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# Epidemiology and morbidity of spina bifida in Hispanic Americans: a systematic review

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## ABSTRACT

**Objective** To comprehensively describe the epidemiology and morbidity of spina bifida in Hispanic Americans and identify risk factors associated with the increased prevalence of spina bifida.

**Design** A systematic review was conducted in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.

**Data sources** Three databases (MEDLINE, Embase and Scopus) were searched between inception of the database and June 2023. Study designs included case–control, descriptive, cross-sectional and databases.

**Eligibility criteria** Observational and experimental analytical studies reporting epidemiology or morbidity of spina bifida in Hispanic Americans or Latinx individuals were eligible.

**Data extraction and synthesis** Data were extracted independently by authors. Descriptive analysis was used to summarise findings.

**Results** Of 392 publications, 32 studies met inclusion criteria. Study periods ranged from 1955 to 2020. A total of 50 382 patients with spina bifida were included and 13 209 identified as Hispanic American (26.2%). Five studies report higher prevalence of spina bifida at birth per 10 000 births in Hispanic Americans compared with non-Hispanic white individuals, while one reported no significant difference (2.11 vs 2.24). Risk factors associated with spina bifida included prenatal exposures, sociodemographic factors and maternal clinical characteristics. Lower levels of maternal education, age and income were associated with an increased risk of spina bifida. Eleven papers found spina bifida had high morbidity among Hispanic Americans resulting in high financial, physical and socioeconomic impacts. There was high study heterogeneity that can be explained by the varying time periods and geographical distribution.

**Conclusion** Increased prevalence and morbidity of spina bifida in Hispanic Americans are due to a variety of interrelated factors relating to existing health disparities. High heterogeneity across the studies suggests a need for future studies and increased standardisation of reporting guidelines.

### WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Numerous studies have established Hispanic American race/ethnicity as a risk factor for spina bifida and have examined various risk factors to explain the increased prevalence in Hispanic Americans.
⇒ There are no existing systematic reviews examining the epidemiology and morbidity of spina bifida in Hispanic Americans.

### WHAT THIS STUDY ADDS

⇒ A comprehensive overview of risk factors for spina bifida in Hispanic Americans.
⇒ Updated prevalence of spina bifida by race/ethnicity and a discussion of the morbidity of spina bifida in Hispanic Americans.

### HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Further studies are necessary to fully delineate the driving factors behind the increased prevalence and morbidity of spina bifida in Hispanic Americans.
⇒ Changes to prevention efforts, such as folate fortification policies, are needed to address the increased prevalence in Hispanic Americans.

## INTRODUCTION

Spina bifida is a leading cause for paediatric disability, resulting in motor and development delays, functional complications and shunt dependency, which ultimately leads to a diminished quality of life.[1] This congenital malformation results from incomplete embryonic neural tube closure by the 25th day of gestation.[1] Severity is dependent on the size and location of the spinal deformity. From 1999 to 2007, spina bifida neonatal mortality rate (NMR) in the USA was 1.6 per 100 000 live births.[2] Of note, pregnancies impacted by spina bifida often result in elective termination rather than live birth or fetal death, skewing both NMR and prevalence of this birth defect.[3]

Approximately 1427 babies are born with spina bifida annually in the USA despite the highly preventable nature of the malformation.[4] Cases of spina bifida that are attributable to inadequate serological levels of folic

acid represent the leading phenotype of incomplete neural tube closure and can be prevented by oral intake of 400 µg of folic acid daily beginning 3 months prior to pregnancy.[5] To help prevent spina bifida caused by inadequate levels of folic acid, the US Food and Drug Administration (FDA) required mandatory fortification of grain products with folic acid in 1998. This initiative coupled with improvements in prenatal vitamin supplementation access, fetal medicine and screening, and establishment of educational programmes resulted in a 34% reduction in spina bifida prevalence in the USA.[6]

Despite ongoing reductions in spina bifida prevalence across the USA, Hispanic Americans continue to have a high birth prevalence of spina bifida. Data from national birth defect registries reported a birth prevalence of 3.8 per 10 000 Hispanic American live births, compared with 3.09 per 10 000 non-Hispanic white (NHW) births.[7] The birth prevalence of spina bifida was inconsistent among races/ethnicities pre-fortification and post-fortification of grain products with folic acid, suggesting these prevention methods may not be appropriately designed to impact Hispanic Americans.[8] Prompted by this persistent cultural disparity, the US FDA approved voluntary folic acid fortification of corn masa flour products in 2016 to target traditional Hispanic American diets.[9] Optimistic projections predicted the mandate would increase average folic acid intake among Hispanic American women by 21%. However, the approved legislation has not yet shown a substantial impact on either the prevalence of spina bifida or consumption of folic acid among Hispanic American women of reproductive age.[10 11]

