Pediatric RESEARCH

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SYSTEMATIC REVIEW

A systematic review on the association of month and season of birth with future anthropometric measures

Zeinab Hemati[1,2], Mojtaba Keikha[3], Roya Riahi[2], Seyede Shahrbanoo Daniali[2], Masoumeh Goudarzi[2] and Roya Kelishadi[2]

BACKGROUND: Prenatal factors might have some health impacts later in life. This study aims to systematically review the current literature on the association between season and month of birth with birth weight as well as with weight status in childhood.
METHODS: The search process was conducted in electronic databases, including papers published until April 2019 in ISI Web of Science, PubMed, Scopus, and Google Scholar. The following search strategy was used with MeSH terms: ("Seasons"[Mesh]) AND ("Obesity"[Mesh] OR "Pediatric Obesity"[Mesh] OR "Obesity, Abdominal"[Mesh] OR "Overweight"[Mesh] OR "Birth Weight"[Mesh] OR "Body Height"[Mesh]). After the selection process, 50 papers were included in this systematic review.
RESULTS: This review showed that individuals who are born in cold season (winter month) have higher body mass index (BMI) and weight in childhood. Birth in March was associated with lower weight and BMI in boys according to most studies. All studies, except one of them, showed that season/month of birth was not associated with birth weight.
CONCLUSIONS: This systematic review confirms a relationship between season and month of birth with birth weight and body size in childhood; however, the impact of confounding factors, for example, vitamin D status, should be considered in the underlying pathway of this association.

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IMPACT:

- The results provide evidence for the effect of season and month of birth on body size in childhood.
- Our systematic review suggests that there is no pattern between birth weight and season/month of birth, and the occurrence of low birth weight was more frequent among infants who were born in summer than others.
- Further research should focus on identifying the impact of confounding factors, for example, vitamin D status in the underlying pathway of this association.
- There was response to the controversial findings about the effect of environment factors, such as season and month of birth, and future anthropometric indices, such as obesity, weight, height, and birth weight.
- Obesity is a complex and multifactorial disorder; the findings of the current study would be useful in determining the relationship pathway between the season and the month of birth with other underlying factors for childhood obesity.

INTRODUCTION

Childhood obesity is one of the most important global health problems, and associated with several short- and long-term health hazards, such as type 2 diabetes, hypertension, cardiovascular diseases, and fatty liver disease.[1] Although obesity is attributed to the combination of a sedentary lifestyle and excess energy intake, and biological factors, its predisposing factors are not well understood. Childhood obesity is a public health problem even in developing countries.[2] The role of genetic factors has been emphasized in family and twin studies,[3,4] but it is not clear to what extent individual susceptibility interacts with lifestyle and other contextual factors in the development of overweight and obesity.[5] The evidence is increasing and suggests that environmental factors during early life may influence the development of obesity.[6–8]

Season of birth is one type of natural experiment that can help generate candidate environmental factors. Certain exposures tend to fluctuate in a regular fashion within a year, while, at the group level, other environmental and genetic factors remained relatively stable.[9] Season and month of birth provide direct support for the "fetal origins of adult disease hypothesis" that intrauterine exposures (independent of genetic effects) may have impacts on health later in life.[10,11] Evidence showed the effect of seasonal variations in pre- and postnatal infant growth.[12] One study reported that infants born in summer had a higher risk of high birth weight compared with those born in winter.[13] The results of a study in ~500,000 participants in China showed shorter leg lengths in individuals born in February–August, and increased waist circumference (WC) in individuals born in March–July.[11]

[1]Nursing and Midwifery Care Research Center, Faculty of Nursing and Midwifery, Isfahan University of Medical Sciences, Isfahan, Iran; [2]Child Growth and Development Research Center, Research Institute for Primordial Prevention of Non-Communicable Disease, Isfahan University of Medical Sciences, Isfahan, Iran and [3]Department of Public Health, Sirjan School of Medical Sciences, Sirjan, Iran
Correspondence: Roya Kelishadi (roya.kelishadi@gmail.com)

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Another study indicated that infants born in March and September have a higher risk of obesity than infants born in October and November.[14] The effects of seasonality of birth on body mass index (BMI) later in life have yielded inconclusive results. In a Canadian study, winter is the peak season for adults' BMI.[5] In the British study, the first 6 months of the year,[3] and in a Chinese study spring and summer,[7] are the peak season for adults' BMI, but studies from Finland and the United Kingdom found no seasonal variation in adult BMI.[15] Therefore, the importance of seasons and months of birth on pre- and postnatal BMI from other studies has been controversial; the aim of this study is to systematically review and summarize the scientific literature on the associations between season/month of birth on birth weight and body size later in life.

MATERIALS AND METHODS

This review was designed in accordance with the protocols of systematic review and meta-analysis (PRISMA).

Search strategy

The search process was conducted in electronic databases, including papers published until 24 April 2019 in ISI Web of Science, PubMed, Scopus, and Google Scholar using the following keywords: (seasons OR season OR seasonal OR "season of birth" OR seasonality OR "month of birth" OR "month-of-birth" OR "birth month" OR month) AND (obesity OR "body mass index" OR weight OR "body weight" OR "overweight" OR "body size" OR adiposity OR "body fatness" OR "BMI" OR fatness OR "body size" OR obese OR "waist circumference" OR "adipose tissue" OR "waist-to-hip ratio" OR "waist-to-height ratio" OR "waist to hip ratio" OR "waist to height ratio" OR "waist–hip ratio" OR "waist hip ratio" OR height OR "leg length" OR "birth weight") AND (birth) and a combination of them.

All elements were searched using both controlled vocabulary terms (Medical Subject Headings) and free-text words. The following search strategy was used with MeSH terms: ("Seasons"[-Mesh]) AND ("Obesity"[Mesh] OR "Pediatric Obesity"[Mesh] OR "Obesity, Abdominal"[Mesh] OR "Overweight"[Mesh] OR "Birth Weight"[Mesh] OR "Body Height"[Mesh]).

