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Do pregnant women living in higher well-being populations experience lower risk of preterm delivery?: A cross-sectional study

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ABSTRACT

Objective: To determine if preterm birth, defined as gestational age <37 weeks, is lower for women living in counties with higher well-being, after accounting for known individual risk factors.

Design: Cross-sectional study of all United States births in 2011.

Participants: We obtained birth data from the National Center for Health Statistics which included 3,938,985 individuals.

Main outcomes measures: Primary outcome measure was maternal risk of preterm delivery by county; primary independent variable was county-level well-being as measured by the Gallup-Sharecare Well-Being Index.

Results: Women living in counties with higher population well-being had a lower rate of preterm delivery. The rate of preterm birth in counties in the lowest WBI quintile was 13.1%, while the rate of preterm birth in counties in the highest WBI quintile was 10.9%. In the model adjusted for maternal risk factors (age, race, Hispanic ethnicity, smoking status, timing of initiation of prenatal visits, multiparity, maternal insurance payer), the association was slightly attenuated with an absolute difference of 1.9% (95% CI 1.7% - 2.1%; P<0.001).

Conclusions: Pregnant women who live in areas with higher population well-being have lower risk of preterm birth, even after accounting for individual risk factors.

STRENGTHS AND LIMITATIONS OF THE STUDY

- In this national study, we utilized two large, unique datasets, including the Gallup-Sharecare Well-being Index and all data on live births in the U.S. in 2011 from the National Center for Health Statistics.
- With these data, the study addressed the gap in that no study has yet examined whether the average well-being of the population in which a woman lives relates to her risk of preterm delivery.
- We summarized rates of preterm birth by quintile of county well-being, and tested for associations between population well-being and gestational age using hierarchical generalized linear models that adjusted for individual maternal risk factors.
- As a cross-sectional study, it cannot assess causation, yet determining whether a relationship exists between population well-being and risk of preterm birth is an essential first step.
- Without an assessment of the well-being of the individual pregnant women, the study cannot determine how population well-being may moderate the effect of women's own well-being or other related individual factors on their risk of preterm delivery.

INTRODUCTION

Despite considerable efforts, preterm birth remains a substantial public health problem in the United States.(1-3) With one in ten babies born at less than 37 weeks gestation, preterm birth is the greatest contributor to infant mortality and a leading cause of long-term neurological disabilities in children, resulting in considerable mortality, morbidity, and long-term costs in the US.(4-6) Research has demonstrated that while individual factors such as maternal age and smoking status influence a pregnant woman's risk of preterm delivery,(3) community environment has additional influence.(7-9) Specific features of where a pregnant woman lives, including neighborhood poverty, local access to healthy foods, and environmental exposures, influence her risk of preterm delivery.(21-24)

While knowing specific community features that are associated with preterm birth risk is helpful, community features do not exist in isolation; rather, community features exist in combination with each other and individuals that live within the community interact uniquely with them. As such, the broader, multi-dimensional context of the physical, mental, and social health of a geographic community within which a pregnant woman lives may constitute a more complete and accurate conceptualization of the environment that influences her risk of preterm delivery. Population well-being is a comprehensive construct that captures these contextual factors (10, 11).

Higher population well-being has inherent positive value, and has been associated with other desirable health outcomes, such as greater life expectancy.(12) If also associated with preterm birth, population well-being may provide a promising novel target for reducing preterm birth rates. No study, however, has examined whether the average well-being of the population in which a woman lives relates to her risk of preterm delivery. To address this gap, we utilized a comprehensive, multi-dimensional assessment of well-being across the United States, the Gallup-Sharecare Well-being Index™, previously known as the Gallup-Healthways Well-Being Index prior to rebranding following Sharecare's 2016 acquisition of Healthways (Gallup-Sharecare, 2011), and data on all live births in the United States in 2011 (National Center for Health Statistics, 2011) to examine whether the rate of preterm birth varies with the overall well-being of the population within which the pregnant woman lives.(13-14) We hypothesized that risk of preterm birth is lower for pregnant women who live in higher well-being populations, even when accounting for known individual maternal risk factors. Such work lays the groundwork for testing whether society-wide interventions to improve well-being might have broad beneficial health effects.

METHODS

Overview

We conducted a cross-sectional study in which we linked data on all live births in the U.S. in 2011 to area-level data on population well-being. Because county was the smallest geographic area available for each mother, we aggregated well-being at the county level as well; moreover, county-level results also may have important policy implications and can inform local communities in developing targeted programs to enhance well-being. Well-being was measured at the level of county (or county equivalent) and births were linked to the mother's county of residence. We summarized rates of preterm birth by quintile of county well-being, and tested for associations between population well-being and gestational age using hierarchical generalized linear models that adjusted for maternal risk factors.

Birth Data

Birth data were obtained from the National Center for Health Statistics (NCHS).(13) The NCHS aggregates and standardizes data on births collected from all 50 states and the District of Columbia. We used restricted geocoded special use files from NCHS; these include maternal risk factors, maternal county of residence, and gestational age (categorized as <20 weeks, 20-27, 28-31,32-33,34-36,37-38,39,40, 41, and 42 or more). This dataset include geocoding at the county level, using the Federal Information Processing System (FIPS) code.(15)

Study Sample

We included all live births during 2011 where the mother's county of residence was not missing, and for which there were WBI survey responses available from that county. We excluded births with missing gestational age.

Outcome

Our primary outcome was preterm delivery, defined as gestational age <37 weeks.(16)

Population Well-being Data

Our primary independent variable was population well-being. Data on population well-being were obtained from the Gallup-Sharecare Well-being Index (WBI) survey for 2011.(14) The survey comprised 55 self-reported items organized into 6 domains: life evaluation; emotional health; physical health; healthy behaviors; basic access and work environment.(17) The Life Evaluation Index measures life satisfaction and optimism about the future. The Emotional Health Index measures daily emotions and the presence or absence of depression. The Physical Health Index assesses the burden of chronic disease and recent illness. The Healthy Behaviors Index assesses the prevalence of smoking, exercising, and eating fruit and vegetables. The Basic Access Index includes perception of safety and access to housing and health care. The Work Environment Index assesses job satisfaction, trust and respect in the workplace and, unlike the other domains, it is collected only from the subset of respondents who report being employed. Each domain is represented by an index, measured on a scale of 0 to 100. A composite score, the Well-Being Index (WBI), was calculated as the unweighted mean of the 6 domain scores, and is reported on a scale of 0-100. Gallup surveyed a unique sample of nearly 1000 individuals 18 years and older every day for approximately 350 days during 2011. A structured sampling design was used with respondents surveyed from all 50 states and the District of Columbia. The survey was administered in both English and Spanish, using both land lines and cell phones. We aggregated individual WBI responses into county scores based the maternal county of residence. For our primary analyses, we used quintiles of county WBI scores as our

independent variable; in secondary analyses, we used county-level quintiles for each of the individual domain scores.

Other Independent Variables

From the NCHS birth dataset we included the following known maternal risk factors for preterm delivery: age (categorized as <=19, 20-24, 25-29, 30-34, 35-39, 40+); race (White, Black, Asian, American Indian/Alaska Native); Hispanic ethnicity; smoking status; start of prenatal visits (1st trimester, 2nd trimester, 3rd trimester, none, not known); and multiparity (single birth versus multiple). We also included infant sex, and, as a marker of socioeconomic status, we included the maternal insurance payer (Medicaid, private, self, other, unknown).

Statistical Analysis

We summarized the outcome and all maternal risk factors by quintile of population WBI, reporting frequency and percent of births in each category. To assess the association between population well-being and preterm birth, we estimated two hierarchical linear models. These models included random effects for county, and were specified using a linear response; such linear probability models are appropriate when the outcome rate is not close to 0 or 1, and the predicted values from the model are also between 0 and 1. The first “unadjusted” model included only county quintile of population well-being. The second adjusted for maternal age, race, ethnicity, smoking status, trimester during which prenatal care was initiated, single or multiple birth, and insurance payer. For both we calculated the Wald P-value for the overall effect of WBI and a separator test for trend across WBI quintiles. In secondary analyses we replicated the main analyses using each of the 6 subdomain scores of the well-being index.

We also estimated a reference model which included no independent variables, and used the county level variance from this model to calculate the variance explained at the county level for each of the models described above, using $R^2 = (\tau^2 - \tau^{*2})/\tau^2$, where τ^{*2} is the county level variance for the model with independent variables.(18)

Missing data

In 2011, fifteen states did not collect information on prenatal visits or payer (AK, AL, AR, AZ, CT, HI, MA, ME, MN, MS, NJ, RI, VA, WV). We did not impute missing data due to nonrandom missingness and likely confounding with the outcome. These missing variables were instead coded as unknown; in sensitivity analyses we omitted these states.

All analyses were performed using Stata 14.2 (2016 StataCorp, College Station, TX). The Yale University Institutional Review Board approved this study.

RESULTS

We used data from 3,938,985 births across 2,989 counties. The mean (SD) county-level preterm birth rate was 11.7% (2.2%) preterm births. Table 1 shows numbers and percentages of children born before and after 37 weeks' gestation, maternal characteristics, and infant sex by quintile of average well-being of the maternal county of residence.

In the unadjusted model, pregnant women living in counties with higher population well-being had a significantly lower risk of preterm birth. This finding was consistent across all WBI quintiles with an absolute difference between the percentage of preterm births in the highest well-being quintile (10.9%) and the lowest well-being quintile (13.1%) of 2.2% (95% CI: [1.8%,2.6%]; p<0.001) (Table 2). After adjusting for maternal risk factors for preterm birth, the trend remained consistent across the quintiles; the absolute difference between the highest and lowest quintiles was attenuated to 1.9% (95% CI: [1.7%, 2.1%]; P<0.001). In sensitivity analyses, results were similar.

In secondary analyses, independent associations between quintiles of each well-being domain and preterm birth are reported in Table 3. Similar to the composite WBI score, all domain scores were significantly associated with maternal risk of preterm birth, in the unadjusted model and the model adjusting for individual maternal risk factors. Different domains, however, explained different amounts of variance of well-being, with the basic access index explaining 14.6% of the county variance. After adjusting for maternal risk factors, women in counties with the highest basic access score experienced an absolute difference in preterm birth rates of 2.4% (95%CI: [2.2%,2.6%]; p<0.001) when compared with women in counties with the lowest basic access score. Similarly, the average physical health score of the county within which a pregnant woman resided was associated with lower rates of preterm birth, in both unadjusted and adjusted models (absolute difference in preterm birth rate: 1.9%, 95%CI: [1.7%, 2.1%]; p<0.001). In the models adjusted for maternal risk factors, healthy behaviors (1.5%, 95%CI: [1.3%, 1.7%]; p<0.001), emotional health (1.0%, 95%CI: [0.6%, 1.4%]; p<0.001), and life evaluation (1.1%, 95%CI: [0.9%, 1.3%]; p<0.001) of the county population negatively correlated with risk of preterm birth.

