Structural Vulnerability Factors and Gestational Weight Gain: A Scoping Review on the Extent, Range, and Nature of the Literature

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Abstract

Background: Inadequate and excessive gestational weight gain (GWG) are rising epidemiological health concerns, affecting a substantial proportion of pregnant women in high-income countries and contributing to a multitude of adverse maternal and infant health outcomes. The aim of this scoping review was to identify key structural vulnerability factors (SVFs) related to GWG, and to examine the extent, range, and nature of the existing literature to inform future research.

Methods: Electronic searches were performed in October 2018 (updated in August 2019) in MEDLINE(R) ALL, EMBASE, PsycINFO, CINAHL, and Sociological Abstracts databases. Eligible studies had an observational design, had to be conducted before COVID-19, in a high-income country, have pregnant participants, and perform inferential statistics between an SVF and GWG.

Results: Of the 157 included articles, the eight SVFs most commonly studied in association with GWG were race/ethnicity (n=91 articles), age (n=87), parity (n=48), education (n=44), income (n=39), marital status (n=28), immigration (n=19), and abuse (n=12). Substantial heterogeneity across study contexts, methodologies, populations, and findings was identified. Studies spanned 22 high-income countries, were predominantly conducted in the USA (77%), and most studies (60%) had a retrospective design. Race/ethnicity was the most extensively studied factor, covering the longest time period (since 1976) and having the largest sample size, and the second-highest proportion of studies reporting a significant relationship with GWG (79%), following immigration status (95%).

Conclusions: Given the heterogeneity in findings across studies, adopting an intersectional approach may enhance our understanding of the complex interplay between SVFs and the

social context in relation to GWG. This nuanced perspective is critical for informing future research and developing effective strategies to address the pervasive perinatal health challenges associated with inadequate and excessive GWG.

Background

Inadequate and excessive gestational weight gain (GWG) have emerged as growing epidemiological health concerns affecting a substantial proportion of pregnant women in high-income countries (1–4). The prevalence of excessive GWG (47%) is notably higher than inadequate GWG (23%), as estimated among pregnant women across the United States, Europe, and Asia (3). The high prevalence of both extremes raises significant concerns, as they are associated with a wide range of adverse maternal and offspring health outcomes (2,3,5–11). In women, inadequate GWG is associated with gestational diabetes mellitus and greater risk of mortality (5,11), while in offspring it is associated with preterm birth, small for gestational age (SGA), and increased risk of perinatal death (2,3,5–7,9,11). Excessive GWG is associated with maternal preeclampsia, caesarian section, gestational diabetes, and mortality (2,3,5–11), as well as large for gestational age (LGA) offspring, macrosomia, and neonatal death (2,3,5–7,9,11).

One of the most prominent evidence-based guidelines defining adequate GWG ranges was established in 1990 and revised in 2009 by the Institute of Medicine (IOM) (12). These guidelines provide weight gain targets based on pre-pregnancy body mass index (BMI): women in the "normal" BMI category are recommended to gain 11.5-16.0 kg throughout their pregnancy, while women in the underweight category should gain more weight (12.7-18.2 kg), and women in the overweight or obese categories should gain less (2.7-6.4 or 5.0-9.1 kg, respectively) (12). The IOM guidelines have been widely adopted across the world, yet high rates of GWG outside recommended ranges persist, highlighting the need to enhance our understanding of the complexity of the determinants of GWG. In its 2009

guideline update, the IOM identified a lack of evidence on GWG among vulnerable populations, as well as disparities related to racial/ethnic and socioeconomic determinants of GWG (12).

To date, three reviews have explored some socioeconomic status (SES) and psychosocial factors associated with GWG. Campbell et al. (2016) conducted a narrative review examining the association between SES factors (i.e., childhood SES, income, neighbourhood, and rural vs. urban areas) and GWG with no mention of the type of study design, GWG guidelines used, or countries included (13). The review provided a high-level overview of studies published in English since 2000, citing one study per SES factor associated with GWG. The authors concluded that income, neighbourhood, and rural vs. urban areas influence GWG. Through a systematic review, O'Brien et al. (2018) examined observational studies focusing on the associations between SES factors (i.e., educational attainment, employment, income, social class, poverty, food security, and health insurance status) and GWG among pregnant adults according to the IOM 2009 guidelines, with no restrictions on countries (14). The review included 16 studies published in English between 2009 and 2016. The authors concluded that low educational attainment was generally associated with GWG outside the recommended range, although the results were mixed, with slightly more studies reporting significant associations (8/16) than no significant associations (6/16). Finally, Athar et al. (2021) conducted a scoping review of observational and experimental studies examining the association between various psychosocial factors (including intimate partner violence, lack of social support, financial distress, food insecurity, chronic stress and depression, eating disorders, and low self-esteem) and GWG