Hand searching. To increase the sensitivity and to select more studies, the reference list of the published studies was checked as well.

Inclusion and exclusion criteria

We included all cross-sectional, case–control, and longitudinal studies on the relationship between season and month of birth with weight, height, and obesity in children and adolescents and birth weight in neonates. We did not consider any time or language limitation.

Limitations were applied to exclude conference papers, editorials, letters, commentary, short survey, and note.

Data management

We used EndNote program for managing and handling extracted references that were searched from databases. Duplicates were removed and entered into a duplicate library.

Study selection strategy

In the systematic search, 20,717 unique references were identified (Fig. 1). Of them, 20,125 were excluded on the basis of the title and abstract. For the remaining 592 articles, the full text was retrieved and critically reviewed. After the selection process, 50 papers were included in this systematic review.

Data collection process

Data extraction and abstraction and quality assessment

Two independent reviewers (Z.H. and M.K.) screened the titles and abstracts of papers, which were identified by the literature search, for their potential relevance, or assessed the full text for inclusion in the review. In the case of disagreement, the discrepancy was resolved in consultation with an expert investigator (R.K.).

The quality of the articles was evaluated using the Newcastle–Ottawa Scale for cohort and cross-sectional studies.[16] This quality scale contained three sections on which a maximum of 9 points was given: the items patient selection (max. of 4 points), comparability (max. of 2 points), and outcome (max. of 3 points). The qualitative scores for each study are listed in Tables 1 and 2.

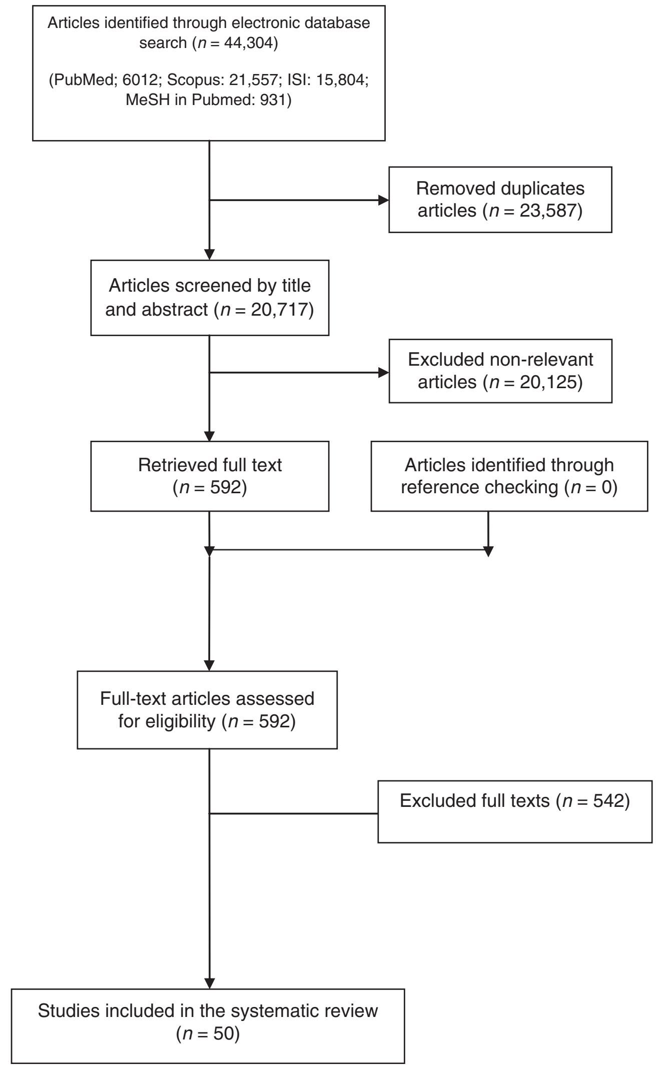

Fig. 1 PRISMA Flow Diagram. Papers' search and review flowchart for selection of primary study.

RESULTS

In this systematic review, we studied the association between month and season of birth with weight, height, and obesity in childen and adolescents, and we also considered the effect of season or month of birth on birth weight in neonates. Different outcomes such as birth weight, weight (weight *Z*-score), BMI, overweight/obesity, and height (height *Z*-score) were studied. Among all included studies, 13 studies provide information on month of birth, 17 studies on season of birth, and 25 studies on both season and month of birth and body size outcomes. The study design and characteristics for all included studies according to the outcome (body size or birth weight) are shown in Tables 1

Table 1. Characteristics of included studies on body size measurement.