DISCUSSION

In this study of all births in the United States in 2011, we found that pregnant women who lived in counties with higher average well-being had significantly lower risk of preterm birth. After accounting for known maternal risk factors, including age, race, ethnicity, smoking status, timing of initiation of prenatal care, multiparity, and payer type, the absolute difference in maternal risk for preterm delivery between the highest well-being counties and the lowest well-being counties was 1.9%. Reducing preterm birth rates by this absolute amount would result in substantial maternal and infant benefits: if the lowest well-being counties experienced this reduced rate, they would have had 3,077 fewer preterm births in 2011 alone, yielding an estimated financial savings of nearly $160 million (19), in addition to fewer long-term consequences of preterm birth such as infant mortality and long-term neurological disabilities. Additional reductions in preterm birth risk in counties from the middle well-being quintiles, which contributed greater total numbers of births in 2011, would only augment these benefits.

Decades of research have delineated a variety of maternal-level risk factors for preterm delivery, including maternal age, smoking status, history of preterm delivery, and socioeconomic status (SES) (2, 3, 20), while recent studies of environmental factors suggest that features of where a pregnant woman lives, including neighborhood poverty, local access to healthy foods, and environmental exposures, additionally influence her risk of preterm delivery (21-24). Our study extends the existing literature by leveraging unique large national data sources to assess how a comprehensive, multi-dimensional measure of population well-being and its various domains relate to individual preterm birth risk across the United States. In completing this study, we found that pregnant women were at lower risk of preterm delivery when living in higher well-being populations than when living in lower well-being populations, even when we accounted for maternal risk factors that are highly correlated with SES , such as insurance payer, age at time of delivery, smoking status, and timing of first prenatal visit (25, 26). This finding adds to the growing literature describing the complex interactions between individuals and their local environment, including natural, built, and social environments, and their combined effects on health outcomes.

Living in a higher well-being population may result in lower risk of preterm delivery for a myriad of reasons, including reasons related to the social environment. Pregnant women who live in higher well-being populations may experience less toxic stress, greater access to social resources, higher levels of trust and tolerance, and/or a greater perception of safety.(11) Prior research has shown that exposure to toxic stress increases the risk of preterm delivery,(30-33) while stronger social support, lesser social isolation, and greater social connectedness are associated with lower risk of preterm delivery, perhaps by reducing the allostatic load or chronic stress experienced by pregnant women.(34-37) Additionally, while experiences of perceived discrimination are associated with increased risk of preterm delivery, experiences of trust and tolerance as well as a greater perception of safety may foster healthier pregnancies and term deliveries.(38-39)

According to our results, pregnant women with the same individual maternal risk profile, including factors associated with SES, experience lower risk of preterm delivery when living in higher well-being populations than when living in lower well-being populations. This finding is consistent with emerging epigenetics (23, 27, 28) and maternal weathering (24, 29) literature. Maternal weathering is a potential explanatory model for well-described race-based disparities in preterm birth risk that attributes increased risk of preterm delivery in certain populations of women to “accelerated aging” from greater exposure to hardship. This model suggests that living in better neighborhoods might attenuate the increased risk associated with these weathering effects.(29) It is possible that the observed risk contributed by weathering and the risk mitigated by living in higher well-being populations are actually related to underlying exposure to toxic stress and buffering from factors such as trust, tolerance, social support, and perceived safety, as described above.

Our study also builds on prior literature that found links between living in areas of greater poverty and preterm birth risk. In the domain analyses, the basic access domain demonstrated the strongest relationship with maternal risk of preterm delivery, even after adjusting for individual maternal risk factors, including insurance provider and smoking, and explained nearly 15% of county-level variance in preterm birth rates. The basic access index domain includes items that assess perceived access to healthcare, clean water, fresh produce, and safe public space as well as ability to afford basic needs such as food and shelter. This finding affirms prior literature reporting that access to basic needs is strongly correlated with health outcomes. Importantly, however, all domains contributed independently to the inverse association between population well-being and maternal risk of preterm delivery. In particular, average county-level physical health, healthy behaviors, and emotional health scores were inversely associated with maternal risk of preterm delivery.

The results of our study have several potential policy implications. Our findings suggest that effective investments in well-being may not only improve overall health and quality of life for populations, but also result in reduced rates of preterm birth for pregnant women living in those populations, an idea worth pursuing. Our domain analyses suggest that improving aggregate basic access in particular could plausibly result in not only greater well-being but also fewer preterm births, though targeting other domains, such as physical health, healthy behaviors, and emotional health, may also yield additional valuable results. Importantly, the effectiveness of various interventions will most likely depend on the contexts within which they are implemented. Currently, efforts are underway across the globe to track and improve population well-being through programmatic and policy-based interventions.(40-43) While some interventions involve multi-sector, community-based programs, many of which are government supported, other interventions involve changes in economic and social policies, such as those aimed at affordable housing, employment, and access to public spaces for physical fitness or social connection.(11, 44-45) Given the relationship between population well-being and preterm birth risk, examining how programs and policies influence not only well-being but also preterm birth could be informative and allow for spread of interventions that effectively increase well-being and reduce preterm birth.

Our study has limitations. First, as a cross-sectional study, it cannot assess causation. However, determining whether a relationship exists between population well-being and risk of preterm birth is an essential first step. Second, this study specifically examines how the average well-being of the adult population within which a pregnant woman lives correlates with her risk of preterm delivery. Because we do not have an assessment of the well-being of the individual pregnant women, we cannot determine how population well-being may moderate the effect of women's own well-being or other related individual factors on their risk of preterm delivery. Nevertheless, the results of this nationwide study of nearly 4 million births demonstrates a clear association between the well-being context within which women live and the risk of preterm delivery. Finally, geographically smaller units (e.g., neighborhood or city) for population well-being may be more relevant to describing the community context for an individual pregnant woman. Nevertheless, the county is a relevant geographic unit in that policies and programs are often enacted at the county level.

Pregnant women who live in populations with higher well-being have lower risk of preterm delivery, even after accounting for known individual maternal risk factors. The well-being of a population is an important end itself, but if causal pathways exist between population well-being and other valued outcomes, investments in population well-being may yield other benefits, potentially including fewer preterm births. Understanding the full effects of population well-being can inform the emerging dialogue about its value as a health investment.

Contributors: CR and BR participated in the initial conception of this study. JH performed all analyses. All authors (CR, BR, JH, ES, MS, AA, KK, ER, and HK) contributed to the study design, interpretation of data, drafting and revising the article, and its final approval. All authors are guarantors.

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Data Sharing: If the paper is accepted for publication, we will post a de-identified data set with county resident well-being data from Gallup-Sharecare on ICSPR Open, a publicly available site. Birth data are available with permission from the National Center for Health Statistics (http://www.cdc.gov/nchs/).

Ethics Approval: This study was approved by the Yale University Institutional Review Board.

Patient and Public Involvement: No patients were involved in this study.

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Table 1. Gestational age at birth and maternal characteristics by maternal county quintile of composite Gallup-Sharecare Well-Being Index (WBI) score

	TOTAL (N=3,938,985)	**Q1** (N=161,964)	**Q2** (N=600,373)	**Q3** (N=1,212,321)	**Q4** (N=1,315,547)	**Q5** (N=648,780)
Gestation age, N (%)						
≥ 37 weeks	3,477,156 (88.3)	140,703 (86.9)	524,922 (87.4)	1,067,099 (88.0)	1,164,674 (88.5)	579,758 (89.4)
< 37 weeks	461,829 (11.7)	21,261 (13.1)	75,451 (12.6)	145,222 (12.0)	150,873 (11.5)	69,022 (10.6)
Mean maternal age, years (SD)	27.9 (6.0)	25.8 (5.7)	26.9 (5.9)	27.7 (6.0)	28.1 (6.1)	29.0 (5.9)
Maternal age in years, N (%)						
≤ 19	331,902 (8.4)	21,052 (13.0)	62,319 (10.4)	106,581 (8.8)	104,220 (7.9)	37,730 (5.8)
20-24	920,923 (23.4)	52,965 (32.7)	166,495 (27.7)	293,924 (24.2)	290,080 (22.1)	117,459 (18.1)
25-29	1,123,453 (28.5)	46,793 (28.9)	174,750 (29.1)	346,867 (28.6)	372,171 (28.3)	182,872 (28.2)
30-34	983,831 (25.0)	28,202 (17.4)	128,213 (21.4)	294,403 (24.3)	342,055 (26.0)	190,958 (29.4)
35-39	462,658 (11.7)	10,480 (6.5)	55,444 (9.2)	136,276 (11.2)	165,157 (12.6)	95,301 (14.7)
≥ 40	116,218 (3.0)	2,472 (1.5)	13,152 (2.2)	34,270 (2.8)	41,864 (3.2)	24,460 (3.8)
Maternal race, N (%)						
White	3,010,346 (76.4)	134,126 (82.8)	437,875 (72.9)	923,217 (76.2)	1,027,093 (78.1)	488,035 (75.2)
Black	629,998 (16.0)	21,510 (13.3)	124,793 (20.8)	214,219 (17.7)	188,715 (14.3)	80,761 (12.4)
American Indian/Alaskan Native American	45,035 (1.1)	4,896 (3.0)	9,839 (1.6)	10,900 (0.9)	12,770 (1.0)	6,630 (1.0)
Asian	253,606 (6.4)	1,432 (0.9)	27,866 (4.6)	63,985 (5.3)	86,969 (6.6)	73,354 (11.3)
Mother is Hispanic, N (%)						
No	2,996,684 (76.1)	146,500 (90.5)	492,335 (82.0)	897,455 (74.0)	940,278 (71.5)	520,116 (80.2)
Yes	942,301 (23.9)	15,464 (9.5)	108,038 (18.0)	314,866 (26.0)	375,269 (28.5)	128,664 (19.8)
Maternal smoking, N (%)						
No	3,400,601 (92.4)	123,008 (83.0)	475,937 (88.5)	1,066,051 (92.4)	1,175,513 (94.2)	560,092 (94.8)
Yes	278,922 (7.6)	25,218 (17.0)	61,999 (11.5)	88,132 (7.6)	72,718 (5.8)	30,855 (5.2)
Missing	259,462 (7.1)	13,738 (9.3)	62,437 (11.6)	58,138 (5.0)	67,316 (5.4)	57,833 (9.8)
Payer, N (%)						
Medicaid	1,462,567 (43.3)	72,640 (55.6)	265,707 (50.8)	487,403 (46.2)	451,382 (40.6)	185,435 (33.1)
Private	1,559,450 (46.1)	45,482 (34.8)	202,817 (38.8)	451,072 (42.8)	537,882 (48.4)	322,197 (57.6)
Self	135,125 (4.0)	5,327 (4.1)	19,694 (3.8)	43,835 (4.2)	46,824 (4.2)	19,445 (3.5)
Other	165,507 (4.9)	5,623 (4.3)	23,798 (4.6)	54,736 (5.2)	57,700 (5.2)	23,650 (4.2)
Unknown	57,360 (1.7)	1,575 (1.2)	10,515 (2.0)	18,064 (1.7)	18,085 (1.6)	9,121 (1.6)
Missing	558,976 (16.5)	31,317 (24.0)	77,842 (14.9)	157,211 (14.9)	203,674 (18.3)	88,932 (15.9)