There is a lack of literature summarising factors that contribute to this disparity of spina bifida in Hispanic Americans. Identifying risk factors that could serve as targets for population interventions is crucial. Thus, a systematic review was conducted aiming to describe the prevalence, aetiological determinants and consequential morbidity of spina bifida within Hispanic Americans. The summarisation of these data suggests potential avenues for future research to address the high birth prevalence and morbidity of spina bifida in Hispanic Americans.

## METHODS

A systematic review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to determine the prevalence and morbidity of spina bifida in Hispanic Americans.[12] PubMed MEDLINE (National Library of Medicine), Embase (Elsevier) and Scopus (Elsevier) were searched on 22 June 2023 using keywords associated with spina bifida and Hispanic Americans or Latinx individuals (see online supplemental table 1 for a full list of search terms). Latinx was included in the search terms as a contemporary gender-neutral or non-binary alternative to Latino or Latina to ensure inclusion of all potential studies. No language, date or article type restrictions were applied, and this protocol was not registered.

After the initial search, duplicates were excluded, and the remaining articles were screened for relevance by title and abstract. Articles progressing to full-text review were screened for final inclusion based on the following prespecified inclusion criteria (see online supplemental table 2): (1) published in or translated into the English language, (2) available full text, (3) population of patients with spina bifida or fetal evidence of spina bifida who identify as Hispanic American in the USA and Canada, (4) provided outcomes of epidemiology and morbidity. No studies were excluded based on language (Spanish or English) if they met the inclusion criteria. Deduplication was performed using EndNote (Clarivate Analytics, Philadelphia, Pennsylvania, USA) and unique articles were screened using Rayyan (https://rayyan.qcri.org/). This systematic review was conducted independently by two reviewers (SA and MV) and disagreements were resolved based on discussion.

Data from included studies were extracted independently by authors (SA and MV) and cross-checked for accuracy. Included articles were reviewed for the following data elements: bibliographical data, study design, number of participants, and outcomes—birth prevalence, risk factors, effect of fortification, morbidity and mortality. Each paper was grouped into two primary variables: population-based estimates (prevalence) and risk of spina bifida (proportion of spina bifida among reported study population). We also evaluated secondary variables including risk factors and morbidity. Risk factors were defined as sociodemographic, cultural, clinical and environmental factors that may correlate with an increased risk of spina bifida. Morbidity was defined as the need for surgical procedures and impact of spina bifida on quality of life.

Descriptive analysis was performed in Microsoft Excel. Percent of Hispanic Americans was calculated using the number of mothers of Hispanic American children diagnosed with spina bifida (HSB) over the total number of patients with spina bifida. Percent Hispanic American inclusion was calculated using only studies including both non-Hispanic and Hispanic American patients then calculated as number of Hispanic American patients over total number of patients of all races. NHW and other races/ethnicities were calculated in the same manner.

Critical appraisal of included studies included risk of bias assessment using the Risk of Bias in Non-randomized Studies-of Exposure tool and quality assessment using the Grading of Recommendations Assessment, Developmental and Evaluation (GRADE) framework. Each study was assessed independently by two reviewers (SA and MV). Disagreements were resolved by a third reviewer through a consensus.

### Study design

Multiple databases were used in the manuscripts included. Study design was determined based on individual manuscript data, and design cited in the manuscript was given priority. For studies included in the systematic review that

used secondary data analysis from existing databases, the design was recorded as retrospective regardless of the design of the data source. Data source descriptions are listed in online supplemental table 3.

### Patient and public involvement

Patients or the public were not involved in the design, conduct, reporting or dissemination plans of this research study.