ID	First author name, ref./location	Type of study	Sample size, age group, gender	S/M*	Outcome and Scale use for assessing	Adjusted covariates	Main result
1	Brabec,[23] Bolivia	Cross-sectional	1108 person (562 girls and 546 boys), below 12 years of age (pre-puberty)	M	HAZ WAZ	Stratified on child sex and adjusted for age	Children born during the rainy season (February–May) were shorter, while children born during the end of the dry season and the start of the rainy season (August–November) were taller. Among boys, births during the latter part of the rainy season (March–April) and the first month of the dry season (May) were associated with shorter heights, whereas births toward the start of the rainy season (October–November) were associated with taller heights. Girls born during the rainy season (February–April) were shorter, while those born during the start of the rainy season (September–October) were taller than girls born at other times of the year. Finding is that birth seasons bore no marked associations with girls' WAZ, whereas among boys we again find that births during the rainy season (particularly March–May) were associated with lower WAZ, and during the end of the dry season (September–November) were associated with higher WAZ
2	Kramer,[27] England	International Collaboration Study	56,780 actors and actresses, aged 20–50 years	S/M	Height (cm)	Year of birth	No differences in height across months or seasons even after controlling for variability in birth year. Birth month effects are minimal or absent in adults
3	Jensen et al.,[15] Denmark	Cross-sectional	337,138 school children, aged 7 years	S/M	*Z*-score, BMI	Age, sex	The differences between seasonality of birth in BMI were very small (<0.01 kg/m^2) and the confidence intervals were wide and overlapping, which illustrated that there was no seasonality of birth in mean BMI at 7 years
4	Chmielewski and Borysławski,[47] Poland	Retrospective Study	848,860 individuals, (483,512 were men and 365,348 were women)	M	Height (cm)	Did not consider potentially significant confounding factors	Subjects of both sexes born in autumn and winter months were significantly shorter than their peers born around the middle of the year. The longest height was found in men born in March–April and in women born in January–April, the shortest in men born December and women born in October
5	Rosset et al.,[29] Poland and in Australia	Retrospective Study	In Poland (53,933) and in Australia (51,118) were examined. The age range of the Australian women 20.50–67.67 years and 29.00–76.00 years in the Polish sample	M	Height (m) and height *Z*-score	Age	No association between month of birth and body height was observed in either Polish or Australian women
6	Mehrang et al.,[26] Australia, Brazil, France, Germany, Great Britain, Japan, and United States of America	International Collaboration Study	6429 subjects from seven countries, namely (1) Australia, (2) Brazil, (3) France, (4) Germany, (5) Great Britain, (6)	S/M	Weight (kg)	Interaction of time and contrary name	The results suggest that there are statistically significant differences between the models of weight variation in Southern and Northern

Table 1. continued

ID	First author name, ref./location	Type of study	Sample size, age group, gender	S/M*	Outcome and Scale use for assessing	Adjusted covariates	Main result
			Japan, and (7) United States of America				Hemispheres. In both Northern and Southern Hemispheres the lowest weight values were observed in the summer. However, the highest weight values were noticed in the winter and in the spring for Northern and Southern Hemispheres, respectively. For the countries in Northern Hemisphere, the curves tend to decrease from their peak value almost in May, which is the middle of the spring and drop to their lowest level approximately in September. In contrast, this weight gain continues until November in Australia; however, in Brazil it roughly plateaus after June before reaching October when the weight values start to increase. The lowest weight values of both Australian and Brazilian participants occur in March when there is a sharp downward trend after the beginning of the summer in Southern Hemisphere. In France and Japan, the amount of weight loss in the summer seems a bit bigger than the other countries. All of the five studied countries in this hemisphere experienced a considerable weight gain during the fall and beginning of the winter. The upward trend of weight in Germany ended in January, while in France, Great Britain, Japan, and United States of America this occurred in February
7	Sohn,[28] Indonesia	Cross-sectional	9262 men and 10,314 women 20–50 years of age	M	Height (cm)	No additional covariate is added	There was no statistically significant difference in height by birth month. However, although weakly significant, men born in the dry season (June–September) were 2.3 mm shorter than those born in the wet season (the remaining months). The corresponding figure for women was 2.6 mm, a statistically significant difference. Converted into *Z*-scores, they were 0.038 and 0.047, respectively
8	Lv,[7] China	Cross-sectional	487,529 (200,529 men and 287,000 women)	M	BMI and WC	Survey site, sex, age, education level, smoking habit, alcohol consumption, physical activity level, sedentary leisure time, height	Month of birth was independently associated with both BMI and WC. Birth months in which participants had higher measures of adiposity were March–July for BMI and March–June for WC. The study's findings suggest that spring- and early summer-born adults had higher BMI and WC
9	Day et al.,[10] United Kingdom	Cross-sectional	Height and BMI measurements were available in 451,435 and 452,399 individuals, respectively	S/M	BMI and height (cm)	Age, sex and socioeconomic position	Season of birth was associated with adult height, but not adult BMI. Peak month of birth differences were seen between June vs. December. Among

Table 1. continued

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							women, adjustment for age at menarche and birth weight attenuated the association between winter births and shorter adult height, but did not attenuate the association between summer births and taller adult height, and augmented the association between autumn births and shorter adult height
10	Pomeroy et al.,[48] South America	Retrospective Study	162 Highland children (89 male) and 184 lowland children (92 male), aged 6 months to 8 years	M	Height (*Z*-score)	Age and sex	Among the highland sample, children born between January and June have shorter stature
11	Tornhammar,[17] Sweden	Cohort	284 subjects, aged 35 years	S	Overweight/obesity	–	Season of birth was not associated with risk of overweight and obesity.
12	Soreca et al.,[20] Pennsylvania	Cross-sectional	375 adult patients with bipolar disorder and 196 adult patients with unipolar major depression	S	BMI	Gender, gender by birth season, time, and age	Observed a significant season-of-birth effect on BMI in patients with bipolar disorder, but not unipolar. Indicated that spring-born patients with bipolar disorder are heavier than individuals with bipolar disorder born in other seasons, although there is no difference in BMI among unipolar patients born in spring or other seasons. Spring-born patients with bipolar disorder have larger BMI than those patients with bipolar disorder who were born in other seasons at all time points (i.e., baseline, 12 months, and 24 months) (est = 2.24, $t = 3.55$, $p = 0.0004$, effect size = 0.26), and that individuals with unipolar depression born in spring did not differ in BMI from those born in other seasons at all time points (i.e., baseline and 8 months) (est = 0.78, $t = 0.94$, $p = 0.35$, effect size = 0.10)
13	Schreier et al.,[32] Finland	Cohort	2003 men and women were	S/M	BMI—body fat obesity (>30 kg/m^2)	Gestational age, sex, father's occupation, parity, birth weight, and age	Men exposed to an unusually warm month at conception time had a lower BMI in adult life. Those women who were conceived during a month with average temperatures in the coldest quartile of this specific month over the time period of 1923–1944 (month-specific quartiles) had lower BMI, lower risk of obesity, and lower fat percentage
14	Krenz-Niedbala et al.,[30] Poland	Two Cross-sectional Study	13,228 subject	S/M	Body weight–height–BMI and fattiness	Allergic diseases and social factors	No evidence for the season-of-birth effect in girls was found in this study. On the other hand, the boys born at the turn of the year were bigger and fatter at the age of 8 years than those born in the mid-year. The effect was, however, revealed only after exclusion of asthmatic children from the analysis. It seems to obscure this effect the individuals born in October–April were