Timing of 1st prenatal visit, N (%)						
1st- 3rd month	2,417,154 (71.5)	88,922 (68.1)	357,044 (68.3)	750,727 (71.2)	807,186 (72.6)	413,275 (73.8)
4th- 6th month	657,371 (19.4)	29,131 (22.3)	114,187 (21.9)	204,381 (19.4)	210,748 (19.0)	98,924 (17.7)
7th month-term	144,107 (4.3)	6,899 (5.3)	25,691 (4.9)	44,460 (4.2)	46,204 (4.2)	20,853 (3.7)
No prenatal visit	47,479 (1.4)	1,854 (1.4)	9,102 (1.7)	14,963 (1.4)	16,223 (1.5)	5,337 (1.0)
Unknown	113,898 (3.4)	3,841 (2.9)	16,507 (3.2)	40,579 (3.8)	31,512 (2.8)	21,459 (3.8)
Missing	558,976 (16.5)	31,317 (24.0)	77,842 (14.9)	157,211 (14.9)	203,674 (18.3)	88,932 (15.9)
Infant sex, N (%)						
Female	1,922,350 (48.8)	79,125 (48.9)	293,350 (48.9)	591,407 (48.8)	642,544 (48.8)	315,924 (48.7)
Male	2,016,635 (51.2)	82,839 (51.1)	307,023 (51.1)	620,914 (51.2)	673,003 (51.2)	332,856 (51.3)
Multiple births, N (%)						
Yes	136,209 (3.5)	4,789 (3.0)	19,735 (3.3)	41,606 (3.4)	45,599 (3.5)	24,480 (3.8)
No	3,802,776 (96.5)	157,175 (97.0)	580,638 (96.7)	1,170,715 (96.6)	1,269,948 (96.5)	624,300 (96.2)

Table 2. Maternal risk of preterm delivery: overall and by county of residence aggregated by quintile of composite Gallup-Sharecare Well-Being Index (WBI) score, unadjusted and adjusted for maternal risk factors

Variable	Coefficient (SE)	P	Wald P	Coefficient (SE)	P	Wald P
Intercept	0.131 (0.001)	<0.001		-0.006 (0.001)	<0.001	
GHWBI score			<0.001			<0.001
Q1	ref			ref		
Q2	-0.006 (0.002)	0.001		-0.006 (0.001)	<0.001	
Q3	-0.013 (0.002)	<0.001		-0.013 (0.001)	<0.001	
Q4	-0.015 (0.002)	<0.001		-0.014 (0.001)	<0.001	
Q5	-0.022 (0.002)	<0.001		-0.019 (0.001)	<0.001	
Maternal age						
≤ 19				ref		
20-24				-0.019 (0.001)	<0.001	
25-29				-0.021 (0.001)	<0.001	
30-34				-0.016 (0.001)	<0.001	
35-39				0.002 (0.001)	0.018	
≥ 40				0.023 (0.001)	<0.001	
Maternal race						
White				ref		
Black				0.051 (0.000)	<0.001	
American Indian/Native American				0.024 (0.002)	<0.001	
Asian				0.011 (0.001)	<0.001	
Mother is Hispanic						
No				ref		
Yes				0.015 (0.000)	<0.001	
Maternal smoking						
No				ref		
Yes				0.030 (0.001)	<0.001	
Payer						
Medicaid				ref		
Private				-0.019 (0.000)	<0.001	
Self				-0.012 (0.001)	<0.001	
Other				-0.013 (0.001)	<0.001	
Unknown				-0.005 (0.001)	<0.001	
Timing of first prenatal visit						
1st- 3rd month				ref		
4th- 6th month				-0.014 (0.000)	<0.001	
7th month-term				-0.032 (0.001)	<0.001	
No prenatal visit				0.123 (0.001)	<0.001	
Unknown				0.048 (0.001)	<0.001	
Infant sex					.	
Female				ref		
Male				0.011 (0.000)	<0.001	
Multiple births						
No				ref		
Yes				0.487 (0.001)	<0.001	
R^2	0.078			0.656		

Table 3. Maternal risk of preterm delivery by county of residence aggregated by quintile of individual Gallup-Sharecare Well-Being Index (WBI) domain scores, unadjusted and adjusted for maternal risk factors

Variable	Unadjusted Model Coefficient (SE)	P	Wald P	Adjusted Model Coefficient (SE)	P	Wald P
Basic Access Index (BAI)			<0.001			<0.001
Q1	ref			ref		
Q2	-0.012 (0.002)	<0.001		-0.009 (0.001)	<0.001	
Q3	-0.021 (0.002)	<0.001		-0.015 (0.001)	<0.001	
Q4	-0.027 (0.002)	<0.001		-0.019 (0.001)	<0.001	
Q5	-0.034 (0.002)	<0.001		-0.024 (0.001)	<0.001	
R^2	0.146			0.656		
Physical Health Index (PHI)			<0.001			<0.001
Q1	ref			ref		
Q2	-0.009 (0.002)	<0.001		-0.007 (0.001)	<0.001	
Q3	-0.013 (0.002)	<0.001		-0.013 (0.001)	<0.001	
Q4	-0.017 (0.002)	<0.001		-0.017 (0.001)	<0.001	
Q5	-0.019 (0.002)	<0.001		-0.019 (0.001)	<0.001	
R^2	0.059			0.657		
Healthy Behaviors Index (HBI)			<0.001			<0.001
Q1	ref			ref		
Q2	-0.003 (0.002)	0.130		-0.005 (0.001)	<0.001	
Q3	-0.008 (0.002)	<0.001		-0.010 (0.001)	<0.001	
Q4	-0.013 (0.002)	<0.001		-0.015 (0.001)	<0.001	
Q5	-0.017 (0.002)	<0.001		-0.015 (0.001)	<0.001	
R^2	0.039			0.654		
Emotional Health Index (EHI)			<0.001			<0.001
Q1	ref			ref		
Q2	-0.011 (0.002)	<0.001		-0.010 (0.001)	<0.001	
Q3	-0.012 (0.002)	<0.001		-0.011 (0.001)	<0.001	
Q4	-0.014 (0.002)	<0.001		-0.013 (0.001)	<0.001	
Q5	-0.012 (0.002)	<0.001		-0.010 (0.002)	<0.001	
R^2	0.032			0.656		
Life Evaluation Index (LEI)			0.004			<0.001
Q1	ref			ref		
Q2	-0.005 (0.002)	0.010		-0.005 (0.001)	<0.001	
Q3	-0.006 (0.002)	0.004		-0.008 (0.001)	<0.001	
Q4	-0.006 (0.002)	0.003		-0.010 (0.001)	<0.001	
Q5	-0.008 (0.002)	<0.001		-0.011 (0.001)	<0.001	
R^2	0.004			0.653		
Work Environment Index (WEI)			<0.001			<0.001
Q1	ref			ref		
Q2	-0.007 (0.002)	<0.001		-0.008 (0.001)	<0.001	
Q3	-0.008 (0.002)	<0.001		-0.009 (0.001)	<0.001	
Q4	-0.010 (0.002)	<0.001		-0.007 (0.001)	<0.001	
Q5	-0.006 (0.002)	0.002		-0.003 (0.002)	0.001	
R^2	0.016			0.653		

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract *– Abstract (Page 2, "Methods: We performed a cross-sectional study…")*
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found – *Page 2*
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported *– Pages 4-5*
Objectives	3	State specific objectives, including any prespecified hypotheses – *Page 5, "…to examine whether maternal risk of preterm birth varies with the overall well-being.."*
Methods		
Study design	4	Present key elements of study design early in the paper – *Page 5, beginning of methods*
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection – *Pages 5-9*
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants – *Page 5-6*
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable – *Pages 6-9*
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group – *Pages 6-9*
Bias	9	Describe any efforts to address potential sources of bias – *Page 7-9*
Study size	10	Explain how the study size was arrived at -- *Page 6, 1st paragraph of Study Sample*
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why – *Pages 7-9*
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding – *Pages 7-9*
		(*b*) Describe any methods used to examine subgroups and interactions – *pages 7-9*
		(*c*) Explain how missing data were addressed – *Page 9*
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy – *N/A*
		(*e*) Describe any sensitivity analyses – *Page 9*

Continued on next page

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed – *Page* 9
		(b) Give reasons for non-participation at each stage – *N/A, this was a population based study at the county level*
		(c) Consider use of a flow diagram – *N/A*
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders – *N/A unit of analysis was the county*
		(b) Indicate number of participants with missing data for each variable of interest – *N/A*
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures – *Pages 9-11 and Tables 1-3)*
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included – *Page 10-11 and Table 2*
		(*b*) Report category boundaries when continuous variables were categorized – *All tables*
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period – *N/a*
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses – *N/A*
Discussion		
Key results	18	Summarise key results with reference to study objectives – *Page 11*
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias – *Page 15*
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence – *Page 11-15*
Generalisability	21	Discuss the generalisability (external validity) of the study results – *Page 11-15*
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based—*Page 16*

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Do pregnant women living in higher well-being populations in the US experience lower risk of preterm delivery?: A cross-sectional study

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SCHOLARONE™ Manuscripts

Do pregnant women living in higher well-being populations in the US experience lower risk of preterm delivery?: A cross-sectional study

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ABSTRACT

Objective: To determine if preterm birth, defined as gestational age <37 weeks, is lower for women living in counties with higher well-being, after accounting for known individual risk factors.

Design: Cross-sectional study of all United States births in 2011.

Participants: We obtained birth data from the National Center for Health Statistics, which included 3,938,985 individuals.

Main outcomes measures: Primary outcome measure was maternal risk of preterm delivery by county; primary independent variable was county-level well-being as measured by the Gallup-Sharecare Well-Being Index.

Results: Women living in counties with higher population well-being had a lower rate of preterm delivery. The rate of preterm birth in counties in the lowest WBI quintile was 13.1%, while the rate of preterm birth in counties in the highest WBI quintile was 10.9%. In the model adjusted for maternal risk factors (age, race, Hispanic ethnicity, smoking status, timing of initiation of prenatal visits, multiparity, maternal insurance payer), the association was slightly attenuated with an absolute difference of 1.9% (95% CI 1.7% - 2.1%; $P<0.001$).