## RESULTS

A total of 392 articles were identified: 101 from PubMed, 168 from Embase and 123 from Scopus. Through the deduplication process, 123 duplicates were removed. Out of 269 articles screened by title and abstract, 74 articles met the full-text review criteria, of which, 32 were included in this review (see online supplemental figure 1 for PRISMA full-text selection flow chart). Five studies were excluded due to overlapping populations (see online supplemental table 4). The excluded studies overlapped with studies meeting the final study criteria and were selected for exclusion based on date of publication and data elements reported. The majority of studies performed retrospective secondary analysis using data collected from existing databases. Four studies used data sourced from external databases to identify participants and perform subgroup analysis, creating a case–control or cross-sectional study.[13–16] For example, the National Birth Defects Prevention Study (NBDPS) represents a large, population-based, multicentre case–control study of major birth defects in the USA. The NBDPS database was used by some studies for secondary data analysis only.[17–19] Other studies used the NBDPS database to perform qualitative analysis.[15 16] Study design and characteristics are shown in table 1.

Study periods ranged from 1955 to 2020; 6.25% of studies (n=2) included data from <1990, 3.13% (n=1) from <1990 to 1998, 62.5% (n=20) from <1997 to >1998, 28.1% (n=9) from >1998 only. All included studies reported a total of 50 382 participants diagnosed with spina bifida and 13 209 mothers of HSB. Participants identifying as Hispanic American comprised of 26.2% of the total study population. Hispanic American inclusion in multirace studies was 28.2%, with 55.7% NHW and 16.1% other races/ethnicities. The overall risk of bias in this study was low. The overall quality of evidence was moderate as per the GRADE recommendations; the lack of randomised control trials reduced the overall categorisation of quality of evidence.

### Prevalence

The overall prevalence and prevalence of spina bifida pre-fortification and post-fortification of grain products with folic acid are shown in table 2, grouped by Hispanic Americans and NHW.

Five studies reported the birth prevalence of spina bifida in Hispanic Americans and NHW.[3 8 17 20 21] Four of these studies reported higher birth prevalence per 10 000 births in Hispanic Americans compared with NHW; Boulet *et al* reported no significant difference (2.11 vs 2.24).[3 8 17 20 21] There was high study heterogeneity that can be explained by the varying time periods and geographical distribution.

Three studies reported the birth prevalence per 10 000 births of spina bifida in Hispanic Americans and NHW individuals pre-folate and post-folate fortification of grains in 1998.[8 18 22] Each paper reported a decrease in both groups following fortification. Two studies, Canfield *et al* and Williams *et al*, noted the Hispanic American birth prevalence remained higher (3.80, 4.18) than in NHW (3.2, 3.37) following fortification.[22 23] Boulet *et al* reported no significant difference in Hispanic American (1.90) and NHW (2.11) birth prevalence. Canfield *et al* and Williams *et al* reported higher prevalence ratios (post/pre-fortification) in NHW (0.65 (0.69–0.72) and 0.66 (0.60–0.73)) compared with Hispanic Americans (0.6 (0.51–0.71) and 0.64 (0.56–0.74)); however, this was not statistically significant.[18 22] Seven studies discussed the influence of the folic acid fortification mandate on the prevalence of spina bifida; the majority of studies demonstrated a decline in prevalence post-fortification.[8 22–27] Three studies reported a 33–40% decrease in HSB cases post-fortification; Williams *et al* and Robbins *et al* reported a 13–34% reduction in NHW spina bifida cases post-fortification.[22 23 27]

### Risk factors

Included articles investigated risk factors among Hispanic Americans leading to spina bifida. The most common categories included maternal exposures, sociodemographic factors and maternal clinical factors. Sociodemographic characteristics of mothers of HSB compared with NHW mothers are shown in table 3.

On average, studies reported 14.6% of HSB mothers were younger than 20 years of age, 30.9% were 20–24, 30.4% were 25–29 and 26.3% were 30–35 years old.[14 18 28] Low education attainment in Hispanic Americans was also discussed as a risk factor for spina bifida; 45.2% completed 0–11 years of education, 35.2% obtained a high school degree and 21.2% completed more than 13 years of education.[14 18 28] Relative to mid-range household incomes, a higher risk of spina bifida was observed for annual household incomes of $20 000–29 000 compared with incomes greater than $40 000.[18] Canfield *et al* reported 60.9% of HSB families have an annual income of less than $19 000, 19.0% report $20 000–29 000, 5.7% report $30 000–39 000, and 3.4% report $40 000 or greater.[18]

Select studies also discussed the complex relationship between acculturation, immigration and their impact on spina bifida (table 4).