Table 1. continued

ID	First author name, ref./location	Type of study	Sample size, age group, gender	S/M*	Outcome and Scale use for assessing	Adjusted covariates	Main result
							taller (by 2–3 cm), heavier (by 2–3 kg), and fatter than those born in May–September
15	Zhang,[49] China	Cross-sectional	833 adult men, 18–52 years of age	M	Height (cm)	Age, socioeconomic variables, parental characteristics And family backgrounds	Adult men born in winter months (November to January) are, on average, 1.04 cm shorter ($p < 0.01$) than those born during the rest of the year
16	Hackett et al.,[15] England	Cohort	11,084, aged between 9 and 10 years	S/M	BMI	Stratified on sex and control for age and index of multiple deprivation	No association was found between BMI categories and month or season of birth. There was no significant association between classification of body weight and season of birth for but a higher prevalence of 'normal weight' in the summer compared with Autumn was found for girls
17	Schwekendiek and Pak,[50] Korea	Cross-sectional	–	S	Height (cm)	–	Among the North Korean children born during the famine, the summer-born children were taller and the autumn-born children were tallest, suggesting that food seasonality might play a role in the birth season height pattern
18	Puch et al.,[31] Poland	Cross-sectional	4672 girls, aged 5–18 years.	S/M	*Z*-scores for height	–	A highly significant relationship between the birth month and average values of height was revealed in pre-adolescent girls. Individuals born in April–September are the shortest
19	Wattie et al.,[5] Canada	Cohort	79,195 participants	S/M	BMI	Sex, age, physical activity, education, income, smoking status, ethnicity, and province, and rural/urban residence	Overall, among the 20–64 year olds, those in the obese III category were 1.54 times more likely to be born in the winter. A summer season-of-birth effect was observed for the obese II/III 40–49 years cohort (OR: 1.59; 95% CI: 1.21–2.11). No season-of-birth effects were observed among any BMI categories for those 12–19 years, or among those 20 years and over in the overweight BMI category
20	Tanaka et al.,[18] Japan	Cross-sectional	69,693 school children (35,884 boys and 33,809 girls), aged 6–15 years	S/M	Height and weight (*Z*-score) and obesity	Gender, age	The mean *Z*-score for height and weight were the highest in subjects born during the months of spring and the lowest in those born during the months of winter ($p < 0.0001$), whereas the means, were significantly higher in children born during the months of summer than in those born during the months of autumn ($p < 0.0001$). A gradually decreasing trend of height and weight was observed in children of both genders born between May and March (from spring to winter). There was no significant difference in degree of obesity among the four seasons of birth for boys and girls. The highest prevalence of obese boys have born during spring (among 6-year-old boys) and summer (among 7-year-old boys),

Table 1. continued

ID	First author name, ref./location	Type of study	Sample size, age group, gender	S/M*	Outcome and Scale use for assessing	Adjusted covariates	Main result
							whereas the highest prevalence of obese girls have born during spring (among 6-year-old girls) and winter (among 10-year-old girls)
21	McGrath et al.,[19] United States of America	Birth cohort	22,123 infant (there were 11,321 males and 10,802 females)	S	Weight (g) Height (cm)	Sex, weeks' gestation, maternal and paternal height, and socioeconomic status	Compared to summer/autumn-born infants, winter/spring-born infants were significantly heavier, taller
22	Kościński et al.,[24] Poland	Cross-sectional	1241 subjects (568 boys and 673 girls), age 6–20 years	M	Height (cm) *Z*-score, weight (kg) *Z*-score	Birth date, sex, SES	Subjects born in October to March proved to be significantly taller and heavier than those born in April to September
23	Banegas et al.,[51] Spain	Cross-sectional	810 person, aged 35–64 years	M	Height (cm)	Age (years), occupation (manual/non-manual), and type of residence (rural/urban)	Male adults born in summer proved to be 1.7 cm taller than their counterparts born in winter (95% CI: 0.2 ± 3.3 cm, $p = 0.03$). No significant ($p = 0.8$) or relevant summer- and winter-related differences in height were found in women. The influence of month of birth on height is greater and reached the statistical significance only in men whose occupation was non-manual (2.1 cm, $p = 0.04$ vs. 1.4 cm, $p = 0.2$ in manual occupations), and in men living in urban residence (2.3 cm, $p = 0.01$ vs. 1.2 cm, $p = 0.3$ in rural residences)
24	Phillips and Young,[3] England	Retrospective Study	1750 men and women, range 59–73 years	S	BMI–obesity (>30 kg/m^2)	Stratified on sex, adjusted for birth weight	In men, BMI and the prevalence of obesity (BMI 30 kg m^2) varied as a function of month of birth and was greater among those born in January–June than among those born in July–December. The prevalence of obesity in men born during the first 6 months of the year was greater than in those born during the past 6 months. Although among women, BMI did not vary by month of birth ($p = 0.525$), monthly variation in prevalence of obesity (BMI >30) was of borderline statistical significance ($p = 0.056$). In women, weights at 1 year did not differ between those born January–June or July–December, even after adjustment for birth weight. Although weights at 1 year also did not show statistically significant seasonal trends, when these values were adjusted for birth weight, 1 year weights were slightly greater in men born during the first half of the year than in those born in the latter half
25	Fitt,[25] New Zealand	Cross-sectional	Height measurements of 21,342 and weight measurements of 21,177 men were available, men	M	Height (in.)/weight (lbs)	–	Those of September and November birth are just shorter than those born in February (the mean difference = 0.31 in.). The lightest men are born in June and the heaviest those born in December with a difference of 1.32 pounds