(15). They analyzed nine articles published in English between 2015 and 2020, with no restrictions on countries. The authors concluded that all the above-mentioned factors were associated with GWG. These narrative (Campbell), systematic (O'Brien), and scoping (Athar) reviews were limited in scope, covering from four to 16 articles each and focusing on publications from 2000 to 2020. There was also considerable variation in the definitions and selection of SES factors and psychosocial concepts, as well as in the design of included studies (observational and/or clinical studies or not specified), the GWG guidelines used, and the reviews' conclusions. Additionally, these reviews did not differentiate between the different contexts of low-, middle-, and high-income countries. Furthermore, two of the three reviews had significant flaws in their search strategies, such as poorly defined keywords, imprecise study selection methods, and a lack of clear inclusion/exclusion criteria.

To overcome these limitations and to address gaps highlighted in the 2009 IOM review, we conducted a comprehensive scoping review of 157 articles on the structural determinants of GWG among vulnerable populations in high-income countries. We drew on Bourgois et al.'s (2017) 'structural vulnerability' framework, which defines structural vulnerability as "*an individual's or a population groups' condition of being at risk for negative health outcomes through their interface with socioeconomic, political and cultural/normative hierarchies"* (16). Our review aimed to identify key structural vulnerability factors (SVFs) associated with GWG and explore the extent (volume of literature, countries and years of publication), range (variety of factors covered), and nature (study design and characteristics of assessed populations) of this body of research.

Methods

This scoping review drew on an adaptation of Arksey and O'Malley's framework (17,18) and used an iterative process for refining the research question and identifying the SVFs. An information specialist and the lead researchers collaboratively identified an *a priori* list of factors and keywords associated with the structural vulnerability framework (see **eTable 1)**. Psychological and biological factors were not included in our choice of factors. An initial compilation of SVFs was performed among the eligible studies during the selection process, which was then subjected to thorough analysis. This process resulted in the final identification of eight SVFs, namely race/ethnicity, age, parity, marital status, income, education, immigration status and abuse (physical, psychological, and sexual). For this review, race and ethnicity are understood as social constructs that are often employed as identifiers in research on health inequalities. These socially constructed categories have "true biological consequences through racism" (19). While both concepts are discussed together due to their overlapping meanings, we acknowledge their distinct significance in specific research contexts: ethnicity is often linked to a person's cultural identity, whereas race generally refers to broad categories of people divided based on ancestral origins and physical characteristics (20). Additionally, age is understood as an SVF, rather than merely a biological factor, as age-related stigma—particularly for pregnant adolescents—along with social policies that overlook age, can increase health risks associated with pregnancy (21).

Other SVFs, beyond the eight retained in our review, were also identified as being associated with GWG; these included employment and working conditions, adverse

childhood events, food security, social support, neighbourhood composition and characteristics, familial responsibilities, language preference, and opportunities for upward mobility. However, these SVFs were reported at a low frequency in the literature (one to six studies in total per factor) and were operationalized such that the findings were difficult to compare between studies. Therefore, these SVFs were not included in our analyses. Preferred Reporting Items for Systematic Reviews and Meta-Analysis Extension for Scoping Reviews (PRISMA-ScR) guidelines were used to ensure comprehensive reporting (22).

Inclusion Criteria

The articles included in this review needed to focus on pregnant women, with at least a subsample of women in each study having experienced one or more SVF. Studies were limited to those with an observational design (prospective, retrospective, or cross-sectional) that used inferential statistics to analyze the relationship between SVFs and GWG. Descriptive studies without statistical comparison were not included in this review. Only peer-reviewed articles published in high-income countries, as classified by the World Bank in 2018 (23), were considered. We limited our analysis to studies conducted in high-income countries to minimize variability arising from different social, cultural, and political contexts. Studies published in languages other than English or French, as well as conference abstracts, were excluded (see **Figure 1** for reasons of exclusion).

Search Strategy

Electronic searches were performed by an information specialist (coauthor KF) from inception of databases up to October 22nd, 2018, and updated August 1st, 2019 in MEDLINE(R) ALL (1946 to July 30th 2019, Ovid), EMBASE (1947 to July 30th, 2019, Ovid), PsycINFO (1806 to July Week 4 2019, Ovid), CINAHL (1976 to 2019, EBSCOhost), and Sociological Abstracts (1904 to 2019, Proquest). Studies were identified using a combination of each database's unique subject headings and keywords pertaining to SVFs and weight gain among vulnerable pregnant women. Databases' limits were used to remove non-peer-reviewed research when feasible (editorials, comments, letter to the editors) and a limit to English and French languages was applied when possible (see **eTable 2** for the search strategies). Exact duplicate records (n=4,508) were removed using the automatic feature in EndNote X9 (Thompson Reuters, San Francisco, CA, USA) and close duplicate records (n=15) were reviewed and removed manually.