Immigration was consistently identified as a risk factor for spina bifida with 100% of the study population originating from Central and South America. Aggregated data from included manuscripts found 39.2% of Hispanic American mothers were US born and 55.6% were foreign

**Table 1** Study characteristics

| Study | Study design | Data source* | Years included | N (HA) | N (total) | Outcomes reported |
|---|---|---|---|---|---|---|
| Agopian *et al*[17] | Retrospective | NBDPS | 1997–2005 | 316 | 923 | Prevalence |
| Au *et al*[58] | Case–control | Multicentre hospitals | 1955–2008 | 397 | 865 | Prevalence, risk factors |
| Boulet *et al*[8] | Retrospective | National Vital Statistics System | 1995–2005 (1997–1998 excluded) | 1437 | 6901 | Prevalence, pre/post-fortification |
| Brender *et al*[30] | Case–control | Texas Neural Tube Defect Project | 1995–2000 | 741 | 741 | Prevalence, risk factors |
| Canfield *et al*[20] | Retrospective | Single-county records | 1989–1991 | 18 | 32 | Prevalence |
| Canfield *et al*[23] | Retrospective | NBDPN | 1995–2000 (1997–1998 excluded) | 535 | 2630 | Prevalence, pre/post-fortification |
| Canfield *et al*[59] | Retrospective | NBDPN | 1999–2001 | 309 | 917 | Prevalence |
| Canfield *et al*[18] | Retrospective | NBDPS | 1997–2003 | 174 | 473 | Prevalence, risk factors, morbidity |
| Carmichael *et al*[29] | Combined descriptive and cross-sectional | Multicounty records | 1999–2003 | 128 | 172 | Prevalence, risk factors, morbidity |
| Chowanadisai *et al*[32] | Cross-sectional | Single-centre clinic | 2010–2011 | 27 | 70 | Prevalence, morbidity |
| Eldridge *et al*[24] | Retrospective | Single-centre clinic | 1981–1995, 1999–2013 | 75 | 145 | Prevalence, pre/post-fortification |
| Foy *et al*[36] | Retrospective | NSBPR | 2000–2019 | 29 | 205 | Prevalence, morbidity |
| Harbert *et al*[37] | Case–control | Single-centre hospital | 2015–2020 | 13 | 96 | Prevalence, morbidity |
| Hoang *et al*†[16] | Case–control | NBDPS | 1997–2009 | 103 | 318 | Prevalence, risk factors, morbidity |
| Kamath *et al*[33] | Retrospective cohort | Multicentre hospitals | 1998–2010 | 75 | 161 | Prevalence, morbidity |
| Kshettry *et al*[34] | Retrospective | NIS | 1988–2010 | 748 | 2683 | Prevalence, morbidity |
| Lavery *et al*[31] | Case–control | Texas–Mexico border counties | 1995–2000 | 84 | 84 | Risk factors |
| Liptak *et al*[48] | Retrospective | National Longitudinal Transition Study 2 | 2000–2005 | — | 130 | Morbidity |
| Mai *et al*[25] | Retrospective | NBDPN | 1992–2016 | 691 | 2593 | Prevalence, pre/post-fortification |
| Mitchell[60] | Combined descriptive and cross-sectional | Spina Bifida Research Resource | 1997–2006 | 40 | 534 | Prevalence |
| Orr *et al*†[13] | Nested case–control | CBDMP | 1983–1988 | 164 | 221 | Risk factors |
| Padula *et al*†[14] | Combined descriptive and cross-sectional | CBDMT | 1997–2006 | 94 | 94 | Prevalence, risk factors |
| Parker *et al*[26] | Case–control | Single-centre clinic | 1976–2011 | 110 | 1164 | Prevalence, pre/post-fortification |
| Parks *et al*[3] | Retrospective database | TBDR | 1999–2005 | 530 | 954 | Prevalence, burden |
| Ramadhani *et al*†[15] | Case–control | NBDPS | 1887–2003 | 1114 | 1114 | Risk factors |
| Robbins *et al*[27] | Retrospective | AHRQ, HCUP, NIS, KID | 1993–2002 | — | 10 000 | Morbidity |
| Rocque *et al*[61] | Cross-sectional | Single-centre clinic | 2016–2020 | 10 | 117 | Morbidity |
| Shin *et al*[19] | Retrospective | NBDPS | 1979–2003 | 1601 | 5165 | Prevalence, morbidity |