Table 1. continued

ID	First author name, ref./location	Type of study	Sample size, age group, gender	S/M*	Outcome and Scale use for assessing	Adjusted covariates	Main result
26	Henneberg and Louw,[22] Africa	Cross-sectional	1522 school children aged 6 to 18 years	M	Weight (*Z*-score) Height (*Z*-score)	–	Children born in May through October are lighter than those born in November through April. Children born in July to August are shorter than those born in other month
27	Pollitt and Arthur,[52] Taiwan	Cohort	225 older infants were enrolled in the study	S	Weight increment (g)	Birth weight and length	The highest weight increment in the 0–3-month period was recorded by infants born in the summer season. In the 3–6-month period the highest and lowest increments were observed in the winter and summer seasons, respectively. Comparison between the mean weight increments for the four cohorts in the 6–9- and 9–12-month period revealed that the maximum and minimum increments in weight occurred in fall and spring, respectively
28	Pagezy and Hauspie,[53] African	Longitudinal survey	34,470 weight measurements	S/M	Weight (g)	–	The growth rate in weight of Ntomba babies showed a cyclic pattern, which appeared to be synchronized with the alternations of dry and rainy seasons. The unfavorable rainy seasons. Decelerated growth in weight to about 0.2 SD below the average rate. (This is ~40 g/month below the average velocity.) The subsequent favorable dry seasons resulted in a catch-up growth. The effects were visible towards the end of each season or in the beginning of the next season and were more pronounced and lasted longer when following the major rainy or dry seasons than when following the minor rainy or dry seasons
29	Hillman and Conway,[21] United States of America	Cohort	9103 patient, <5–30+ years	M	Overweight	–	The birth dates for overweight patients were unevenly distributed, with peak frequencies noted in March and September and lowest frequencies in October and November (*p* value <0.001). The monthly pattern for normal and underweight subjects showed a relative deficit during June and July, and differed significantly from the pattern for the overweight group

HAZ height-for-age, *Z*-score, *WAG* weight-for-age, *Z*-score, *S* season, *M* months.

Table 2. Characteristics of included studies on birth weight.

ID	First author name, ref./ location	Type of study	Sample size, age group, gender	S/M*	Outcome and Scale use for assessing	Adjusted covariate	Main result
1	Wu et al.,[54] China	Cross-sectional	23,064 infants	S	Low birth weight (<2500 g) and macrosomia (≥4000 g)	Adjustment by infant sex and mother's age	The present study demonstrated that the risk of macrosomia varied by season. The ORs for macrosomia were 0.85 (95% CI: 0.75–0.98) and 0.87 (95% CI: 0.77–0.99) for infants born in the summer and autumn, respectively, compared to infants born in the spring. Compared to infants born in the spring, the OR for low birth weight was 0.75 (95% CI: 0.56–1.11) for infants born in the summer. Similarly, compared with infants born in the spring, the ORs for low birth weight were 0.98 (95% CI: 0.70–1.20) and 0.82 (95% CI: 0.61–1.10) for infants born in the autumn and winter, respectively. Seasonal variation was not associated with a risk for low birth weight
2	Day et al.,[10] United Kingdom	Cross-sectional	255,769 individuals (100,128 men, 155,641 women) and	S/M	Birth weight (kg)	Age, sex, and socioeconomic position	Individuals born in summer (June–July–August) had higher mean birth weight, and individuals born in winter (December–January–February) had lower birth weight
3	Bahrami et al.,[55] Iran	Cross-sectional	5313 women and their infant	S	Birth weight (g)		The highest birth weight was observed in spring and lowest birth weight was observed in summer
4	Jensen et al.,[56] Denmark	Cohort	326,520 children	S/M	Birth weight (g)	Sunshine hours	There was a clear seasonal pattern in BW which, however, changed gradually across the study period. The highest BWs were seen during fall (September–October) from 1936 to 1963, but a new peak gradually grew from the early 1940s during early summer (May–June) and became the highest from 1964 to 1989
5	Schreier et al.,[32] Finland	Cohort	11,237 men and women were included in the analysis on birth weight	S/M	Birth weight (g)	Gestational age, sex, father's occupation, and parity	There were no seasonal- or temperature-mediated influences on birth weight
6	Torche and Corvalan,[57] South America	Cohort	4,968,912 births	S/M	Birth weight (g)	Stratify sample by geographic region and adjusted for maternal sociodemographic characteristics	Infants born in spring or fall are, on average, 16 g heavier than those born in the winter ($p < 0.001$). In the low-latitude northern region, there is marked annual periodicity with highest birth weight in spring and lowest birth weight in the fall. In the central interior region, infants born in the spring and fall weigh, on average, 21 g more than those born in the winter ($p < 0.001$)
7	Chodick et al.,[58] Israel	Cohort	–	S	Birth weight (g)	–	Our interpretation of the presented data is that in undeveloped regions low birth weight during wet seasons is probably associated with malnutrition and exposure to infectious diseases. On the other hand, birth weight in developed countries has a varying seasonal pattern that depends on latitude. In low- and high-latitude developed regions, babies born during the winter are at increased risk of low birth weight, possibly because of inadequate exposure to sunlight in the final stages of pregnancy
8	Chodick et al.,[13] Israel	Cross-sectional	235,152 singleton live births	S/M	Birth weight (g)	Year of birth, sex, maternal age, diabetes, and several meteorological factor	A significant seasonal pattern in birth weights was observed, with a peak in July and a trough in January. In 6 of the 7 years, the month with the lowest monthly average birth weight (range 3245–3262 g) was observed between December and February, whereas in 6 of the 7 years, the month with the highest monthly average birth weight (range 3287–3307 g) was observed between May and July. The lowest birth weight occurred in January, followed by a gradual increase until the peak in July