The impact of the COVID-19 pandemic on SVFs, healthcare and community services, as well as health outcomes is widely documented (24–27). Including studies published during the pandemic would have required further consideration of context-dependent or timing-specific factors (e.g., confinement), thus further complexifying the analyses of the results. Therefore, the search strategy was not updated to include research from the COVID-19 period.

Selection Process

Covidence systematic review software (Veritas Health Innovation, Australia, 2019; available at www.covidence.org) was utilized for the study selection process (28). Initially,

all citations underwent title and abstract screening, followed by full-text screening of relevant articles, which was conducted independently by two reviewers at both stages of the process. Discrepancies related to the inclusion and exclusion of articles among reviewers were resolved by the lead researcher in consultation with the reviewers. To ensure consistency and coherence in the interpretation of citations and predetermined eligibility criteria, a calibration exercise was conducted with 75 articles prior to the title and abstract screening. Citations deemed irrelevant at the full-text stage were assigned an exclusion reason.

Data Charting and Synthesis

Data charting was undertaken in two phases. In the first phase, eligible articles were recorded in a pre-piloted Excel data charting file to extract relevant information, including the study characteristics, GWG assessment, SVF, and key findings related to GWG. The second phase was initiated after the selection of the final eight SVFs. In the data charting file, associations between each SVF and GWG were documented as "S" for significant, "NS" for non-significant, or left blank if the SVF was not assessed. When studies reported both significant and non-significant associations for a specific SFV due to variations between subgroups (e.g., non-significant relationship among normal weight participants but significant relationships among overweight and obese participants), the association was reported as "S & NS" in supplemental material and as significant in the "Results" section below. This approach aimed to ensure that the associations between SFVs and GWG among any subset of women were adequately represented in the review. When multiple statistical models with different adjustments were presented, the most adjusted model was kept for

data charting. The iterative process and multiple revisions of each article were instrumental in identifying the final eight factors and ensuring data accuracy.

The final Excel file, which contains the comprehensive data charting, includes information on the first author, year of publication, country, study design, information on GWG (measurement and guideline used), sample characteristics and size, key findings, additional notes, and references. The complete file is available in **eTable 3**.

Terminology associated with GWG

The terminology and reference values associated with GWG guidelines varied according to the publishing date and geographical context. In this review, the terms "inadequate" and "excessive" are used to describe GWG below or above GWG guidelines, respectively, while "adequate" is used to designate GWG that falls within guidelines.

Results

Selection of articles

Database searches using the identified criteria yielded 11,382 articles. Following duplicate removal, 6,874 articles were screened for titles and abstracts, 582 articles underwent full-text screening, and 157 articles were included in the final dataset (see **Figure 1** for details).

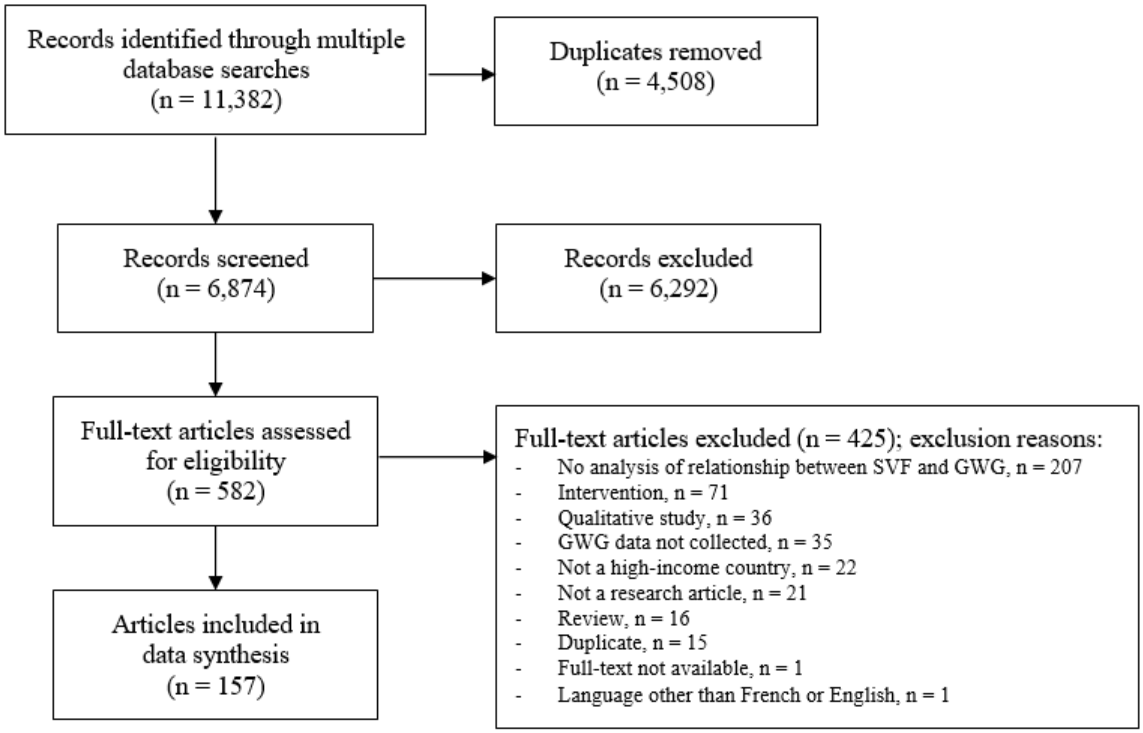

Figure 1. PRISMA flowchart illustrating the article selection process.