Continued

**Table 1** Continued

| Study | Study design | Data source* | Years included | N (HA) | N (total) | Outcomes reported |
|---|---|---|---|---|---|---|
| Shumate *et al*[28] | Retrospective | TBDR | 1999–2014 | 1172 | 1846 | Prevalence, risk factors |
| Smith *et al*[35] | Retrospective | NSBPR | 2009–2015 | 1092 | 4364 | Prevalence, morbidity |
| Strassburg *et al*[21] | Retrospective | Los Angeles County Records | 1973–1977 | 101 | 202 | Prevalence, risk factors |
| Williams *et al*[22] | Retrospective | NBDPN | 1995–2002 | 1281 | 4468 | Pre/post-fortification |

*See online supplemental table 3 for a detailed description of the data source.
†Studies used pre-existing retrospective or prospective databases in conjunction with subgroup analysis.
AHRQ, Agency for Healthcare Quality and Research; CBDMP, California Birth Defects Monitoring Program; CBDMT, California Center of the National Birth Defects Prevention Study; HA, Hispanic American; HCUP, Healthcare Cost and Utilization Project; KID, Kids' Inpatient Database; NBDPN, National Birth Defect Prevention Network; NBDPS, National Birth Defects Prevention Study; NIS, Nationwide Inpatient Sample; NSBPR, National Spina Bifida Patient Registry; TBDR, Texas Birth Defects Registry.

born (table 4).[14 15 18 28 29] Canfield *et al* reported 32% of HSB parents immigrated <5 years ago (OR=3.28, 95% CI=1.46 to 7.37), whereas only 23.9% of parents immigrated >5 years ago (OR=2.45, 95% CI=1.49 to 4.03).[18] In contrast, Ramadhani *et al* noted longer residency in the USA portends higher risk of spina bifida; 30.2% of HSB mothers lived in the USA for >5 years compared with 18% for ≤5 years.[15] Factors historically associated with acculturation, such as preferred interview language or primary home language, demonstrated elevated prevalence.[18] Canfield *et al* reported significantly increased odds of spina bifida were found in Hispanic American mothers who primarily interviewed in Spanish and for parents in which Spanish was the primary home language (OR=2.18, 95% CI=1.60 to 2.95, OR=1.73, 95% CI=1.31 to 2.29).[18]

Elevated prenatal exposure to toxins and clinical variables were frequently reported as risk factors of spina bifida, shown in table 4.[13 14 18 30 31] Brender *et al* found that spina bifida was strongly associated with the mother's proximity to cultivated fields (OR=2.4, 95% CI 1 to 5.7) and the use of pesticides around the house, yard/garden or on oneself (OR=1.7, 95% CI 0.96 to 2.9; OR=2.1 95% CI=1.0 to 4.2; OR=1.3 95% CI=0.67 to 2.5).[30] Orr *et al* reported elevated odds of spina bifida and exposure of Hispanic American mothers to contaminants at hazardous waste sites (OR=1.27, 95% CI=0.56 to 2.89).[13] Padula *et al* concluded that exposure to carbon dioxide, nitric oxide and nitrogen dioxide was strongly associated with spina bifida among US-born Hispanic American mothers (OR 2.7–4.1).[14] Additionally, Canfield *et al* identified clinical factors, such as gestational diabetes and

**Table 2** Birth prevalence per 10 000 births among HA and NHW

| **Overall** | | | | |
|---|---|---|---|---|
| **Study** | **HA** | **NHW** | **N (HA)** | **N (NHW)** |
| Agopian *et al*[17] | 3.26 (2.9–3.6) | 2.57 (2.34–2.79) | 154 | 171 |
| Boulet *et al**[8] | 2.11 | 2.24 | 1437 | 4274 |
| Canfield *et al*[20] | 5.9 (4.9–6.8) | 5.1 (4.8–5.3) | 18 | 13 |
| Parks *et al**[3] | 4.43 | 3.35 | 530 | 326 |
| Strassburg *et al*[21] | 4.70 | 3.82 | 101 | 91 |

| **Pre-fortification and post-fortification** | | | | | | |
|---|---|---|---|---|---|---|
| | **HA** | | **NHW** | | | |
| **Study** | **Pre** | **Post** | **Pre** | **Post** | **N (HA)** | **N (NHW)** |
| Boulet *et al*†[8] | 2.69 | 1.90 | 2.91 | 2.11 | 1437 | 4274 |
| Canfield *et al*†[23] | 6.30 | 3.80 | 4.9 | 3.2 | 535 | 2028 |
| Williams *et al*‡[22] | 6.49 | 4.18 | 5.13 | 3.37 | 1281 | 2672 |

*Birth prevalence was calculated per 10 000 births from data reported in the manuscript.
†Pre-fortification (1995–1996); early post-fortification (1999–2000).
‡Pre-fortification (October 1995–1996); post-fortification (October 1998–2002).
HA, Hispanic American; N, number of spina bifida cases; NHW, non-Hispanic white.