Table 2. continued

ID	First author name, ref./location	Type of study	Sample size, age group, gender	S/M*	Outcome and Scale use for assessing	Adjusted covariate	Main result
9	McGrath et al.,[19] Australian	Cohort	1240 singletons born	S/M	Birth weight (g)	–	Winter- and spring-born infants are slightly heavier compared to summer and autumn-born infants (25 g difference between neonates born in October vs. May). This effect had a strong 12-month periodicity. Infants born in October were the heaviest (3484 g), while May-born infants were the lightest (3459 g; $p = 0.001$)
10	Elter et al.,[59] Turkey	Retrospective Study	3333 singleton live births	S/M	Birth weight (g)	Maternal age and parity, mode of delivery, sex, and temperature, humidity, rainfall, and daylight values for each trimester	In the present study, we observed a seasonal pattern in birth weight. A seasonal pattern was observed with lowest birth weights in women who had their last menstrual periods in summer and autumn
11	Jonge et al.,[12] United States of America	Cohort	24,325 infant (11,091 whites, 11,477 blacks, 1536 Puerto Ricans and 221 subjects)	S	Birth weight (g) Weight gain	Adjustment for study site, sex, gestational age, maternal education, maternal age, maternal BMI, and birth order	Black infants born in the fall had a significantly lower birth weight (3.12–0.42 kg) than those born in the winter (3.16–0.43 kg, $p = 0.002$). Weight gain (g/months) for black and Puerto Rican infants during the first 4 months of life was significantly lower for those born during the fall (black: 816–186; Puerto Rican: 820–181) compared to those born in the spring (black: 844–194, $p < 0.001$) and summer (Puerto Rican: 861–185, $p < 0.04$). Birth weight and early infancy weight gain varied by season and were modified by ethnicity
12	Murray et al.,[60] Northern Ireland	Cohort	418,817 singleton live births after 36 completed weeks of pregnancy	M	Birth weight (g)	Adjustment was made for year of birth, duration of gestation, maternal age, number of previous pregnancies, sex, and social class of infants at birth and for meteorological variables relating to each trimester	A clear seasonal pattern in birth weight was observed, with lowest mean birth weight in late spring and summer. Adjusted mean birth weights were 25.5, 29.6, and 31.6 g lower in May, June, and July, respectively, than in January. The mean birth weights of females born in March, April, May, June, and July were 22.4, 17.3, 27.3, 27.6, and 36.1 g lower, respectively, than those of females born in January. These differences were statistically significant, but they did not remain so after adjustment for mean daily maximum temperature during the second trimester. Seasonal differences in birth weight were slightly less marked in males and remained, especially for the months of June and July, after adjustment for mean daily maximum temperature during the second trimester
13	Gloria-Bottinia,[61] Italy	cross-sectional	5291 infants	S	Birth weight (g)	–	The analysis shows that the effect of season on birth weight in male newborns from Rh (−) mothers is the same in Rome and Sassari. The infants born in winter had higher birth weight and those born in summer had low birth weight
14	Waldie et al.,[62] New Zealand	Cohort	20,021 infants and for follow-up: 2-year intervals from age 3 years (51,037) to age 15 years (5976), and subsequently at 18 (5993), 21 (5992), and most recently at age 26 years (5980)	S	Birth weight (g) and length	Number of weeks of breastfeeding, and number of cigarettes smoked	Our findings revealed that the birth length and weight of this Dunedin cohort was strongly influenced by the amount of bright sunshine coincident with the early months of pregnancy. The infants born in winter had higher birth weight and those born in summer had low birth weight. In the sub-sample of members enrolled in the DMHDS height varied up to 8-mm depending on month of birth, with maximum length in October (conception during mid-summer) and minimum length in January (conception during shorter autumn days)
15	Phillips and Young,[3] England	Cohort	1750 men and women	S/M	Birth weight (g)	–	BMI rose with increasing birth weight in men and women. In men, BMI and the prevalence of obesity (BMI 30 kg/m^2) varied as a function of month of birth and was greater among those born in

Table 2. continued

ID	First author name, ref./ location	Type of study	Sample size, age group, gender	S/M*	Outcome and Scale use for assessing	Adjusted covariate	Main result
							January ± June than among those born in July ± December. The relationship between birth weight and adult obesity was also stronger in those born in the 6 months of the year or following cold winters than in those born in the last 6 months of the year or following mild winters
16	Yang and Leung,[63] China	Cohort	202 Chinese infants in Chengdu City (112 boys, 90 girls) and 174 Hong Kong infants in their first 2 years of life	S	Weight (kg) Height (cm)		The seasonal effect on weight growth for the two groups is the same with the fastest growth in winter and slowest in summer and with a mean difference of about 0″ 16 kg. For length, the fastest is in summer for Chengdu infants but in winter for Hong Kong infants. The difference between the slowest and fastest is ~0.49 cm for the two groups
17	Matsuda et al.,[64] Japan	Cohort (10-year follow-up)	16,796,415 (males born to primiparae, 3,723,037; males born to multiparae, 4,923,701; females born to primiparae, 3,509,102; females born to multiparae, 4,640,575).	S/M	Birth weight (g)	–	Seasonal patterns of mean birth weight show two peaks in May and October–November and two troughs in June–September and December
18	Pollitt and Arthur,[52] Taiwan	Cohort	225 older infants	S	Birth weight (*Z*-score) and weight increment (g)	Birth weight and length	The highest and lowest mean birth weights were recorded in the spring and summer seasons, respectively. Spring was not only the highest but was also significantly different ($p < 0.05$) from the mean birth weights of infants born in the fall and summer seasons. The highest weight increment in the 0–3-month period was recorded by infants born in the summer season. In the 3–6-month period, the highest and lowest increments were observed in the winter and summer seasons, respectively. Comparison between the mean weight increments for the four cohorts in the 6–9- and 9–12-month period revealed that the maximum and minimum increments in weight occurred in fall and spring, respectively
19	Adair and Pollitt,[65] Taiwan	Cohort	A sample of 225 rural Taiwanese women, aged 19 and 30 years with infants	S/M	Bright weight (g)	–	The lowest mean birth weights were also recorded for the warm, rainy summer months. Furthermore, a disproportionate number of infants weighing <1 SD below the mean birth weight were born between May and October. For first-study infants, there were both monthly differences in birth weight ($F = 2.01$, $p = 0.03$) and differences in birth weight between infants born during warm (mean = 2.915 g) vs. cold (mean = 3.067 g) seasons ($t = 2.27$, $p = 0.025$). Although there were no differences in birth length, infants born during the warm season had significantly lower relative weights assessed by Rohrer's index (wt/13) compared to those born during the cold season ($t = 4.49$, $p < 0.01$). No significant effects of season on birth weight, birth length, or Rohrer's index were apparent among second-study infants
20	Bantje,[66] Tanzania	Cross-sectional	6140 singleton live births	S/M	Birth weight (g)	–	This study has shown that consistent seasonal variations in mean birth weight and incidence of low birth weight occur in a rural society mainly dependent on agriculture
21	Roberts et al.,[67] Gambia	Cohort	81 women and their infant	S/M	Birth weight (kg)	Sex	During the dry season from January–May the birth weight of infants rose gradually. The mean birth weight of children in May, adjusted for sex (male), from 1976 to 1980 was 3.31 kg. In June and July was observed a rapid fall in birth weight of 0–48 kg
22		Cohort	A total of 1,524,229 births	S/M	Birth weight (g)	–	