Synthesis of results

This review identified eight SVFs most frequently studied in relation to GWG: race/ethnicity (58% of articles), age (55%), parity (31%), education (28%), income (25%), marital status (18%), immigration (12%) and abuse (physical, psychological, or sexual; 8%). While the influence of race/ethnicity and age on GWG have been studied since the 1970s, other factors gained attention a decade or two later (e.g., 1980s for marital status, and 1990s for parity, income, education, immigration status, and abuse). The IOM 2009 guidelines (12) were the most commonly used, followed by the IOM 1990 guidelines (30). Other guidelines, such as those determined by a country's health department, were used in a small segment of studies. GWG was reported either as a continuous outcome or categorized and compared between groups of pregnant women (i.e., one group having a

236 higher or lower GWG than the other) or between GWG adequacy groups (i.e., inadequate,
237 adequate, excessive). The study samples ranged greatly in size, with 46 women in the
238 smallest study and nearly eight million women in the largest study. Most studies (60%) had
239 a retrospective design, 32% were prospective, and 9% were cross-sectional. GWG data
240 were retrieved from medical records (39%), birth certificates (20%), participant self-report
241 (20%), or measured by the study team (17%); five studies (3%) used two different methods
242 for collecting GWG data, and two studies (1%) did not clearly state their GWG collection
243 method. The characteristics of each study and their association with the eight SVFs are
244 shown in **eTable 3.** A synthesis of the studies examined is detailed below and presented in
245 **Table 1**.
246
247 **Table 1**. Summary of the literature exploring key structural vulnerability factors (SVFs)
248 associated with gestational weight gain (GWG).

Structural vulnerability factor	Number of studies assessing specific SVF	Countries of publication	Years of publication	Number of studies finding a significant association between the SVF and GWG (%)
Race/ethnicity	91	Australia, Belgium, Canada, Czech Republic, Ireland, Netherlands, New Zealand, Norway, Singapore, Spain, Sweden, Switzerland, USA,	1976 - 2019	72/91 (79%)
Age	87	Australia, Austria, Belgium, Canada, Ireland, Japan, Korea, Netherlands, New Zealand, Norway,	1977-2019	46/87 (53%)

		Saudi Arabia, Singapore, Slovenia, Sweden, Switzerland, Taiwan, USA		
Parity	48	Australia, Belgium, Canada, Korea, Netherlands, New Zealand, Singapore, Sweden, Switzerland, USA	1990-2019	38/48 (79%)
Marital status	28	Belgium, Canada, Sweden, USA	1985-2019	15/28 (54%)
Income	39	Canada, Korea, Netherlands, Singapore, USA	1995-2019	20/39 (51%)
Education	44	Belgium, Canada, Croatia, Korea, Netherlands, Norway, Spain, Sweden, USA	1992-2019	34/44 (77%)
Immigration status	19	Australia, Canada, France, Ireland, New Zealand, USA	1997-2018	18/19 (95%)
Abuse (physical, psychological, and/or sexual)	12	Iceland, Taiwan, USA	1996-2017	9/12 (75%)

***Race and ethnicity*.** Ninety-one out of the 157 included studies (58%) assessed the relationship between race/ethnicity and GWG (**eTable 4**). Seventy-two studies (79%) found a significant association between GWG and race/ethnicity, whereas 19 studies (21%) found no significant association. Studies were published from 1976 to 2019 and were conducted in the USA (75 studies, 82%), Canada (three studies, 3%), Australia, the Netherlands (two studies each, 2%), Belgium, Czech Republic, New Zealand, Norway, Singapore, Spain, Sweden, and Switzerland (one study each, 1%), and one study (1%) was conducted in multiple countries (New Zealand, Australia, and Ireland). The sample sizes ranged from 56 to 7,966,573 women. Twenty-eight studies (31%) included a population

that was primarily affected by an SVF (adolescents, women with a low income, unmarried women, and/or women from a racial/ethnic minority group). The most studied racial or ethnic groups were White, Black, and Hispanic, with 31 studies (34%) specifying both a woman's racial group and their Hispanic/non-Hispanic identity. One of the least represented groups was Indigenous women.