Conclusions: Pregnant women who live in areas with higher population well-being have lower risk of preterm birth, even after accounting for individual risk factors.

STRENGTHS AND LIMITATIONS OF THE STUDY

- In this national study, we utilized two large, unique datasets, including the Gallup-Sharecare Well-being Index and all data on live births in the U.S. in 2011 from the National Center for Health Statistics.
- With these data, this study was the first to examine whether the average well-being of the population in which a woman lives, defined as a broader, multi-dimensional, self-reported context of the physical, mental, and social health of the geographic community, including the overall life evaluation of its residents, relates to her risk of preterm delivery.
- We summarized rates of preterm birth by quintile of county well-being, and tested for associations between population well-being and gestational age using hierarchical generalized linear models that adjusted for individual maternal risk factors.
- As a cross-sectional study, it cannot assess causation, yet determining whether a relationship exists between population well-being and risk of preterm birth is an essential first step.
- Without an assessment of the well-being of the individual pregnant women, the study cannot determine how population well-being may moderate the effect of women's own well-being or other related individual factors on their risk of preterm delivery.

INTRODUCTION

Despite considerable efforts, preterm birth remains a substantial public health problem in the United States (1-3). With one in ten babies born at less than 37 weeks gestation, preterm birth is the greatest contributor to infant mortality and a leading cause of long-term neurological disabilities in children, resulting in considerable mortality, morbidity, and long-term costs in the US (4-6). Research has demonstrated that while individual factors such as maternal age and smoking status influence a pregnant woman's risk of preterm delivery (3), community environment has additional influence (7-9).

Research has shown that where a woman lives affects her risk of preterm birth. Decades of study have demonstrated that specific features of the local environment, including neighborhood poverty, local access to healthy foods, and environmental exposures, influence a pregnant woman's risk of preterm delivery.(10-14) In addition to these features, the way that the community views the overall quality of life in their community is another important, yet often unconsidered, feature of the community. Population well-being is a comprehensive construct that captures these contextual factors and incorporates community members' perceptions of the quality of their life in their community (15,16). Well-being at the population or community level influences health and well-being at the individual level, with a change in well-being of individuals in a community having an effect on others (17). As such, the population well-being of a community within which pregnant women live – defined as a broader, multi-dimensional, self-reported context of the physical, mental, and social health of the geographic community, including the overall life evaluation of its residents – may constitute a more complete and accurate conceptualization of the environment that influences the women's risk of preterm delivery.

Higher population well-being is not only an outcome worth achieving for its own sake, but also has been associated with other desirable health outcomes, such as greater life expectancy.(18) If also associated with preterm birth, population well-being may provide a promising novel target for reducing preterm birth rates. Prior studies have examined the relationship of socioeconomic factors with preterm birth, but community well-being is a distinct construct and no study has examined whether the average well-being of the population in which a woman lives relates to her risk of preterm delivery. To address this gap, we utilized a comprehensive, multi-dimensional assessment of well-being across the United States, the Gallup-Sharecare Well-being Index™, previously known as the Gallup-Healthways Well-Being Index prior to rebranding following Sharecare's 2016 acquisition of Healthways (Gallup-Sharecare, 2011), and data on all live births in the United States in 2011 (National Center for Health Statistics, 2011) to examine whether the rate of preterm birth varies with the overall well-being of the population within which the pregnant woman lives (19, 20). We hypothesized that risk of preterm birth is lower for pregnant women who live in higher well-being populations, even when accounting for known individual maternal risk factors. Such work lays the groundwork for testing whether society-wide interventions to improve well-being might have broad beneficial health effects.

METHODS

Overview

We conducted a cross-sectional study in which we linked data on all live births in the U.S. in 2011 to area-level data on population well-being. Because county was the smallest geographic area available for each mother, we aggregated well-being at the county level as well. Well-being was measured at the level of county (or county equivalent) and births were linked to the mother's county of residence. We summarized rates of preterm birth by quintile of county well-being, and tested for associations between population well-being and gestational age using hierarchical generalized linear models that adjusted for maternal risk factors.

Birth Data

Birth data were obtained from the National Center for Health Statistics (NCHS)(20). The NCHS aggregates and standardizes data on births collected from all 50 states and the District of Columbia. We used restricted geocoded special use files from NCHS; these include maternal risk factors, maternal county of residence, and gestational age (categorized as <20 weeks, 20-27, 28-31,32-33,34-36,37-38,39,40, 41, and 42 or more). This dataset include geocoding at the county level, using the Federal Information Processing System (FIPS) code (21).

Study Sample

We included all live births during 2011 where the mother's county of residence was not missing, and for which there were WBI survey responses available from that county. We excluded births with missing gestational age. In 2011, fifteen states did not collect information on prenatal visits or payer (AK, AL, AR, AZ, CT, HI, MA, ME, MN, MS, NJ, RI, VA, WV). We did not impute missing data due to nonrandom missingness and likely confounding with the outcome. These missing variables were instead coded as unknown; in sensitivity analyses we omitted these states.

Outcome

Our primary outcome was preterm delivery, defined as gestational age <37 weeks.(22)

Population Well-being Data

Our primary independent variable was population well-being. Data on population well-being were obtained from the Gallup-Sharecare Well-being Index (WBI) survey for 2011 (19). To develop the WBI, survey items that aligned with prior research on well-being were compiled by experts in the field (23-25). Based on the existing literature, items were selected so that the survey would include both hedonic well-being (i.e., people's feelings and thoughts about their lives) and eudemonic well-being (i.e., an individual's judgments about the meaning and purpose in one's life) (26). The survey therefore includes items assessing daily emotional experience and a wide variety of evaluative domains, such as overall life, standard of living, and satisfaction with community, work, relationships, and personal health. Data from a large, representative national sample was then used to perform factor analysis to determine the final set of questions. Criterion validity of geographically aggregated data was established by examining correlations with health and socioeconomic indicators (27). Principal component and confirmatory factor analyses were then used to create an instrument valid for measuring individual well-being. The individual well-being measure has acceptable reliability, internal and external validity (28).

In 2011, the WBI comprised 55 self-reported items organized into 6 domains: life evaluation; emotional health; physical health; healthy behaviors; basic access and work environment.(24) The Life Evaluation Index measures life satisfaction and optimism about the future. The Emotional Health Index measures daily emotions and the presence or absence of depression. The Physical Health Index assesses the burden of chronic disease and recent illness. The Healthy Behaviors Index assesses the prevalence of smoking, exercising, and eating fruit and vegetables. The Basic Access Index includes perception of safety and access to housing and health care. The Work Environment Index assesses job satisfaction, trust and respect in the workplace and, unlike the other domains, it is collected only from the subset of respondents who report being employed. Each domain is represented by an index, measured on a scale of 0 to 100. A composite score, the Well-Being Index (WBI), was calculated as the unweighted mean of the 6 domain scores, and is reported on a scale of 0-100. Gallup surveyed a unique sample of nearly 1000 individuals 18 years and older every day for approximately 350 days during 2011. A structured sampling design was used with respondents surveyed from all 50 states and the District of Columbia. The survey was administered in both English and Spanish, using both land lines and cell phones. We aggregated individual WBI responses into county scores based the maternal county of residence. For our primary analyses, we used quintiles of county WBI scores as our

independent variable; in secondary analyses, we used county-level quintiles for each of the individual domain scores.

Other Independent Variables

From the NCHS birth dataset we included the following known maternal risk factors for preterm delivery: age (categorized as <=19, 20-24, 25-29, 30-34, 35-39, 40+); race (White, Black, Asian, American Indian/Alaska Native); Hispanic ethnicity; smoking status; start of prenatal visits (1st trimester, 2nd trimester, 3rd trimester, none, not known); and multiparity (single birth versus multiple). We also included infant sex, and, as a marker of socioeconomic status, we included the maternal insurance payer (Medicaid, private, self, other, unknown).

Statistical Analysis

We summarized the outcome, WBI score, and all maternal risk factors by quintile of population WBI, reporting frequency and percent of births in each category. To assess the association between population well-being and preterm birth, we estimated two individual level mixed effects linear models. Both models had the same dichotomous outcome (preterm birth) and both included a random intercept for county. Though logistic regression models are conventional used for dichotomous outcomes, linear probability models such as these are appropriate when the outcome rate is not close to 0 or 1, and the predicted values from the model are also between 0 and 1. One advantage of using a linear model is that the intercept and coefficients have direct interpretations as a reference rate and risk differences respectively. The first model was unadjusted, including only county quintile of population well-being. The second adjusted for maternal age, race, ethnicity, smoking status, trimester during which prenatal care was initiated, single or multiple birth, and insurance payer. For both models we calculated the Wald P-value for the overall effect of WBI and a separate test for trend in effects across WBI quintiles. In secondary analyses we replicated the main analyses using each of the 6 domain scores of the well-being index.

We also estimated a reference model which included no independent variables, and used the county level variance from this model to calculate the variance explained at the county level for each of the models described above, using $R^2 = (\tau^2 - \tau^{*2})/\tau^2$, where τ^{*2} is the county level variance for the model with independent variables.(29)

All analyses were performed using Stata 14.2 (2016 StataCorp, College Station, TX). The Yale University Institutional Review Board approved this study.

RESULTS

We used data from 3,938,985 births across 2,989 counties, representing 99.6% of all US births in 2011. The mean (SD) county-level preterm birth rate was 11.7% (2.2%) preterm births. Table 1 shows numbers and percentages of children born before and after 37 weeks' gestation, maternal characteristics, and infant sex by quintile of average well-being of the maternal county of residence.

The observed rate of preterm birth decreased across WBI quintiles from 13.1% in the lowest quintile to 10.9% in the highest quintile (Table 1). In the unadjusted model, pregnant women living in counties with higher population well-being had a significantly lower risk of preterm birth: -.2.2% (95% CI: [-2.6%, -1.8%]; p<0.001) (Table 2). After adjusting for maternal risk factors for preterm birth, the trend remained consistent across the quintiles; the absolute difference between the highest and lowest quintiles was attenuated to -1.9% (95% CI: [-2.2%, -1.6%]; P<0.001). In sensitivity analyses, results were similar.

In secondary analyses, independent associations between quintiles of each well-being domain and preterm birth are reported in Table 3. Similar to the composite WBI score, all domain scores were significantly associated with maternal risk of preterm birth, in the unadjusted model and the model adjusting for individual maternal risk factors. Different domains, however, explained different amounts of variance of well-being, with the basic access index explaining 14.6% of the county variance. After adjusting for maternal risk factors, women in counties with the highest basic access score experienced an absolute difference in preterm birth rates of -2.4% (95%CI: [-2.2%,-2.6%]; p<0.001) when compared with women in counties with the lowest basic access score. Similarly, the average physical health score of the county within which a pregnant woman resided was associated with lower rates of preterm birth, in both unadjusted and adjusted models (absolute difference in preterm birth rate: -1.9%, 95%CI: [-1.6%, -2.1%]; p<0.001). In the models adjusted for maternal risk factors, healthy behaviors (-1.5%, 95%CI: [-1.2%, -1.8%]; p<0.001), emotional health (-1.0%, 95%CI: [-0.7%, -1.3%];

p<0.001), and life evaluation (-1.1%, 95%CI: [-0.8%, -1.4%]; p<0.001) of the county population negatively correlated with risk of preterm birth.