Table 2. continued

ID	First author name, ref./location	Type of study	Sample size, age group, gender	S/M*	Outcome and Scale use for assessing	Adjusted covariate	Main result
	Selvin and Janerich,[68] United States of America						The seasonal trend in birth weight was characterized by high weight infants born in the months of March, April, and May and significantly low-weight infants born in June, July, and August. This seasonal pattern was consistent for all birth orders with the exception of February
23	Salber and Badshaw,[69] African	Cross-sectional	The data were obtained from records of 3165 European, 1058 Colored, 2190 Bantu, and 1403 Indian births in Durban, Capetown, and Pietermaritzburg	S	Birth weight (g)	–	At birth ranks 1 and 2–5, there is no appreciable difference between the mean weights of summer- and winter-born babies in any of the four racial groups. At birth rank "6 and over," both male and female Indian babies born in the summer months are heavier than those born in the winter months, males by 0–52 ± 0–24 lb and females by 0 77 ± 0–22 lb, respectively. Results for Colored and Bantu babies of high birth rank are conflicting. The males of both these racial groups show no appreciable seasonal variation, but female Colored babies are 0 85 ± 0–32 lb heavier in the summer months and female Bantu babies are 0–44 ± 0 20 lb heavier in the winter months. The number of European babies of high birth rank is too small to permit a seasonal comparison
24	Li,[70] China	Cross-sectional	258 mothers and newborn	S/M	Birth weight (g)	Mother's age, nativity of mother, sex, and order of birth	The present study shows the existence of a reduction in birth weight in the winter and early spring months and an increase in the summer and early autumn months. The lowest mean occurs in February (2907 ± 44 g), while the highest is in July (3185 ± 68 g); the difference between these two extreme values is 278 ± 81 g, which is significant. The existence of the lowest birth weight in the cold months which increases as the warm weather advances, reaching its maximum during the hot months

S season, *M* months, *BMI* body mass index, *WC* waist circumference.

and 2. The association between month and season of birth with weight, height, and obesity is shown in Table 1, and characteristics of included studies on birth weight are presented in Table 2.

Included studies have been conducted in different countries across the world.

Effects of season and month of birth on weight, overweight, and obesity

In most studies, there was a significant relation between season/month of birth and intended outcome, but in two studies, no significant relationship was observed.[14,17] According to most studies, birth in the spring season (March) was associated with higher weight and overweight/obesity in both sexes.[3,7,18–21] However, several studies showed that those who were born in cold season (winter month) had higher BMI and weight.[5,22–25] Also, those born in March were associated with low weight and BMI, especially in boys, according to most studies.[14,18,23,26] According to the frequency of studies, the lowest weight and BMI were observed among girls who were born in December (Table 1; Supplementary Figs. S1 and S2).

Quality assessments of included studies were as follows:

The results of the quality assessment of the studies showed that the articles were generally of good quality. Only 11% of articles had scores of 4 and 5, and about 90% of papers received a score >5. Overall, 43% of articles had a score >7.

Effects of season and month of birth on child's height

Among all studies on height, in three studies, no significant relationship between season/month of birth and height was observed.[27–29] The occurrence of short stature in those who were born in cold seasons (winter) was more likely based on the frequency of studies. However, a study by Krenz-Niedbala et al.[30] showed that those who were born in cold season (born from October to April) were taller than those who were born from May to September. Also, studies by Henneberg and Louw[22] and Puch et al.[31] reported that short stature was more frequent among hot season-born individuals (Table 1 and Supplementary Figs. S3 and S4).