Age. Eighty-seven out of the 157 studies (55%) considered the association between age and GWG (**eTable 5**). Forty-six studies (53%) found a significant association and 41 studies (47%) found no significant association. A comparison of GWG between adolescents and adults was conducted in 36 of these studies, with 25/36 studies (69%) finding a significant association and 11/36 (31%) finding no significant association. Articles were published from 1977 to 2019 and took place in the USA (67 studies, 77%), Taiwan (3 studies, 34%), Canada, Japan, Korea (2 studies each, 2%), Australia, Austria, Belgium, the Netherlands, Norway, Saudi Arabia, Singapore, Slovenia, Sweden, Switzerland (one study each, 1%), and one study involved three countries (New Zealand, Australia, Ireland). Sample sizes ranged from 55 to 3,960,796 women; thirty-five studies (40%) were specific to women with an SVF (adolescents, women with a low income, women of a racial/ethnic minority group, unmarried women, low education, and/or multiparous women). Age was primarily assessed as a categorical variable, with a diverse range of age categories used (e.g., <25 years vs. ≥25 years; and <20 years, 20-29 years, 30-39 years, and ≥40 years). The age ranges defining adolescence varied between studies, with some studies categorizing women up to the age of 16 as adolescents, while others considered those up to the age of 19 as adolescents.

Parity. Forty-eight of the 157 studies (31%) examined the relationship between parity and GWG (**eTable 6**). Significant associations between these factors were reported in 38 studies (79%), while 10 studies (21%) reported no association. Publication years ranged from 1990 to 2019. Studies were conducted in the USA (37 studies, 77%), Canada, Sweden (two studies each, 4%), Australia, Belgium, Korea, the Netherlands, New Zealand, Singapore, and Switzerland (one study each, 2%). The smallest sample size was 55 women, whereas the largest was 2,976,805 women. Twenty-two studies (46%) had a population that primarily included women with an SVF (racial/ethnic minority group, adolescents, and/or women with a low income). The terms 'nulliparous' and 'primiparous' were often used to refer to women whose first delivery was examined in the study. The GWG of nulliparous or primiparous women was generally compared to that of multiparous women. A more in-depth assessment of parity was performed in 15 studies (31%), in which either more categories of parity were included (e.g., zero, one, two, three or more previous births) or parity was assessed as a continuous variable.

Marital status. Twenty-eight of the 157 studies (18%) assessed the association between marital status and GWG, with 15 studies (54%) finding a significant association and 13 studies (46%) finding no significant association (**eTable 7**). Studies were published between 1985 and 2019 in the USA (25 studies, 89%), Belgium, Canada, and Sweden (one study each, 4%). Sample sizes ranged from 101 to 251,342 women, with half of the studies involving a population affected by one or more SVF (women with a low income, a racial/ethnic minority group, multiparous, and/or adolescents). Categories used to assess

marital status varied between studies; the general categories of 'married' and 'unmarried' were commonly used, but some studies opted for more specific categories such as 'married/cohabitating with partner', and 'single/separated', or 'married/partnered', 'separated/divorced', or 'single/no partner'.

Income. Thirty-nine of the 157 studies (25%) examined the association between income and GWG (**eTable 8**). Twenty studies (51%) found a significant association, whereas 19 (49%) found no significant association. Article publication years ranged from 1995 to 2019. The studies were conducted in the USA (33 studies, 85%), Canada, Korea (two studies each, 5%), the Netherlands, and Singapore (one study each, 3%). The smallest sample size was 75 women and the largest was 515,148 women. Thirteen studies (33%) were restricted to a population that had one or more SVF (adolescents, women from a racial/ethnic minority group, and/or women with a low income). Studies seldom used the same income categories (e.g., $0-500, $501-1,000, and ≥$1,000; <$20,000 v ≥$20,000; or <100% of federal poverty line vs. >100% federal poverty line). Nearly half (18/39) of all studies used a proxy measure to assess a woman's income status (e.g., use of Medicaid, or enrollment in the Special Supplemental Nutrition Program for Women, Infants and Children (WIC) in the USA).

Education. Forty-four of the 157 studies (28%) examined the association between GWG and education level (**eTable 9**). Of these, 34 (77%) reported a significant association whereas 10 (23%) reported no significant association. Studies were conducted between 1992 and 2019 in the USA (33 studies, 75%), Sweden (three studies, 7%), Canada (two

