO categories	Yes
Musaiger et al. (2014)[34]	Cross-sectional	735	Adolescents	OW + OB	No	NA	Yes, BO[f]
Musaiger et al. (2014)[35]	Cross-sectional	406	Adults	OW + OB	No	NA	No
Ochiai et al. (2012)[10]	Cross-sectional	4026	Children	OW	Yes	Separated analysis for number of younger siblings and number of older siblings	Yes
Pawloski et al. (2010)[29]	Cross-sectional	344	Adolescents	OW + OB	No	NA	No
Ravelli & Belmont (1979)[31,c,f]	Cross-sectional	283 028	Adults	OB	Yes	Stratified analysis by BO	Yes, NS
Rios-Castillo et al. (2012)[6]	Cohort	652	Children	OW	No	NA	No
Robinson et al. (2009)[26,c]	Cohort	2096	Adults	OB	No	NA	No
Sgaramella et al. (1980)[30,c,d]	Cross-sectional	2432	Children	OB	Yes	Stratified analysis by NS	No
Wang et al. (2007)[13]	Cross-sectional	7959	Adolescents	OW	Yes	Only child category was compared with BO categories	Yes[g]

Abbreviations: BMI, body mass index; BO, birth order; FFM, fat-free-mass; FM, fat mass; NS, number of siblings; NA, not applicable; NG, not given; OB, obesity; OW, overweight.
[a]Did the study consider the link between birth order and number of siblings in the analysis?
[b]"Yes" means there was an association with birth order and number of siblings; "No" means there was no association with birth order and number of siblings.
[c]Not included in the meta-analysis.
[d]Evaluated birth order adjusted for number of siblings.
[e]Study is no longer available online.
[f]For males only.
[g]Evaluated number of siblings adjusted for birth order.
[h]For females only.

association.[3,5,6,13,29,32,34,35] Of the 3 linear regression coefficients calculated, 1 showed a negative association between birth order and BMI,[3] whereas the other 2 showed no association.[9]

The random-effects pooled OR was 1.47 (95%CI, 1.12–1.93), with $I^2 = 85.7\%$ (Figure 2A)[3,5–8,10,13,25,29,32–35] (comparing lower birth order with higher birth order). When 2 studies that evaluated BMI as a continuous variable (kg/m^2) were examined,[3,9] the random-effects pooled β was -0.10 (95%CI, -0.36 to 0.16), with $I^2 = 51.9\%$ (data not shown in Figure 2A).

In the meta-regression analysis, the age group of the sample and the adjustment for confounders explained 31.8% and 24.3% of the heterogeneity between the studies, respectively (see Table S3 in the Supporting Information online).

Number of siblings

Fourteen studies were included in the meta-analysis, providing 15 estimates of the OR of the association of number of siblings with overweight and/or obesity and 3 linear regression coefficients that described the association with continuously measured BMI. For those studies that estimated ORs, 6 reported a negative association between overweight/obesity and number of siblings,[3,7,8,10,13,25] 1 reported higher odds of overweight/obesity among individuals with a higher number of siblings,[33] and the remaining 7 found no association.[5,6,13,29,32,34,35] Of the 3 linear regression coefficients calculated, 1 showed a positive association between number of siblings and BMI,[3] whereas the remaining 2 showed no association.[9]

The random-effects pooled OR obtained was 1.46 (95%CI, 1.17–1.84), with $I^2 = 73.1\%$ (Figure 2B)[3,5–8,10,13,25,29,32–35] (comparing lower number of siblings with higher number of siblings). When the 2 studies that evaluated BMI as a continuous variable (kg/m^2) were examined,[3,9] the random-effects pooled β was 0.28 (95%CI, 0.02–0.54), with $I^2 = 69.8\%$ (data not shown in figure).

In the meta-regression analysis, the age group of the sample and the adjustment for confounders explained 100% and 56.4% of the heterogeneity between the studies, respectively (see Table S3 in the Supporting Information online).

Relationship between birth order and number of siblings

Twenty studies were included in the systematic review, 11 of which analyzed the effects of birth order and number of siblings separately, without examining the association between the two.[5,6,8,9,11,12,26,29,32,34,35] The main objective of most of these studies was to assess risk factors for overweight/obesity in general, ie, not specifically the association between either birth order or number of siblings and overweight/obesity.[6,8,9,26,29,32,34,35]

Two of the remaining 9 studies evaluated the relationship between number of siblings and obesity stratified by birth order[3,31] and found that only children have a higher risk of obesity. Two papers assessed the association between birth order and obesity stratified by the number of siblings[28,30]: 1 reported no association[30] and the other reported a higher risk of obesity among individuals with lower birth order.[28] One study reported that only children or firstborns had a lower risk of overweight/obesity when compared with those born fourth or later.[33] On the other hand, 4 studies analyzed birth order by comparing only children with children in other categories (oldest/middle/later born) and reported a higher risk of overweight/obesity among only children.[7,10,13,25] Children without siblings had a higher risk of overweight/obesity compared with those with 1 or more siblings.[7,10,13,25] These last 5 studies[7,10,13,25,33] were included in the meta-regression, and the results showed a risk of overweight/obesity of 1.80 (95%CI, 1.35–2.39) among only children when compared with later-born children. In contrast, the results of a comparison of firstborn children with later-born children were not significant (OR = 1.15, 95%CI, 0.82–1.60) (Table S3 in the Supporting Information online).