**Table 3** Sociodemographic factors

| | | | | | |
|---|---|---|---|---|---|
| Maternal age | <20 | 20–24 | 25–29 | 30–34 | 35+ |
| Canfield *et al*[18] | 13.2% (23) | 28.2% (49) | 32.2% (56) | 17.8% (31) | 8.6% (15) |
| Padula *et al*[14] | 14.9% (14) | 36.2% (34) | 33.0% (31) | 17.0% (16) | 5.3% (5) |
| Shumate *et al*[28] | 15.7% (185) | 28.4% (335) | 26.0% (306) | 17.9% (211) | 12.2% (144) |
| HA average | 14.6% | 30.9% | 30.4% | 17.6% | 8.7% |
| NHW average | 7.83% | 23.54% | 31.64% | 23.95% | 13.04% |
| Household income | <$10 000 | $10 000–19 000 | $20 000–29 000 | $30 000–39 999 | $40 000+ |
| Canfield *et al* HA[18] | 40.2% (70) | 20.7% (36) | 19.0% (33) | 5.7% (10) | 3.4% (6) |
| Canfield *et al* NHW[18] | 7.7% (23) | 11.4% (34) | 14.4% (43) | 12.7% (38) | 42.8% (128) |
| Maternal education | 0–6 | 7–11 | 12 | 13–15 | 16+ |
| Canfield *et al*[18] | 14.4% (25) | 28.7% (50) | 35.6% (62) | 18.4% (32) | 2.3% (4) |
| Padula *et al**[14] | 45.7% (43) | | 39.4% (37) | 21.3% (20) | |
| Shumate *et al**[28] | 47.8% (537) | | 30.5% (343) | 21.6% (243) | |
| HA average | 45.2% | | 35.2% | 21.2% | |
| NHW average | 9.6% | | 26.7% | 63.7% | |

*Reported maternal education levels of <12 years, 12 years and >12 years.
HA, Hispanic American; NHW, non-Hispanic white.

obesity, were significantly associated with spina bifida in Hispanic American mothers (OR=1.77, 95% CI=1.07 to 2.91, OR=1.7, 95% CI=1.09 to 2.67).[18]

### Morbidity

Spina bifida has high morbidity, imposing financial, physical and socioeconomic impacts on Hispanic Americans (table 5).

Three studies analysed shunt placement for hydrocephalus and found between 82% and 91% of patients required a shunt.[32–34] Kamath *et al* found a significant association between mobility and health-related quality of life (HRQoL) and reported 39% of HSB were non-ambulatory.[33] Two additional studies also found reduced mobility in HSB.[32 35] Two studies described high levels of bladder and bowel incontinence; Chowanadisai *et al* reported 92.6% and 66.7% of HSB suffer from bladder or bowel incontinence, respectively.[32 35] Smith *et al* reported 18.1% and 11.7% of HSB underwent bladder or bowel incontinence surgeries, respectively, and 7.5% underwent a vesicostomy.[35] Multiple studies reported low fetal surgery rates (3.5–30.8%) among Hispanic Americans; Harbert *et al* noted only 12.7% of people who qualified for fetal surgery were Hispanic American.[36 37] Three studies discussed the impact of spina bifida on fetal death; two reported vast differences ranging from 7.8% to 62.2%.[3 19 34]

## DISCUSSION

Spina bifida disproportionately impacts Hispanic Americans.[38 39] The overall prevalence of spina bifida in Hispanic Americans was reported to be 3.80 per 10 000 births of spina bifida in Hispanic Americans (CI 3.6, 4.0) from 1997 to 2007.[7] The majority of papers reported a higher prevalence in Hispanic Americans compared with NHW, which remains higher than predicted after mandatory and voluntary folate fortification initiatives. Birth prevalence of spina bifida in Hispanic Americans did decrease following fortification but continued to remain higher than NHW. This suggests either ineffective fortification measures, Hispanic American-specific risk factors or a combination of both.[11]