328 studies, 5%), Belgium, Croatia, Korea, the Netherlands, Norway, and Spain (one study
329 each, 2%). The sample sizes ranged from 55 to 2,796,805 participants. Fifteen studies
330 (34%) were specific to women with an SVF (racial/ethnic minority group and/or women
331 with a low income). Education was measured as a continuous variable in three studies (7%),
332 with the remaining studies measuring education as a categorical variable. Categories varied
333 between studies, with some studies including only two categories (e.g., less than high
334 school vs. high school or more), and others including up to five categories (e.g., 0-8 years,
335 9-11 years, 12 years, 13-15 years, or ≥16 years of education).
336
337 ***Immigration status.*** Nineteen of the 157 studies (12%) assessed the relationship between
338 immigration status and GWG, with all but one finding significant associations between
339 these factors (**eTable 10**). Studies were published from 1997 to 2018 in the USA (14
340 studies, 74%), Canada (three studies, 16%), France (one study, 5%), and one study (5%)
341 included multiple countries (New Zealand, Australia, and Ireland). The smallest sample
342 size was 46 women and the largest was 250,857. Nine studies (47%) were limited to women
343 with an SVF (racial/ethnic minority group, adolescent, and/or low-income). Approximately
344 half of the studies considered immigration status as a dichotomous variable (i.e., born in
345 their country of residence or foreign-born), and six studies (32%) categorized women
346 according to their length of time in their country of residence (e.g., US-born, lived in the
347 USA ≥10 years, lived in the USA <10 years). In all six studies, the length of time since an
348 women's immigration had a significant effect on GWG.
349

Physical, psychological, and sexual abuse. Twelve of the 157 studies (8%) considered the association between experiencing abuse and GWG (**eTable 11**). Nine studies (75%) found a significant association and three (25%) found no significant association. Studies were published from 1996 to 2017 in the USA (10 studies, 83%), Iceland, and Taiwan (one study each, 8%). Sample sizes ranged from 337 to 251,342 women. Half of the studies included a population with one or more SVF (adolescents, low-income, and/or racial/ethnic minority group). Studies primarily assessed the impact of physical abuse on GWG, but sexual and psychological abuse were also examined. The timing of abuse (e.g., during childhood, before pregnancy, or during pregnancy) and perpetrator of abuse (e.g., intimate partner) were considered in some studies.

Discussion

This scoping review, focusing on the pre-COVID-19 pandemic period, highlights the extent, range, and nature of the literature on SVFs and GWG in high-income countries. We identified eight SVFs that were most commonly explored in 157 observational studies published between 1976 and 2019 across 22 countries. Most studies were conducted in the USA, used a retrospective design, and examined diverse populations in which a subgroup or the entire sample experienced one or more SVFs. Among all SVFs examined, race/ethnicity was the most extensively studied, with research spanning the longest period (1976-2019) and involving the largest sample size (n=7,966,573). Race/ethnicity had the second-highest proportion of studies reporting a significant relationship with GWG (n=72/91, 79%), surpassed only by immigration status (significant association in n=18/19

studies, 95%). This review also demonstrates a substantial heterogeneity in study contexts, methodologies, populations, and findings, posing a challenge for determining clear trends in the associations between SVFs and GWG across studies. The following sections compare our findings with previous reviews and identify key challenges and considerations for future research.

1. Comparison with previous reviews

Similar to the findings of Campbell et al. and Athar et al. (13,15), who reported a high prevalence of association between their studied vulnerability factors and GWG, we found that the majority of studies reported significant associations between SVFs and GWG. The proportion of articles in our review reporting significant associations ranged from 51% for those assessing the relationship between GWG and income, to 95% for those examining the association with immigration status. This contrasts with O'Brien et al. (14), who concluded that only low educational attainment was associated with GWG. However, O'Brien et al. also reported mixed results, with eight out of 16 studies showing significant associations and six showing non-significant associations. Our review also further expands the list of vulnerability factors known to influence GWG, adding the concepts of race/ethnicity, age, parity, marital status, immigration, and abuse to the factors previously identified by Campbell, Athar, and O'Brien.

2. Collecting, analyzing, and comparing GWG

Several methodological challenges need to be acknowledged when comparing a wide breadth of studies examining inadequate GWG. First, there is substantial heterogeneity in the way that GWG was collected: close to 60% of studies extracted information on GWG from medical records or birth certificates, while most of the remaining studies relied on measurements by researchers or self-reported data. Second, guidelines used to categorize GWG adequacy varied between studies: the most commonly used were the IOM 2009 guidelines, followed by the IOM 1990 guidelines. In fewer than 10% of studies, other GWG guidelines were applied such as guidelines determined by a country's health department. The use of different guidelines may lead to misclassification of adequate GWG between studies. Third, statistical analyses used to assess the relationship between SVFs and GWG differed between studies, where some examined the influence of SVFs at a superficial level comparing frequencies of inadequate GWG among different groups of women (e.g., vulnerable vs. less vulnerable), while others performed more in-depth analyses using multivariable models with covariate adjustment (e.g., odds of excessive GWG for a racial/ethnic minority group compared to White, adjusted for age, income, education, etc.). As such, confounding variables and covariates were not always controlled for or comparable between studies. Furthermore, comparator groups varied with some studies comparing the likelihood of inadequate GWG to two distinct groups (e.g., adults vs. adolescents), while others assessed it within the same group of women (e.g., likelihood of excessive vs. adequate GWG among adolescents).