Of the 9 studies that examined the link between exposures (birth order and number of siblings), 4 were of high quality[7,10,13,25] and 5 were of lower or average quality.[3,28,30,31,33]

DISCUSSION

Overall, the meta-analyses found associations between both lower (vs higher) birth order and number of siblings with overweight/obesity. However, most of the studies reviewed did not account for the relationship between birth order and number of siblings, which makes it impossible to separate any independent effects of these 2 variables. Since the total number of siblings is equal to birth order minus 1 plus the number of younger siblings, interpreting a regression (y = birth order + number of siblings) means that the coefficient for number of siblings (holding birth order constant) is actually an effect of the number of younger siblings, while the effect of birth order (holding number of siblings constant) is confounded by the number of older siblings.

This is problematic because birth order and number of siblings each suggest different biological and behavioral mechanisms by which the risk of obesity is

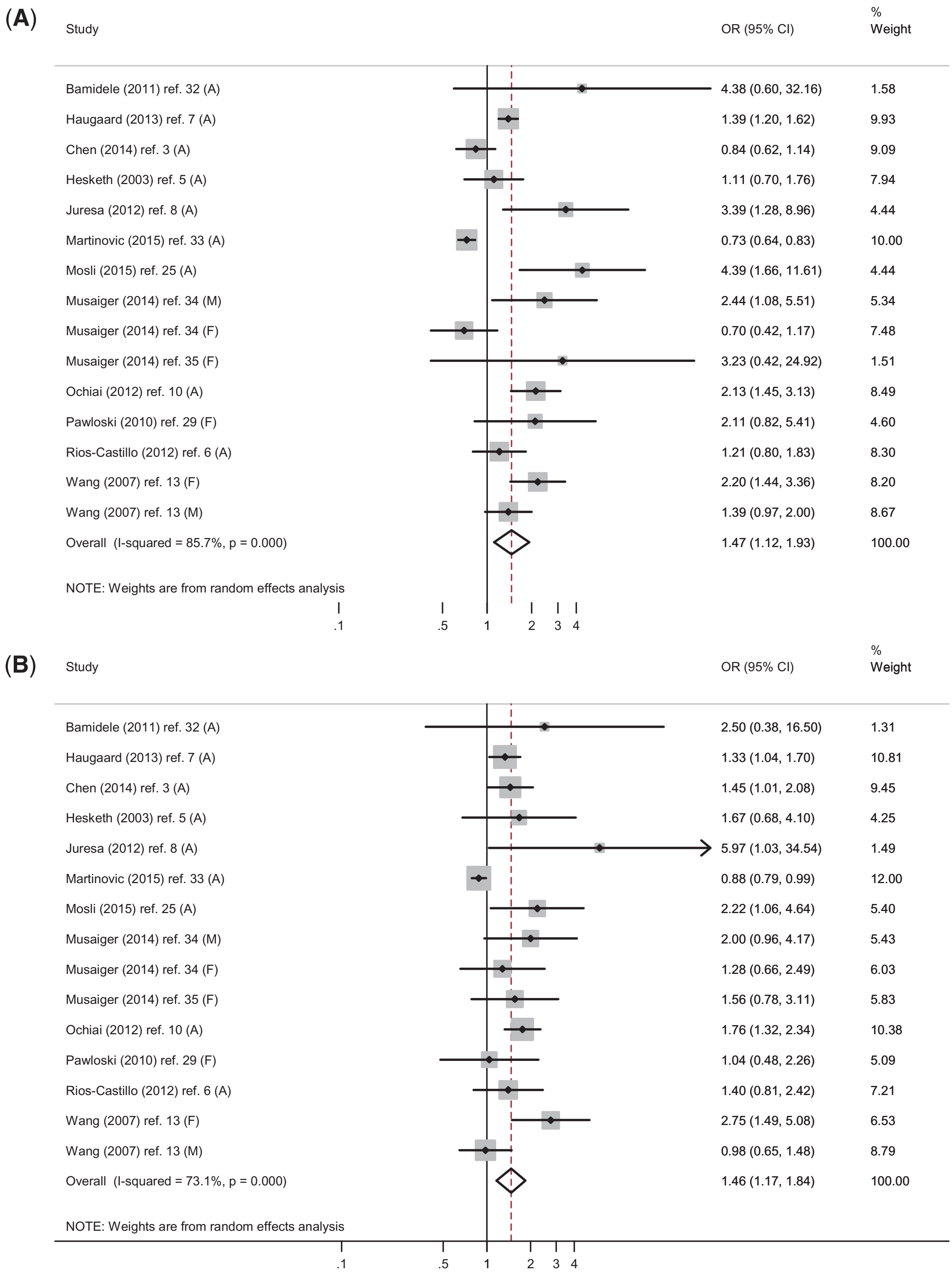

Figure 2 (**A**) **Meta-analysis of studies evaluating birth order and overweight/obesity. (B) Meta-analysis of studies evaluating number of siblings and overweight/obesity.** *Abbreviations:* A, estimate for all (males and females); F, estimate for females; M; estimate for males.

increased. Lower-birth-order infants tend to be smaller at birth than later-born infants[16–18] and more likely to experience catch-up growth, a pattern of growth associated with obesity risk.[19] According to Khong et al,[36] pregnancy results in permanent anatomical changes in the spiral arteries that may be related to the number of previous pregnancies. This finding shows an increasing birth weight with increasing parity.

However, an alternative explanation is that birth order may act as a proxy for the number of siblings. The presence of siblings may provide greater opportunity for games and other physical activities.[15] Hallal et al[15] suggest that a higher number of siblings, regardless of the activity level of each individual sibling, promotes active lifestyles in the long run. Moreover, boys without any sibling have been shown to spend more time watching television than those with siblings.[20] Siblings may also be a stimulus for child-to-child interactions, cooperative play, or activities that increase the time each child devotes to physical activity.[21]

In addition, it has been shown that only children have significantly higher nutrient intakes than children with siblings,[37] perhaps because a mother of an only child is more concerned with persuading the child to eat than a mother with several children.[38] Therefore, additional siblings may also decrease the availability of food for each child, resulting in the reduction of the OR for overweight, particularly for families living in poverty.[21]

Of the studies in this systematic review, 9 tried to separate the effects of birth order and number of siblings on overweight/obesity using different methods.[3,7,10,13,25,28,30,31,33] Some of them adjusted the analyses for birth order or number of siblings,[3,28,30,31] others evaluated birth order using the only child as the reference category,[13,25,33] and the remaining ones conducted additional analyses.[7,10] Haugaard et al[7] compared only children with firstborn children and reported a higher risk of obesity among only children. They also compared firstborn children (excluding only children) with children in other birth order categories and found no association with obesity.