The most common risk factors identified were poor socioeconomic status (SES), immigration, toxic exposures and clinical factors. Poor SES stands as one established risk factor for spina bifida primarily in connection to limited access and affordability of healthcare as well as prenatal and preconceptual care.[40 41] Low educational attainment, maternal age and income status were commonly reported. On average, 45.2% of Hispanic American mothers included in this review obtained less than a high school diploma compared with 8.9% of the US population in 2021.[42] The average maternal age at first birth for the general US population in 2021 was 27.3 years old compared with 25.5 years for Hispanic American women.[43] However, in our review, 45.5% of mothers were younger than 25 years old. Hispanic Americans are disproportionately represented among the impoverished demographic; in 2017, individuals of Hispanic descent constituted 18.3% of the overall American population, yet accounted for 27.2% of the population residing in poverty.[44] Chronic conditions, such as spina bifida, increase the risk of poverty. Approximately 40.2% of HSB families report an annual income of less than $10 000.[18] Low SES communities often have a high percentage of immigrants who are well-known to face healthcare disparities due to language barriers, low health literacy, limited access to care and fear of seeking healthcare.[45] These

**Table 4** Risk factors

| Maternal nativity | | |
|---|---|---|
| **Study** | **US-born HA mother** | **Foreign-born HA mother** |
| Canfield *et al*[18] | 46.0% (64) | 54.0% (75)* |
| Carmichael *et al*[29] | 17.4% (30) | 57.0% (98)† |
| Padula *et al*[14] | 46.8% (44) | 59.6% (56)† |
| Ramadhani *et al*[15] | 36.8% (63) | 56.7% (97)* |
| Shumate *et al*[28] | 49.1% (580) | 50.9% (601)† |
| Average | 39.2% | 55.6% |
| **Additional risk factors** | | |
| **Study** | **% (n)** | **Risk factor** |
| Brender *et al*[30] | 14.3 (12) | Proximity to cultivated field |
| | 50 (42) | Pesticides in home |
| Canfield *et al*[18] | 20.1 (35) | Obesity |
| | 12.6 (22) | Gestational diabetes |
| Lavery *et al*[31] | Protective | Choline/betaine |
| Orr *et al*[13] | 3.7 (6) | NPL site |
| Padula *et al*[14] | – | $CO_2$, NO, $NO_2$ |
| | 78.7 (74) (none)<br>20.2 (19) (passive)<br>5.3 (5) (active)<br>1.1 (1) (both) | Smoke |

*Percentages and absolute numbers represent mothers born in Mexico or Central America.
†Percentages and absolute numbers represent HA mothers; however, 'foreign' is not explicitly defined in the study.
$CO_2$, carbon dioxide; HA, Hispanic American; n, number of participants; $NO_2$, nitrogen dioxide; NO, nitric oxide; NPL, National Priorities List.

**Table 5** Morbidity

| Surgical procedures | |
|---|---|
| **Study** | **Procedure** |
| Chowanadisai *et al*[32] | 82% shunt placement |
| Foy *et al*[36] | 3.5% fetal surgery, 96.6% postnatal repair |
| Harbert *et al*[37] | 30.8% fetal surgery, 53.8% postnatal repair |
| Kamath *et al*[33] | 91% shunt placement |
| Kshettry *et al*[34] | Increased OR=1.2 (1 to 1.5) for shunt placement |
| **Quality of life measures** | |
| **Study** | **Health-related quality of life measures** |
| Chowanadisai *et al*[32] | Reduced self-care<br>92.6% bladder incontinence, 66.7% bowel incontinence Reduced mobility scores |
| Kamath *et al*[33] | 39% non-ambulatory |
| Kshettry *et al*[34] | Increased OR=1.9 (0.9 to 4.2) for fetal death |
| Liptak *et al*[48] | Negative effect on social life |
| Parks *et al*[3] | 62.2% fetal death |
| Shin *et al*[19] | 7.8% fetal death |
| Smith *et al*[35] | 61.4% bladder incontinence, 56.1% bowel incontinence<br>26.4% non-ambulatory |

communities face higher exposure to air pollutants and other environmental hazards. In addition, these communities are more likely to live in food deserts or experience food insecurity, increasing the risk of vitamin deficiencies, obesity and diabetes mellitus type 2.[18 44 46 47]