DISCUSSION

In this study of nearly all births in the United States in 2011, we found that pregnant women who lived in counties with higher average well-being had significantly lower risk of preterm birth. After accounting for known maternal risk factors, including age, race, ethnicity, smoking status, timing of initiation of prenatal care, multiparity, and payer type, the absolute difference in maternal risk for preterm delivery between the highest well-being counties and the lowest well-being counties was 1.9%. If this relationship is causal, and if the lowest well-being counties experienced this reduced rate, they would have had 3,077 fewer preterm births in 2011 alone, yielding an estimated financial savings of nearly $160 million (30), in addition to fewer long-term consequences of preterm birth such as infant mortality and long-term disabilities. Additional reductions in preterm birth risk in counties from the middle well-being quintiles, which contributed greater total numbers of births in 2011, would augment these benefits.

Decades of research have delineated a variety of maternal-level risk factors for preterm delivery, including maternal age, smoking status, history of preterm delivery, and socioeconomic status (SES) (2, 3, 31), while recent studies of environmental factors suggest that features of where a pregnant woman lives, including neighborhood poverty, local access to healthy foods, and environmental exposures, additionally influence her risk of preterm delivery (10, 11, 13, 14). Our study extends the existing literature by leveraging large national data sources to assess how a comprehensive, multi-dimensional measure of population well-being, including the self-reported overall quality of life, and its various domains relate to individual preterm birth risk across the United States. In completing this study, we found that pregnant women were at lower risk of preterm delivery when living in higher well-being populations than when living in lower well-being populations, even when we accounted for maternal risk factors that are highly correlated with SES, such as insurance payer, age at time of delivery, smoking status, and timing of first prenatal visit (32, 33). This finding adds to the growing literature describing the complex interactions between individuals and their local environment, including natural, built, and social environments, and their combined effects on health outcomes.

The relationship will identify could plausibly be causal through several mechanisms, including reasons related to the social environment. Pregnant women who live in higher well-being populations may experience less toxic stress, greater access to social resources, higher levels of trust and tolerance, and/or a greater perception of safety.(16) Prior research has shown that exposure to toxic stress increases the risk of preterm delivery,(34-37) while stronger social support, less social isolation, and greater social connectedness are associated with lower risk of preterm delivery, perhaps by reducing the allostatic load or chronic stress experienced by pregnant women.(38-43) Additionally, while experiences of perceived discrimination are associated with increased risk of preterm delivery, experiences of trust and tolerance as well as a greater perception of safety may foster healthier pregnancies and term deliveries.(44-46)

According to our results, pregnant women with the same individual maternal risk profile, including factors associated with SES, experience lower risk of preterm delivery when living in higher well-being populations than when living in lower well-being populations. This finding is consistent with emerging epigenetics (13, 47, 48) and maternal weathering (24, 29) literature. The maternal weathering model suggests that certain populations of women have an increased risk of preterm delivery due to "accelerated aging" that they experience as a result of greater exposure to hardship. This model suggests that living in better neighborhoods might attenuate the increased risk associated with these weathering effects.(49) It is possible that the observed risk contributed by weathering and the risk mitigated by living in higher well-being populations are actually related to underlying exposure to toxic stress and buffering from factors such as trust, tolerance, social support, and perceived safety.

Our study also builds on prior literature that found links between living in areas of greater poverty and increased risk of preterm birth. In the domain analyses, the basic access domain demonstrated the strongest relationship with maternal risk of preterm delivery. Even after adjusting for individual maternal risk factors, including insurance provider and smoking, the basic access domain explained nearly 15% of county-level variance in preterm birth rates. The basic access index domain includes items that assess perceived access to healthcare, clean water, fresh produce, and safe public space as well as ability to afford basic needs such as food and shelter. This finding affirms prior literature reporting that access to basic needs is strongly correlated with health outcomes. Importantly, however, all domains contributed independently to the inverse association between population well-being and maternal risk of preterm delivery, though to varying degrees. Average county-level physical health, healthy behaviors, and emotional health scores were associated with a one- to two-percent lower maternal risk of preterm delivery.

The results of our study have several potential implications. Our findings suggest the possibility that effective population- and community-level investments in well-being may not only improve overall health and quality of life for populations, but also contribute to reduced rates of preterm birth for pregnant women living in those populations, an idea worth pursuing. Our domain analyses suggest that improving aggregate basic access, in particular, could plausibly result in not only greater well-being but also fewer preterm births. Targeting other domains, such as physical health, healthy behaviors, and emotional health, may yield additional improvements. Importantly, the effectiveness of various interventions will most likely depend on the contexts within which they are implemented. Currently, efforts are underway across the globe to track and improve population well-being through programmatic and policy-based interventions.(4, 6, 50-52) While some interventions involve multi-sector, community-based programs, many of which are government supported, other interventions involve changes in economic and social policies, such as those aimed at affordable housing, employment, and access to public spaces for physical fitness or social connection.(16, 53, 54) Given the relationship between population well-being and preterm birth risk, examining the association of such programs and policies with preterm birth could be informative and allow for spread of interventions that effectively increase well-being and reduce preterm birth.

Our study has limitations. First, as a cross-sectional study, it cannot assess causation. However, determining whether a relationship exists between population well-being and risk of preterm birth is an essential first step. Second, this study specifically examines how the average well-being of the adult population within which a pregnant woman lives correlates with her risk of preterm delivery. Because we do not have an assessment of the well-being of the individual pregnant women, we cannot determine how population well-being may moderate the effect of women's own well-being or other related individual factors on their risk of preterm delivery. Additionally, we did not have data on maternal income, wealth, or education level, so we could not directly adjust for these socioeconomic variables. Nevertheless, we utilized available maternal-level variables that are known to be associated with socioeconomic status as proxies in order to control for the effect of socioeconomic status on preterm birth and isolate the effect of community well-being. Finally, we did not have well-being data available at geographically smaller units (e.g., neighborhood or city), which may be more relevant than county well-being in describing the community context for an individual pregnant woman. While counties are distinct from the smaller, often more homogeneous, geographic units of neighborhoods and census tracts, policies and programs are often enacted at the county level. Thus, results may drive action at the county-level, while also informing local communities in developing targeted programs to enhance well-being.

Pregnant women who live in populations with higher well-being have lower risk of preterm delivery, even after accounting for known individual maternal risk factors. The well-being of a population is an important end itself, but if causal pathways exist between population well-being and other valued outcomes, investments in population well-being may yield other benefits, potentially including fewer preterm births. Understanding the full effects of population well-being can inform the emerging dialogue about its value as a health investment.

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Data Sharing: If the paper is accepted for publication, we will post a de-identified data set with county resident well-being data from Gallup-Sharecare on ICSPR Open, a publicly available site. Birth data are available with permission from the National Center for Health Statistics (http://www.cdc.gov/nchs/).

Ethics Approval: This study was approved by the Yale University Institutional Review Board.

Patient and Public Involvement: No patients were involved in this study.

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Table 1. Gestational age at birth and maternal characteristics by maternal county quintile of composite Gallup-Sharecare Well-Being Index (WBI) score

	TOTAL (N=3,938,985)	**Q1** (N=161,964)	**Q2** (N=600,373)	**Q3** (N=1,212,321)	**Q4** (N=1,315,547)	**Q5** (N=648,780)
Wellbeing Index, mean (SD)	59.6 (2.9)	64.4 (0.8)	66.7 (0.7)	68.8 (0.7)	71.5 (1.4)	67.6 (2.9)
Gestation age, N (%)						
≥ 37 weeks	3,477,156 (88.3)	140,703 (86.9)	524,922 (87.4)	1,067,099 (88.0)	1,164,674 (88.5)	579,758 (89.4)
< 37 weeks	461,829 (11.7)	21,261 (13.1)	75,451 (12.6)	145,222 (12.0)	150,873 (11.5)	69,022 (10.6)
Mean maternal age, years (SD)	27.9 (6.0)	25.8 (5.7)	26.9 (5.9)	27.7 (6.0)	28.1 (6.1)	29.0 (5.9)
Maternal age in years, N (%)						
≤ 19	331,902 (8.4)	21,052 (13.0)	62,319 (10.4)	106,581 (8.8)	104,220 (7.9)	37,730 (5.8)
20-24	920,923 (23.4)	52,965 (32.7)	166,495 (27.7)	293,924 (24.2)	290,080 (22.1)	117,459 (18.1)
25-29	1,123,453 (28.5)	46,793 (28.9)	174,750 (29.1)	346,867 (28.6)	372,171 (28.3)	182,872 (28.2)
30-34	983,831 (25.0)	28,202 (17.4)	128,213 (21.4)	294,403 (24.3)	342,055 (26.0)	190,958 (29.4)
35-39	462,658 (11.7)	10,480 (6.5)	55,444 (9.2)	136,276 (11.2)	165,157 (12.6)	95,301 (14.7)
≥ 40	116,218 (3.0)	2,472 (1.5)	13,152 (2.2)	34,270 (2.8)	41,864 (3.2)	24,460 (3.8)
Maternal race, N (%)						
White	3,010,346 (76.4)	134,126 (82.8)	437,875 (72.9)	923,217 (76.2)	1,027,093 (78.1)	488,035 (75.2)
Black	629,998 (16.0)	21,510 (13.3)	124,793 (20.8)	214,219 (17.7)	188,715 (14.3)	80,761 (12.4)
American Indian/Alaskan	45,035 (1.1)	4,896 (3.0)	9,839 (1.6)	10,900 (0.9)	12,770 (1.0)	6,630 (1.0)
Native American	253,606 (6.4)	1,432 (0.9)	27,866 (4.6)	63,985 (5.3)	86,969 (6.6)	73,354 (11.3)
Asian						
Mother is Hispanic, N (%)						
No	2,996,684 (76.1)	146,500 (90.5)	492,335 (82.0)	897,455 (74.0)	940,278 (71.5)	520,116 (80.2)
Yes	942,301 (23.9)	15,464 (9.5)	108,038 (18.0)	314,866 (26.0)	375,269 (28.5)	128,664 (19.8)
Maternal smoking, N (%)						
No	3,400,601 (92.4)	123,008 (83.0)	475,937 (88.5)	1,066,051 (92.4)	1,175,513 (94.2)	560,092 (94.8)
Yes	278,922 (7.6)	25,218 (17.0)	61,999 (11.5)	88,132 (7.6)	72,718 (5.8)	30,855 (5.2)
Missing	259,462 (7.1)	13,738 (9.3)	62,437 (11.6)	58,138 (5.0)	67,316 (5.4)	57,833 (9.8)
Payer, N (%)						
Medicaid	1,462,567 (43.3)	72,640 (55.6)	265,707 (50.8)	487,403 (46.2)	451,382 (40.6)	185,435 (33.1)
Private	1,559,450 (46.1)	45,482 (34.8)	202,817 (38.8)	451,072 (42.8)	537,882 (48.4)	322,197 (57.6)
Self	135,125 (4.0)	5,327 (4.1)	19,694 (3.8)	43,835 (4.2)	46,824 (4.2)	19,445 (3.5)
Other	165,507 (4.9)	5,623 (4.3)	23,798 (4.6)	54,736 (5.2)	57,700 (5.2)	23,650 (4.2)
Unknown	57,360 (1.7)	1,575 (1.2)	10,515 (2.0)	18,064 (1.7)	18,085 (1.6)	9,121 (1.6)
Missing	558,976 (16.5)	31,317 (24.0)	77,842 (14.9)	157,211 (14.9)	203,674 (18.3)	88,932 (15.9)
Timing of 1st prenatal visit, N (%)						
1st- 3rd month	2,417,154 (71.5)	88,922 (68.1)	357,044 (68.3)	750,727 (71.2)	807,186 (72.6)	413,275 (73.8)
4th- 6th month	657,371 (19.4)	29,131 (22.3)	114,187 (21.9)	204,381 (19.4)	210,748 (19.0)	98,924 (17.7)
7th month-term	144,107 (4.3)	6,899 (5.3)	25,691 (4.9)	44,460 (4.2)	46,204 (4.2)	20,853 (3.7)
No prenatal visit	47,479 (1.4)	1,854 (1.4)	9,102 (1.7)	14,963 (1.4)	16,223 (1.5)	5,337 (1.0)
Unknown	113,898 (3.4)	3,841 (2.9)	16,507 (3.2)	40,579 (3.8)	31,512 (2.8)	21,459 (3.8)
Missing	558,976 (16.5)	31,317 (24.0)	77,842 (14.9)	157,211 (14.9)	203,674 (18.3)	88,932 (15.9)
Infant sex, N (%)						
Female	1,922,350 (48.8)	79,125 (48.9)	293,350 (48.9)	591,407 (48.8)	642,544 (48.8)	315,924 (48.7)
Male	2,016,635 (51.2)	82,839 (51.1)	307,023 (51.1)	620,914 (51.2)	673,003 (51.2)	332,856 (51.3)
Multiple births, N (%)						
Yes	136,209 (3.5)	4,789 (3.0)	19,735 (3.3)	41,606 (3.4)	45,599 (3.5)	24,480 (3.8)
No	3,802,776 (96.5)	157,175 (97.0)	580,638 (96.7)	1,170,715 (96.6)	1,269,948 (96.5)	624,300 (96.2)