[7] These results show that a higher risk of obesity is explained by the lack of siblings (ie, being an only child), rather than by birth order. Martinovic et al[33] tried to link birth order to the number of siblings by combining only children and firstborns into a single category and then comparing that category with other birth order categories. However, this approach precludes an explanation of to what degree being an only child or being firstborn affects the risk of overweight/obesity. Ochiai et al[10] performed separated analysis for the number of younger siblings and the number of older siblings. They found that only children had a higher risk of overweight in both analyses. Furthermore, even when the birth order categories (oldest, middle, and younger born) were combined into 1 category (children with siblings), the results showed that only children had an increased the risk of being overweight. This finding was independent of study quality.

Strengths and limitations

Six studies were not included in the meta-analysis. However, it is unlikely that the modified pooled estimate was affected by the exclusion of these studies, which provided no information on the measure of association to be included in the meta-analysis. These studies had sufficient sample sizes ($n \geq 500$), and most of them reported an association between birth order, number of siblings, and overweight/obesity in the same direction as that found in the present review.

The strength of this systematic review and meta-analysis is that it was not limited to study design or group age. Moreover, this is the first systematic review and meta-analysis to focus on both birth order and number of siblings and their association with overweight/obesity.

CONCLUSION

The findings of this systematic review and meta-analysis suggest a slightly increased risk of overweight and/or obesity among only children. The meta-analysis showed that both lower birth order and lower number of siblings are associated with increased risk of overweight/obesity; however, most of the included studies were not designed to estimate the effects of these 2 factors independently. Among studies that did try to separate these effects, being an only child was consistently found to be the key risk factor. Lastly, studies that aim to understand the effects of birth order or number of siblings on overweight/obesity should examine the link between these 2 factors.

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Author contributions. F.O.M. was responsible for the literature review, the results analysis, the data interpretation, and the writing of the final article. M.C.F.A. and F.C.B. were responsible for the data interpretation and the writing of the final article. A.A.S., C.L.M., and D.L.D. were responsible for the methodology and the data analysis. All authors discussed the results and implications and commented on the manuscript at all stages.

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Supporting Information

The following Supporting Information is available through the online version of this article at the publisher's website:

Table S1 **Quality and methodological assessment of included studies**

Table S2 **Summary of included studies**

Table S3 **Univariate meta-regression and pooled odds ratio estimates of birth order and number of siblings on overweight and/or obesity**

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