Low SES not only heightens the risk of having an infant with spina bifida, but also exacerbates the burden associated with managing this condition.[48] The estimated lifetime cost of care for spina bifida is $791 900 including $214 900 in caregiving costs.[49] Therefore, the financial costs of spina bifida care are particularly formidable for low SES families.[18] Hispanic Americans also face an increased likelihood of experiencing challenges in affording essential caregiving services, as the most frequent race/ethnicity without health insurance coverage.[50] In 2020, 18.3% of Hispanic Americans were uninsured compared with 5.4% of NHW. Insurance status, whether uninsured or underinsured, may significantly impact these families' quality of care. Children with spina bifida report reduced quality of life compared with their same-aged peers.[51] This is exacerbated in Hispanic Americans in both direct and indirect HRQoL measures.[3 19 32–37]

Despite this increased risk and morbidity, Hispanic Americans are under-represented in research including studies of both prevention and treatment initiatives. In the landmark randomised control trial, the Management of Myelomeningocele Study (MOMS), Hispanic Americans only accounted for 3.8% of the study population. The MOMS established that prenatal repair demonstrates improved functional outcomes and reduced morbidity compared with postnatal repair.[52] We found low prenatal repair rates in Hispanic Americans which could be explained by their low likelihood to qualify for fetal surgery through insurance.[36 37] Additional factors that may influence the decision to undergo prenatal repair include cost of travel to treatment centres, eligibility for the procedure and cultural factors. Among participants without insurance, 83.3% reported the cost of travel to the centre or hospital as a significant financial factor influencing their decision.[53] Furthermore, obesity may be a disqualifying factor; body mass index >35 was an exclusion criterion for the MOMS and obesity was significantly associated with mothers of HSB.[25 47] Lack of cultural competency and language differences were commonly cited as barriers to undergoing prenatal surgery.[54] The role of low rates of birth termination among Hispanic

Americans due to religious, cultural and health access issues should be considered as a possible influence on the overall disease incidence and prevalence.

The impact of spina bifida manifests itself as a self-perpetuating cycle influenced by low SES. Hispanic Americans face an elevated risk of having an infant with spina bifida secondary to a multitude of preconception and post-conception risk factors discussed above. These risk factors can influence the access to services and procedures, such as fetal repair, which have the greatest potential to improve lifetime morbidity.[7 36 37] Diminished ability to afford essential caregiving services, as well as physical and occupational therapy, further amplifies the morbidity associated with this condition.[50]

There are multiple limitations to this study. There is a lack of standardised measures for risk factors, morbidity and prevalence. Studies also varied in size, time period and region which significantly impacts prevalence rates and demographic factors. Many studies had small sample sizes. Hispanic Americans continue to be under-represented in participation. The role of prenatal care and deficiencies in access to care are poorly measured critical determinants. Health literacy is also an important topic lacking data to support context-specific interventions. Additional research to improve standards in reproductive health is imperative. We recognise that many risk factors in this study influence the prevalence and morbidity of spina bifida in Hispanic Americans. Further research is needed to understand the impact of these risk factors on influencing the epidemiology and patient-related outcomes among Hispanic American mothers and their children.

### Future directions

Many of the risk factors identified in this review are well-known mediators impacting health outcomes among Hispanic Americans (ie, SES, toxic exposures, immigration status and diabetes mellitus). The best interventions would target population-specific factors that uniquely contribute to increased disease prevalence and poor patient outcomes. Investigating the role of religion and cultural beliefs in spina bifida prevalence and treatment choices could help address the disparities in prevention of spina bifida and access to effective treatment when new births are diagnosed. Interventions to aid in improved preconceptual and prenatal access as well as education among reproductively active Hispanic Americans are crucial. Providers should be cognisant of health literacy in patients given low levels of educational attainment seen in mothers of HSB; educational campaigns may need to be adjusted for health literacy differences. Furthermore, it is pivotal to identify safer and more effective routes of passive folic acid supplementation, such as additional stable grain products or fortified salt.[55–57] These efforts can be further integrated into existing regional and national policies. It is difficult to eliminate the role of toxic exposures as this is strongly linked with economic livelihood of many families. Providing education and awareness among high-risk populations could be a reasonable approach to initiate larger interventions.

## CONCLUSION

Hispanic Americans continue to face increased morbidity and rates of spina bifida despite folate fortification efforts and education programmes. This increased burden is multifaceted and may be explained by the existing health disparities and structural inequities faced by Hispanic Americans. Further studies are necessary to fully delineate the driving factors behind the increased prevalence and morbidity of spina bifida in this population.

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