Effects of season and month of birth on birth weight

According to most studies, the occurrence of low birth weight was more frequent among infants born in summer than others. No pattern was observed for the association between high birth weight and season/month of birth (Table 2; Supplementary Figs. S5 and S6). Overall, only one study showed that season/month of birth was not associated with birth weight.[32]

DISCUSSION

This systematic review evaluated the relationship between season and month of birth on obesity, weight, and height and birth weight. Several studies have assessed the effects of season and month of birth on BMI categories. A study by Lv et al.[7] on 487,529 Chinese men and women reported that month of birth was independently associated with both BMI and WC. Birth months in which subjects had higher measures of adiposity were March–June for WC and March–July for BMI. The findings of this study suggest that adults born in spring and early summer had higher WC and BMI. A study in Hertfordshire, United Kingdom, indicated that men born after winters using average temperatures of December and January were more likely to have a higher BMI in adult life.[3] The Canadian study also reported seasonal effects on obesity in adult life, and subjects born in winter/spring were more likely to be morbidly obese (BMI ≥ 40 kg/m^2).[5] In another study, the effects of season of birth on adult WC and BMI were shown.[20] The season-of-birth pattern that has been most commonly described is higher rates of obesity in individuals born in winter–spring;[18,33] however, different patterns in different age cohorts have also been described.[5] One study that was conducted on Japanese school children (6–15 years) showed that, because of the increase in the number of adipose tissues during the cold conditions, birth weight and early exposure to cold conditions have an association with obesity during adulthood.[18]

Another study in 1322 children at the age of 8 years (born in 1999 and examined in 2007) showed that the ultraviolet B–vitamin D mechanism is responsible for the season-of-birth effect on later body size.[30] A previous study found adult obesity to be associated with low vitamin D during the second or third trimester of pregnancy.[34] Another study showed that there was a significant interaction of race by season of birth in the levels of weight gain in early infancy, and there was no relationship between season of birth and early infancy weight gain with sex, first-born status, birth weight, study site, or initiation of breastfeeding.[12] Other studies from Finland and the United Kingdom found no interaction between seasonal variation and adult BMI.[14,32] It is possible that the seasonality of birth in later BMI will emerge in adulthood and is not present in childhood; however, no previous study examined this. Only the Canadian study found no seasonal variation in BMI among children aged 12–19 years.[5] However, the study was cross-sectional and did not include a follow-up of the children later in life.

In the current study, we observed an association between season and month of birth with infant height. The occurrence of short stature in those who are born in cold seasons (winter) was more likely based on the frequency of studies. In a study among children aged 6–15 years in Tokushima, Japan, height gradually decreases until March (from spring to winter) and then increases from April, and reaches a peak in May or June; therefore, height was influenced by variation in month and season of birth.[18]

A study by Krenz-Niedbala et al.,[30] in Poland, among 1322 children aged 8 years showed that those who were born in cold season (born in October–April) were taller than those in May–September;[30] also, studies by Puch et al.[31] among 4672 girls aged 5–18 years, and Henneberg and Louw[22] among 1522 school children aged 6–18 years in Africa, showed that short stature was more frequent among individuals born in hot season. A study on children born in May through October was found to be lighter than those born in November through April. Another study on 562 girls and 546 boys in Bolivia demonstrated that children born during February–May (the rainy season) were shorter, while children born during the end of the dry season and the start of the rainy season (August–November) were taller.[23]

Various mechanisms may explain these effects, including changes in the force of gravity or electromagnetic field, global factors (e.g., the total amount of energy reaching the earth acting through ultraviolet-dependent production of vitamin D, hemisphere-related climatic conditions) (e.g., solar radiation, rainfall, hours of insolation, day length, and temperature), and other environmental factors (e.g., physical activity or nutrition) or cultural influences.[10,31] On the other hand, exposure to sunlight and in utero vitamin D exposure are the important mechanisms that can have an effect on season of birth and child's height. In the present systematic review, we observed that there is no pattern between birth weight and season/month of birth, and according to most studies, the occurrence of low birth weight was more frequent among infants who were born in summer than others.

Limitations of the study

Our review faces some limitations. Although controlled trials support the role of maternal 25(OH) vitamin D as the causal mechanism in the association of season of birth and birth weight,[35] controversial results are reported in other studies.[36,37] Therefore, it is likely that additional mechanisms specific to certain environments may also play a role, yet the physiological processes behind the resulting impact on birth weight remain unclear. Vitamin D is important for bone development and may act as a rate-limiting factor for growth. In accordance with the results of the studies in the present systematic review, births in winter and cold seasons may increase the risk of overweight and obesity in individuals. Although there are prospective and longitudinal (cohort) studies in the present systematic review, there are some factors that may affect the relationship between season and month of birth with birth weight and body size, such as air temperature and climate change.[38–40] Geographic differences, latitudes, and ethnic differences, as well as the possible role of confounding factors in the relationship between levels of sunlight exposure and subsequent levels of vitamin D should also be taken into account. Consequently, the exact determination of the relationship between exposure and outcomes of this review becomes difficult. In addition to the possible role of the above-mentioned factors, it may also be necessary to consider the cohort or even period effect to determine the relationship pathway between season and month of birth and BMI.[41–46] In spite of these limitations, this review provides comprehensive information on the association of season of birth with future weight status.

CONCLUSION

The results of the studies included in the present systematic review showed that children who were born in cold seasons have a higher BMI than those born in other seasons. However, given the possible role of confounding factors in the relationship between season and month of birth with birth weight and body size, we suggest assessing vitamin D levels and other potential confounding factors in future studies. The current findings should be confirmed by future longitudinal studies.

Effects of season and month of birth on weight, overweight, and obesity

This review showed that individuals who are born in cold season (winter month) have higher BMI and weight in childhood.

Effects of season and month of birth on child's height

We observed the relationship between season and month of birth with infant height. The occurrence of short stature in those who are born in cold seasons (winter) was more likely based on many studies.

Effects of season and month of birth on birth weight

All studies, except one of them, showed that season/month of birth was not associated with birth weight.

AUTHOR CONTRIBUTIONS

Z.H., R.K., and M.K.: substantial contribution to conception and design, acquisition of data, analysis, and interpretation of data. Z.H., M.K., R.R., S.S.D., and M.G.: drafting the paper or revising it critically for important intellectual content. Z.H., R.K., and M.K.: final approval of the version to be submitted. All authors contributed in making revisions, approved the final draft, and accepted the responsibility of the paper content.

ADDITIONAL INFORMATION

The online version of this article (https://doi.org/10.1038/s41390-020-0908-4) contains supplementary material, which is available to authorized users.

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