Table 2. Maternal risk of preterm delivery: overall and by county of residence aggregated by quintile of composite Gallup-Sharecare Well-Being Index (WBI) score, unadjusted and adjusted for maternal risk factors

Variable	Coefficient (95% CI)	P	Wald P	Coefficient (SE)	P	Wald P
Intercept	0.131 [0.128,0.134]	<0.001		0.120 [0.118,0.123]	<0.001	
GHWBI score			<0.001			<0.001
Q1	ref			ref		
Q2	-0.006 [-0.010,-0.002]	0.001		-0.006 [-0.009,-0.003]	<0.001	
Q3	-0.013 [-0.017,-0.009]	<0.001		-0.013 [-0.016,-0.010]	<0.001	
Q4	-0.015 [-0.019,-0.012]	<0.001		-0.014 [-0.017,-0.012]	<0.001	
Q5	-0.022 [-0.026,-0.018]	<0.001		-0.019 [-0.022,-0.016]	<0.001	
Maternal age						
≤ 19				ref		
20-24				-0.019 [-0.020,-0.017]	<0.001	
25-29				-0.021 [-0.022,-0.020]	<0.001	
30-34				-0.016 [-0.017,-0.014]	<0.001	
35-39				0.002 [0.000,0.003]	0.018	
≥ 40				0.023 [0.021,0.025]	<0.001	
Maternal race						
White				ref		
Black				0.051 [0.050,0.052]	<0.001	
American Indian/Native				0.024 [0.021,0.027]	<0.001	
American				0.011 [0.009,0.012]	<0.001	
Asian						
Mother is Hispanic						
No				ref		
Yes				0.015 [0.014,0.015]	<0.001	
Maternal smoking						
No				ref		
Yes				0.030 [0.029,0.031]	<0.001	
Unknown				0.004 [0.002,0.007]		
Payer						
Medicaid				ref		
Private				-0.019 (0.000)	<0.001	
Self				-0.012 (0.001)	<0.001	
Other				-0.013 (0.001)	<0.001	
Unknown				-0.005 (0.001)	<0.001	
Timing of first prenatal visit						
1st- 3rd month				ref		
4th- 6th month				-0.019 [-0.020,-0.018]	<0.001	
7th month-term				-0.012 [-0.014,-0.011]	<0.001	
No prenatal visit				-0.013 [-0.014,-0.011]	<0.001	
Unknown				-0.005 [-0.008,-0.002]	<0.001	
				-0.004 [-0.006,-0.003]		
Infant sex					.	
Female				ref		
Male				0.011 [0.010,0.011]	<0.001	
Multiple births						
No				ref		
Yes				0.487 [0.485,0.489]	<0.001	
R^2	0.078			0.656		

Table 3. Maternal risk of preterm delivery by county of residence aggregated by quintile of individual Gallup-Sharecare Well-Being Index (WBI) domain scores, unadjusted and adjusted for maternal risk factors

Variable	Unadjusted Model Coefficient [95% CI]	P	Wald P	Adjusted Model Coefficient[95% CI]	P	Wald P
Basic Access Index (BAI)			<0.001			<0.001
Q1	ref			ref		
Q2	-0.012 [-0.016,-0.009]	<0.001		-0.009 [-0.012,-0.006]	<0.001	
Q3	-0.021 [-0.024,-0.017]	<0.001		-0.015 [-0.017,-0.012]	<0.001	
Q4	-0.027 [-0.031,-0.024]	<0.001		-0.019 [-0.022,-0.016]	<0.001	
Q5	-0.034 [-0.037,-0.030]	<0.001		-0.024 [-0.027,-0.021]	<0.001	
R^2	0.146			0.656		
Physical Health Index (PHI)			<0.001			<0.001
Q1	ref			ref		
Q2	- 0.009 [-0.012,-0.005]	<0.001		-0.007 [-0.010,-0.005]	<0.001	
Q3	-0.013 [-0.016,-0.009]	<0.001		-0.013 [-0.015,-0.010]	<0.001	
Q4	-0.017 [-0.020,-0.013]	<0.001		-0.017 [-0.019,-0.014]	<0.001	
Q5	-0.019 [-0.023,-0.016]	<0.001		-0.019 [-0.021,-0.016]	<0.001	
R^2	0.059			0.657		
Healthy Behaviors Index (HBI)			<0.001			<0.001
Q1	ref			ref		
Q2	-0.003 [-0.007,0.001]	0.130		-0.005 [-0.008,-0.002]	<0.001	
Q3	-0.008 [-0.011,-0.004]	<0.001		-0.010 [-0.013,-0.008]	<0.001	
Q4	-0.013 [-0.017,-0.010]	<0.001		-0.015 [-0.017,-0.012]	<0.001	
Q5	-0.017 [-0.021,-0.013]	<0.001		-0.015 [-0.018,-0.012]	<0.001	
R^2	0.039			0.654		
Emotional Health Index (EHI)			<0.001			<0.001
Q1	ref			ref		
Q2	-0.011 [-0.014,-0.007]	<0.001		-0.010 [-0.013,-0.008]	<0.001	
Q3	-0.012 [-0.015,-0.008]	<0.001		-0.011 [-0.014,-0.009]	<0.001	
Q4	-0.014 [-0.018,-0.010]	<0.001		-0.013 [-0.016,-0.010]	<0.001	
Q5	-0.012 [-0.016,-0.008]	<0.001		-0.010 [-0.013,-0.007]	<0.001	
R^2	0.032			0.656		
Life Evaluation Index (LEI)			0.004			<0.001
Q1	ref			ref		
Q2	-0.005 [-0.009,-0.001]	0.010		-0.005 [-0.008,-0.002]	<0.001	
Q3	-0.006 [-0.009,-0.002]	0.004		-0.008 [-0.011,-0.005]	<0.001	
Q4	-0.006 [-0.009,-0.002]	0.003		-0.010 [-0.013,-0.007]	<0.001	
Q5	-0.008 [-0.011,-0.004]	<0.001		-0.011 [-0.014,-0.008]	<0.001	
R^2	0.004			0.653		
Work Environment Index (WEI)			<0.001			<0.001
Q1	ref			ref		
Q2	-0.007 [-0.011,-0.003]	<0.001		-0.008 [-0.010,-0.005]	<0.001	
Q3	-0.008 [-0.012,-0.004]	<0.001		-0.009 [-0.011,-0.006]	<0.001	
Q4	-0.010 [-0.013,-0.006]	<0.001		-0.007 [-0.010,-0.005]	<0.001	
Q5	-0.006 [-0.010,-0.002]	0.002		-0.003 [-0.006,0.000]	0.001	
R^2	0.016			0.653		

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract *– Abstract (Page 2, "Methods: We performed a cross-sectional study…")*
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found – *Page 2*
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported *– Pages 4-5*
Objectives	3	State specific objectives, including any prespecified hypotheses – *Page 5, "…to examine whether maternal risk of preterm birth varies with the overall well-being.."*
Methods		
Study design	4	Present key elements of study design early in the paper – *Page 5, beginning of methods*
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection – *Pages 5-9*
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants – *Page 5-6*
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable – *Pages 6-9*
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group – *Pages 6-9*
Bias	9	Describe any efforts to address potential sources of bias – *Page 7-9*
Study size	10	Explain how the study size was arrived at -- *Page 6, 1st paragraph of Study Sample*
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why – *Pages 7-9*
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding *– Pages 7-9*
		(*b*) Describe any methods used to examine subgroups and interactions – *pages 7-9*
		(*c*) Explain how missing data were addressed – *Page 9*
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy – *N/A*
		(*e*) Describe any sensitivity analyses – *Page 9*

Continued on next page

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed – *Page* 9
		(b) Give reasons for non-participation at each stage – *N/A, this was a population based study at the county level*
		(c) Consider use of a flow diagram – *N/A*
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders – *N/A unit of analysis was the county*
		(b) Indicate number of participants with missing data for each variable of interest – *N/A*
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures – *Pages 9-11 and Tables 1-3)*
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included – *Page 10-11 and Table 2*
		(*b*) Report category boundaries when continuous variables were categorized – *All tables*
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period – *N/a*
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses – *N/A*
Discussion		
Key results	18	Summarise key results with reference to study objectives – *Page 11*
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias – *Page 15*
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence – *Page 11-15*
Generalisability	21	Discuss the generalisability (external validity) of the study results – *Page 11-15*
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based—*Page 16*

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Do pregnant women living in higher well-being populations in the US experience lower risk of preterm delivery?: A cross-sectional study

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Do pregnant women living in higher well-being populations in the US experience lower risk of preterm delivery?: A cross-sectional study

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ABSTRACT

Objective: To determine if preterm birth, defined as gestational age <37 weeks, is lower for women living in counties with higher well-being, after accounting for known individual risk factors.