Finally, most studies (60%) used a retrospective design, which comes with certain limitations, including a lack of control over data collection tools and methods, as well as potential biases related to the selection of participants, recall of information, and

confounding factors (31). This heterogeneity in data collection methods, guidelines application, and analytical approaches limits the ability to draw direct associations between SVFs and inadequate GWG across different groups of women.

3. ***Defining, categorizing, and comparing structural vulnerability factors***

Differences in definitions and categorizations of each SVF add complexity when comparing study findings. Inconsistencies arose in the definition of SVF constructs across studies, often treating groups as equivalent without considering their social context (e.g., equating 'single' and 'unmarried' women in relationship status comparisons). Additionally, many SVFs have been analyzed as continuous or categorical variables, with differing thresholds and reference groups used across studies. For example, the relationship between age and GWG was analyzed using total years of age or categories such as adults and adolescents (with varying cut points for adolescent and adult age groups). Parity was occasionally examined as a continuous variable, yet most studies dichotomized this SVF into nulliparous and multiparous groups. Income measurements included total household income, percentage of federal income, and poverty-to-income-ratio, while education was reported as total years of education in some studies, and categorized by the highest level of educational attainment in others. The choice of categories may not only affect the observed relationship between the SVF and GWG, but also influences the representation of smaller or more marginalized groups of women, particularly in the case of race/ethnicity. For instance, the relationship between Indigeneity and GWG was not prominently reported in the studies included in our review. Indigenous women were often either excluded from studies (e.g., Cavicchia et al., (32)), or were grouped in with other racial/ethnic groups

(e.g., Headen et al., (33)). These systematic differences in definitions, categorization, and representation inevitably compromise the ability to generate clear comparisons between studies and subsequently to determine the association between each SVF and GWG.

4. Intersectionality and vulnerability

The complexity of analyzing intersecting and overlapping social identities, along with diverse contextual, situational, and geographical factors, contributes to the heterogeneity in defining, categorizing, and comparing SVFs associated with GWG. These socially constructed vulnerability factors are experienced concomitantly and cannot be easily disentangled (34,35). The intersectional paradigm presents methodological challenges, including selecting appropriate statistical methods, in the study of inequality (36).

Quantitative researchers should be sensitized to the importance and complexity of considering multiple interacting dimensions of social identities that may be relevant in their specific domain (37). Among the studies included in our review, Holowko et al. (38) reflected intersectional considerations in their investigation of the social patterning of GWG in a woman's first and second pregnancy, for example by testing the interaction between education and GWG in these sequential pregnancies. However, in other studies, the application of an intersectional approach (e.g., interactive or additive effect of SVFs on GWG) remained uncommon. This is consistent with Bohren et al.'s 2024 scoping review on maternal health, which found that no clinical interventions adopted an intersectional approach, relying instead on unidimensional measures of vulnerability factors (39). These findings reiterate the need for more intersectional research in the field of perinatal health.

The intersectional lens encourages moving beyond oversimplified approaches when analyzing vulnerability factors that shape pregnancy experience and health outcomes (39). Although this approach can be complex, it could provide a clearer understanding of within-group diversity and the synergies that produce health inequalities (39). For example, a pregnant adolescent might simultaneously face low educational attainment, single marital status, and low income. Trying to isolate the most impactful factor on GWG oversimplifies their interconnectedness within a person's biography and social context. Huynh et al. demonstrated that excessive GWG was more likely to be experienced by educated Hispanic, and less likely among educated White women, but more common among educated women living in a low or medium socioeconomic neighbourhood (40). By studying the combination of SVFs with an intersectional approach, we can gain insight into health disparities and better predict the combination of factors, contexts, or living circumstances that place women at greater risk of GWG outside the recommended range.

5. ***Varying Social Contexts of Vulnerability Factors***

While all studies in this review took place in high-income countries, the social, economic, cultural, structural, and political contexts nevertheless vary significantly. For instance, comparing women from different regions of the United States is not equivalent to comparing women between the United States and Japan. Factors like a woman's racial and ethnic identity are influenced by the social environment, impacting the extent of discrimination or racism she may face. Moreover, the health disparities resulting from immigration depend on factors such as the woman's country of origin, age at immigration,

and the duration since immigration, but these aspects are often overlooked in GWG research. These differences inevitably constrain the comparison of GWG when assessing studies on a global scale. For the least studied Indigenous groups, a study may consider other factors such as historical, geographical, and sociopolitical factors. Many of these factors are recognized to be the underlying causes of health inequality through the unequal allocation of power and resources (41), far surpassing the realms of factors such as age, race/ethnicity, income, and parity. Given these circumstances, it becomes evident that comparisons within specific countries and regions may provide a more accurate portrayal of the association between SVFs and GWG, as this approach enables the consideration of the distinct contextual nuances at play.

Strengths and Limitations of the Scoping Review

This scoping review stands out for its comprehensive inclusion of a substantial range of articles featuring varying populations, methodologies, and statistical approaches. An iterative process was used to refine the research question and identify the final eight SVFs related to GWG. SVFs were developed based on Bourgois' structural vulnerability framework, and the keywords and search strategy were thoroughly developed by a university librarian (KF) in collaboration with our multidisciplinary research team. To maximize the breath of our search strategy, we used more than 50 keywords and their related terms (see eTables 1 and 2). In contrast, Athar et al. used a single keyword (psychosocial factors) (15), Campbell et al. used "socioeconomic or SES," (13) and O'Brien et al. used 13 keywords to define SES (14). Furthermore, our inclusion and exclusion criteria were clearly outlined, unlike Campbell et al., who did not report any

criteria (13). Our study also included a broader range of populations than previous reviews; for instance, O'Brien et al. excluded adolescent pregnancies and restricted their review to singleton pregnancies (14), while Athar et al. excluded women with preexisting psychiatric or physical comorbidities (15), while our review did not have these exclusion criteria. By focusing on complex relationships between SVFs and GWG, this scoping review identified possible barriers for research aiming to link independent SVF with GWG, as typically done in systematic or meta-analysis reviews.

Nonetheless, we acknowledge certain limitations. Articles from 2020 and beyond were not included in this review due to the pandemic's unique context. However, including more recent research would likely highlight the importance of intersectionality, especially considering the individual, social, and economic impacts of COVID-19. Studies conducted in low- or middle-income countries were also excluded due to the significant variations in the impacts of SVFs on GWG across vastly different contexts. Consequently, our findings are limited to more affluent environments. Finally, our choice to draw on a broad scope of articles limited the ability to determine the direction of the associations between each SVF and GWG, as inconsistencies between articles regarding many aspects, such as their population characteristics, use of subgroups, and categorization of variables, made the data unsuitable for direct comparison.

Conclusion

This scoping review examined the extent, range, and nature of published associations between eight most commonly studied SVFs and GWG in high-income countries before the COVID-19 pandemic. The review highlights the substantial heterogeneity across study

contexts, methodologies, populations, and findings, presenting a challenge for identifying clear trends between SVFs and GWG. In light of this variability, and in line with O'Brien et al. (14), we suggest that future studies put an emphasis on prospective and objective measures of weight gain during pregnancy. Furthermore, we recommend that subsequent reviews prioritize the synthesis of information from studies conducted with comparable social contexts, populations, and methodologies. Finally, we suggest researchers consider the guiding principles of an intersectional approach by studying clusters of SVFs to better understand how individual characteristics, living conditions, and social contexts collectively influence GWG. Such an approach may help develop a more detailed understanding of the relationship between SVFs and GWG and facilitate the identification of subgroups of women who are at higher risk of inadequate or excessive GWG. This information can be used by healthcare professionals, service providers, and policymakers to help optimize GWG and promote maternal and child health.

List of abbreviations: Gestational weight gain (GWG), Institute of Medicine (IOM), Socioeconomic status (SES), Structural vulnerability factor (SVF)

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performed the literature search; SO contributed to the design of the review and reviewing the manuscript; ASM contributed to the design of the review and reviewing the manuscript; BFB contributed to the design of the review, solving the conflicts, supervised the conduct of the review and to writing the manuscript. All authors read and approved the final manuscript.

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Supplementary Information

All supplementary material can be found on Zenodo: DOI 10.5281/zenodo.13311640

1. eTable 1: Supplemental Table 1. Structural vulnerability factors* used for database searches and study screening for a scoping review on the association between structural vulnerability factors and gestational weight gain.

2. eTable 2: Supplemental Table 2. Search strategy used for each database to identify articles that assessed the relationship between structural vulnerability factors and gestational weight gain.
3. eTable 3: Supplemental Table 3. Data charting for all studies included in the scoping review.
4. eTable 4: Supplemental Table 4. Data charting for all studies assessing the association between race/ethnicity and GWG.
5. eTable 5: Supplementary Table 5. Data charting for all studies assessing the association between age and GWG.
6. eTable 6: Supplemental Table 6. Data charting for all studies assessing the association between parity and GWG.
7. eTable 7: Supplemental Table 7. Data charting for all studies assessing the association between marital status and GWG.
8. eTable 8: Supplemental Table 8. Data charting for all studies assessing the association between income and GWG.
9. eTable 9: Supplemental Table 9. Data charting for all studies assessing the association between education and GWG.
10. eTable 10: Supplemental Table 10. Data charting for all studies assessing the association between immigration and GWG.
11. eTable 11: Supplemental Table 11. Data charting for all studies assessing the association between abuse and GWG.