Design: Cross-sectional study of all United States births in 2011.

Participants: We obtained birth data from the National Center for Health Statistics, which included 3,938,985 individuals.

Main outcomes measures: Primary outcome measure was maternal risk of preterm delivery by county; primary independent variable was county-level well-being as measured by the Gallup-Sharecare Well-Being Index (WBI).

Results: Women living in counties with higher population well-being had a lower rate of preterm delivery. The rate of preterm birth in counties in the lowest WBI quintile was 13.1%, while the rate of preterm birth in counties in the highest WBI quintile was 10.9%. In the model adjusted for maternal risk factors (age, race, Hispanic ethnicity, smoking status, timing of initiation of prenatal visits, multiparity, maternal insurance payer), the association was slightly attenuated with an absolute difference of 1.9% (95% CI 1.7% - 2.1%; P<0.001).

Conclusions: Pregnant women who live in areas with higher population well-being have lower risk of preterm birth, even after accounting for individual risk factors.

STRENGTHS AND LIMITATIONS OF THE STUDY

- In this national study, we utilized two large, unique datasets, including the Gallup-Sharecare Well-being Index and all data on live births in the U.S. in 2011 from the National Center for Health Statistics.
- With these data, this study was the first to examine whether the average well-being of the population in which a woman lives, defined as a broader, multi-dimensional, self-reported context of the physical, mental, and social health of the geographic community, including the overall life evaluation of its residents, relates to her risk of preterm delivery.
- We summarized rates of preterm birth by quintile of county well-being, and tested for associations between population well-being and gestational age using hierarchical generalized linear models that adjusted for individual maternal risk factors.
- As a cross-sectional study, it cannot assess causation, yet determining whether a relationship exists between population well-being and risk of preterm birth is an essential first step.
- Without an assessment of the well-being of the individual pregnant women, the study cannot determine how population well-being may moderate the effect of women's own well-being or other related individual factors on their risk of preterm delivery.

INTRODUCTION

Despite considerable efforts, preterm birth remains a substantial public health problem in the United States.(1-3) With one in ten babies born at less than 37 weeks gestation, preterm birth is the greatest contributor to infant mortality and a leading cause of long-term neurological disabilities in children, resulting in considerable mortality, morbidity, and long-term costs in the US.(4-6) Research has demonstrated that while individual factors such as maternal age and smoking status influence a pregnant woman's risk of preterm delivery,(3) community environment has additional influence.(7-9)

Research has also shown that where a woman lives affects her risk of preterm birth. Decades of study have demonstrated that specific features of the local environment, including neighborhood poverty, local access to healthy foods, and environmental exposures, influence a pregnant woman's risk of preterm delivery.(10-14) In addition to these features, the way that the community views the overall quality of life in their community is another important, yet often unconsidered, feature of the community. Population well-being is a comprehensive construct that captures these contextual factors and incorporates community members' perceptions of the quality of their life in their community (15, 16). Well-being at the population or community level influences health and well-being at the individual level, with a change in well-being of individuals in a community having an effect on others(17). As such, the population well-being of a community within which pregnant women live – defined as a broader, multi-dimensional, self-reported context of the physical, mental, and social health of the geographic community, including the overall life evaluation of its residents – may constitute a more complete and accurate conceptualization of the environment that influences the women's risk of preterm delivery.

Higher population well-being is not only an outcome worth achieving for its own sake, but also has been associated with other desirable health outcomes, such as greater life expectancy.(18) If also associated with preterm birth, population well-being may provide a promising novel target for reducing preterm birth rates. Prior studies have examined the relationship of socioeconomic factors with preterm birth, but community well-being is a distinct construct and no study, has examined whether the average well-being of the population in which a woman lives relates to her risk of preterm delivery. To address this gap, we utilized a comprehensive, multi-dimensional assessment of well-being across the United States, the Gallup-Sharecare Well-being Index™, previously known as the Gallup-Healthways Well-Being Index prior to rebranding following Sharecare's 2016 acquisition of Healthways (Gallup-Sharecare, 2011), and data on all live births in the United States in 2011 (National Center for Health Statistics, 2011) to examine whether the rate of preterm birth varies with the overall well-being of the population within which the pregnant woman lives(19, 20). We hypothesized that risk of preterm birth is lower for pregnant women who live in higher well-being populations, even when accounting for known individual maternal risk factors. Such work lays the groundwork for testing whether society-wide interventions to improve well-being might have broad beneficial health effects.

METHODS

Overview

We conducted a cross-sectional study in which we linked data on all live births in the U.S. in 2011 to area-level data on population well-being. Because county was the smallest geographic area available for each mother, we aggregated well-being at the county level as well. Well-being was measured at the level of county (or county equivalent) and births were linked to the mother's county of residence. We summarized rates of preterm birth by quintile of county well-being, and tested for associations between population well-being and gestational age using hierarchical generalized linear models that adjusted for maternal risk factors.

Birth Data

Birth data were obtained from the National Center for Health Statistics (NCHS).(20) The NCHS aggregates and standardizes data on births collected from all 50 states and the District of Columbia. We used restricted geocoded special use files from NCHS; these include maternal risk factors, maternal county of residence, and gestational age (categorized as <20 weeks, 20-27, 28-31,32-33,34-36,37-38,39,40, 41, and 42 or more). This dataset include geocoding at the county level, using the Federal Information Processing System (FIPS) code.(21)

Study Sample

We included all live births during 2011 where the mother's county of residence was not missing, and for which there were WBI survey responses available from that county. We excluded births with missing gestational age. In 2011, fifteen states did not collect information on prenatal visits or payer (AK, AL, AR, AZ, CT, HI, MA, ME, MN, MS, NJ, RI, VA, WV). We did not impute missing data due to nonrandom missingness and likely confounding with the outcome. These missing variables were instead coded as unknown; in sensitivity analyses we omitted these states.

Outcome

Our primary outcome was preterm delivery, defined as gestational age <37 weeks.(22)

Population Well-being Data

Our primary independent variable was population well-being. Data on population well-being were obtained from the Gallup-Sharecare Well-being Index (WBI) survey for 2011.(19) To develop the WBI, survey items that aligned with prior research on well-being were compiled by experts in the field (23-25). Based on the existing literature, items were selected so that the survey would include both hedonic well-being (i.e., people's feelings and thoughts about their lives) and eudemonic well-being (i.e., an individual's judgments about the meaning and purpose in one's life) (26). The survey therefore includes items assessing daily emotional experience and a wide variety of evaluative domains, such as overall life, standard of living, and satisfaction with community, work, relationships, and personal health. Data from a large, representative national sample was then used to perform factor analysis to determine the final set of questions. Criterion validity of geographically aggregated data was established by examining correlations with health and socioeconomic indicators (27). Principal component and confirmatory factor analyses were then used to create an instrument valid for measuring individual well-being. The individual well-being measure has acceptable reliability, internal and external validity (28).

In 2011, the WBI comprised 55 self-reported items organized into 6 domains: life evaluation; emotional health; physical health; healthy behaviors; basic access and work environment.(24) The Life Evaluation Index measures life satisfaction and optimism about the future. The Emotional Health Index measures daily emotions and the presence or absence of depression. The Physical Health Index assesses the burden of chronic disease and recent illness. The Healthy Behaviors Index assesses the prevalence of smoking, exercising, and eating fruit and vegetables. The Basic Access Index includes perception of safety and access to housing and health care. The Work Environment Index assesses job satisfaction, trust and respect in the workplace and, unlike the other domains, it is collected only from the subset of respondents who report being employed. Each domain is represented by an index, measured on a scale of 0 to 100. A composite score, the Well-Being Index (WBI), was calculated as the unweighted mean of the 6 domain scores, and is reported on a scale of 0-100. Gallup surveyed a unique sample of nearly 1000 individuals 18 years and older every day for approximately 350 days during 2011. A structured sampling design was used with respondents surveyed from all 50 states and the District of Columbia. The survey was administered in both English and Spanish, using both land lines and cell phones. We aggregated individual WBI responses into county scores based the maternal county of residence. For our primary analyses, we used quintiles of county WBI scores as our

independent variable; in secondary analyses, we used county-level quintiles for each of the individual domain scores.

Other Independent Variables

From the NCHS birth dataset we included the following known maternal risk factors for preterm delivery: age (categorized as <=19, 20-24, 25-29, 30-34, 35-39, 40+); race (White, Black, Asian, American Indian/Alaska Native); Hispanic ethnicity; smoking status; start of prenatal visits (1st trimester, 2nd trimester, 3rd trimester, none, not known); and multiparity (single birth versus multiple). We also included infant sex, and, as a marker of socioeconomic status, we included the maternal insurance payer (Medicaid, private, self, other, unknown).

Statistical Analysis

We summarized the outcome, WBI score, and all maternal risk factors by quintile of population WBI, reporting frequency and percent of births in each category. To assess the association between population well-being and preterm birth, we estimated two individual level mixed effects linear models. Both models had the same dichotomous outcome (preterm birth) and both included a random intercept for county) Though logistic regression models are conventional used for dichotomous outcomes, linear probability models such as these are appropriate when the outcome rate is not close to 0 or 1, and the predicted values from the model are also between 0 and 1. One advantage of using a linear model is that the intercept and coefficients have direct interpretations as a reference rate and risk differences respectively. The first model was unadjusted, including only county quintile of population well-being. The second adjusted for maternal age, race, ethnicity, smoking status, trimester during which prenatal care was initiated, single or multiple birth, and insurance payer. For both models we calculated the Wald P-value for the overall effect of WBI and a separate test for trend in effects across WBI quintiles. In secondary analyses we replicated the main analyses using each of the 6 domain scores of the well-being index.

We also estimated a reference model which included no independent variables, and used the county level variance from this model to calculate the variance explained at the county level for each of the models described above, using $R^2 = (\tau^2 - \tau^{*2})/\tau^2$, where τ^{*2} is the county level variance for the model with independent variables.(29)

All analyses were performed using Stata 14.2 (2016 StataCorp, College Station, TX). The Yale University Institutional Review Board approved this study.

Patient and Public Involvement: No patients or the public were involved in the planning and design of this study.

RESULTS

We used data from 3,938,985 births across 2,989 counties, representing 99.6% of all US births in 2011. The mean (SD) county-level preterm birth rate was 11.7% (2.2%) preterm births. Table 1 shows numbers and percentages of children born before and after 37 weeks' gestation, maternal characteristics, and infant sex by quintile of average well-being of the maternal county of residence.

The observed rate of preterm birth decreased across WBI quintiles from 13.1% in the lowest quintile to 10.9% in the highest quintile (Table 1). In the unadjusted model, pregnant women living in counties with higher population well-being had a significantly lower risk of preterm birth. -.2.2% (95% CI: [-2.6%, -1.8%]; p<0.001) (Table 2). After adjusting for maternal risk factors for preterm birth, the trend remained consistent across the quintiles; the absolute difference between the highest and lowest quintiles was attenuated to -1.9% (95% CI: [-2.2%, -1.6%]; P<0.001). In sensitivity analyses, results were similar.

In secondary analyses, independent associations between quintiles of each well-being domain and preterm birth are reported in Table 3. Similar to the composite WBI score, all domain scores were significantly associated with maternal risk of preterm birth, in the unadjusted model and the model adjusting for individual maternal risk factors. Different domains, however, explained different amounts of variance of well-being, with the basic access index explaining 14.6% of the county variance. After adjusting for maternal risk factors, women in counties with the highest basic access score experienced an absolute difference in preterm birth rates of -2.4% (95%CI: [-2.2%,-2.6%]; p<0.001) when compared with women in counties with the lowest basic access score. Similarly, the average physical health score of the county within which a pregnant woman resided was associated with lower rates of preterm birth, in both unadjusted and adjusted models (absolute difference in preterm birth rate: -1.9%, 95%CI: [-1.6%, -2.1%]; p<0.001). In the models adjusted for maternal risk factors, healthy behaviors (-1.5%, 95%CI: [-1.2%, -1.8%]; p<0.001), emotional health (-1.0%, 95%CI: [-0.7%, -1.3%]; p<0.001), and life evaluation (-1.1%, 95%CI: [-0.8%, -1.4%]; p<0.001) of the county population negatively correlated with risk of preterm birth.

DISCUSSION

In this study of nearly all births in the United States in 2011, we found that pregnant women who lived in counties with higher average well-being had significantly lower risk of preterm birth. After accounting for known maternal risk factors, including age, race, ethnicity, smoking status, timing of initiation of prenatal care, multiparity, and payer type, the absolute difference in maternal risk for preterm delivery between the highest well-being counties and the lowest well-being counties was 1.9%. If this relationship is causal, and if the lowest well-being counties experienced this reduced rate, they would have had 3,077 fewer preterm births in 2011 alone, yielding an estimated financial savings of nearly $160 million (30), in addition to fewer long-term consequences of preterm birth such as infant mortality and long-term disabilities. Additional reductions in preterm birth risk in counties from the middle well-being quintiles, which contributed greater total numbers of births in 2011, would augment these benefits.

Decades of research have delineated a variety of maternal-level risk factors for preterm delivery, including maternal age, smoking status, history of preterm delivery, and socioeconomic status (SES) (2, 3, 31), while recent studies of environmental factors suggest that features of where a pregnant woman lives, including neighborhood poverty, local access to healthy foods, and environmental exposures, additionally influence her risk of preterm delivery (10, 11, 13, 14). Our study extends the existing literature by leveraging a large national data sources to assess how a comprehensive, multi-dimensional measure of population well-being, including the self-reported overall quality of life, and its various domains relate to individual preterm birth risk across the United States. In completing this study, we found that pregnant women were at lower risk of preterm delivery when living in higher well-being populations than when living in lower well-being populations, even when we accounted for maternal risk factors that are highly correlated with SES, such as insurance payer, age at time of delivery, smoking status, and timing of first prenatal visit (32, 33). This finding adds to the growing literature describing the complex interactions between individuals and their local environment, including natural, built, and social environments, and their combined effects on health outcomes.

The relationship will identify could plausibly be causal through several mechanisms, including reasons related to the social environment. Pregnant women who live in higher well-being populations may experience less toxic stress, greater access to social resources, higher levels of trust and tolerance, and/or a greater perception of safety.(16) Prior research has shown that exposure to toxic stress increases the risk of preterm delivery,(34-37) while stronger social support, less social isolation, and greater social connectedness are associated with lower risk of preterm delivery, perhaps by reducing the allostatic load or chronic stress experienced by pregnant women.(38-43)

Additionally, while experiences of perceived discrimination are associated with increased risk of preterm delivery, experiences of trust and tolerance as well as a greater perception of safety may foster healthier pregnancies and term deliveries.(44-46)

According to our results, pregnant women with the same individual maternal risk profile, including factors associated with SES, experience lower risk of preterm delivery when living in higher well-being populations than when living in lower well-being populations. This finding is consistent with emerging epigenetics (13, 47, 48) and maternal weathering (24, 29) literature. The maternal weathering model suggests that certain populations of women have an increased risk of preterm delivery due to “accelerated aging” that they experience as a result of greater exposure to hardship. This model suggests that living in better neighborhoods might attenuate the increased risk associated with these weathering effects.(49) It is possible that the observed risk contributed by weathering and the risk mitigated by living in higher well-being populations are actually related to underlying exposure to toxic stress and buffering from factors such as trust, tolerance, social support, and perceived safety.

Our study also builds on prior literature that found links between living in areas of greater poverty and increased risk of preterm birth. In the domain analyses, the basic access domain demonstrated the strongest relationship with maternal risk of preterm delivery. Even after adjusting for individual maternal risk factors, including insurance provider and smoking, the basic access domain explained nearly 15% of county-level variance in preterm birth rates. The basic access index domain includes items that assess perceived access to healthcare, clean water, fresh produce, and safe public space as well as ability to afford basic needs such as food and shelter. This finding affirms prior literature reporting that access to basic needs is strongly correlated with health outcomes. Importantly, however, all domains contributed independently to the inverse association between population well-being and maternal risk of preterm delivery, though to varying degrees. Average county-level physical health, healthy behaviors, and emotional health scores were associated with a one- to two-percent lower maternal risk of preterm delivery.

The results of our study have several potential implications. Our findings suggest the possibility that effective population- and community-level investments in well-being may not only improve overall health and quality of life for populations, but also contribute to reduced rates of preterm birth for pregnant women living in those populations, an idea worth pursuing. Our domain analyses suggest that improving aggregate basic access, in particular, could plausibly result in not only greater well-being but also fewer preterm births. Targeting other domains, such as physical health, healthy behaviors, and emotional health, may yield additional improvements. Importantly, the effectiveness of various interventions will most likely depend on the contexts within which they are implemented. Currently, efforts are underway across the globe to track and improve population well-being through programmatic and policy-based interventions.(4, 6, 50-52) While some interventions involve multi-sector, community-based programs, many of which are government supported, other interventions involve changes in economic and social policies, such as those aimed at affordable housing, employment, and access to public spaces for physical fitness or social connection.(16, 53, 54) Given the relationship between population well-being and preterm birth risk, examining the association of such programs and policies with preterm birth could be informative and allow for spread of interventions that effectively increase well-being and reduce preterm birth.

Our study has limitations. First, as a cross-sectional study, it cannot assess causation. However, determining whether a relationship exists between population well-being and risk of preterm birth is an essential first step. Second, this study specifically examines how the average well-being of the adult population within which a pregnant woman lives correlates with her risk of preterm delivery. Because we do not have an assessment of the well-being of the individual pregnant women, we cannot determine how population well-being may moderate the effect of women's own well-being or other related individual factors on their risk of preterm delivery. Additionally, we did not have data on maternal income, wealth, or education level, so we could not directly adjust for these socioeconomic variables. Nevertheless, we utilized available maternal-level variables that are known to be associated with socioeconomic status as proxies in order to control for the effect of socioeconomic status on preterm birth and isolate the effect of community well-being. Finally, we did not have well-being data available at geographically smaller units (e.g., neighborhood or city), which may be more relevant than county well-being in describing the community context for an individual pregnant woman. While counties are distinct from the smaller, often more homogeneous, geographic units of neighborhoods and census tracts, policies and programs are often enacted at the county level. Thus, results may drive action at the county-level, while also informing local communities in developing targeted programs to enhance well-being.

Pregnant women who live in populations with higher well-being have lower risk of preterm delivery, even after accounting for known individual maternal risk factors. The well-being of a population is an important end itself, but if causal pathways exist between population well-being and other valued outcomes, investments in population well-being may yield other benefits, potentially including fewer preterm births. Understanding the full effects of population well-being can inform the emerging dialogue about its value as a health investment.

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Data Sharing: If the paper is accepted for publication, we will post a de-identified data set with county resident well-being data from Gallup-Sharecare on ICSPR Open, a publicly available site. Birth data are available with permission from the National Center for Health Statistics (http://www.cdc.gov/nchs/).

Ethics Approval: This study was approved by the Yale University Institutional Review Board.

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Table 1. Gestational age at birth and maternal characteristics by maternal county quintile of composite Gallup-Sharecare Well-Being Index (WBI) score

	TOTAL (N=3,938,985)	**Q1** (N=161,964)	**Q2** (N=600,373)	**Q3** (N=1,212,321)	**Q4** (N=1,315,547)	**Q5** (N=648,780)
Wellbeing Index, mean (SD)	59.6 (2.9)	64.4 (0.8)	66.7 (0.7)	68.8 (0.7)	71.5 (1.4)	67.6 (2.9)
Gestation age, N (%)						
≥ 37 weeks	3,477,156 (88.3)	140,703 (86.9)	524,922 (87.4)	1,067,099 (88.0)	1,164,674 (88.5)	579,758 (89.4)
< 37 weeks	461,829 (11.7)	21,261 (13.1)	75,451 (12.6)	145,222 (12.0)	150,873 (11.5)	69,022 (10.6)
Mean maternal age, years (SD)	27.9 (6.0)	25.8 (5.7)	26.9 (5.9)	27.7 (6.0)	28.1 (6.1)	29.0 (5.9)
Maternal age in years, N (%)						
≤ 19	331,902 (8.4)	21,052 (13.0)	62,319 (10.4)	106,581 (8.8)	104,220 (7.9)	37,730 (5.8)
20-24	920,923 (23.4)	52,965 (32.7)	166,495 (27.7)	293,924 (24.2)	290,080 (22.1)	117,459 (18.1)
25-29	1,123,453 (28.5)	46,793 (28.9)	174,750 (29.1)	346,867 (28.6)	372,171 (28.3)	182,872 (28.2)
30-34	983,831 (25.0)	28,202 (17.4)	128,213 (21.4)	294,403 (24.3)	342,055 (26.0)	190,958 (29.4)
35-39	462,658 (11.7)	10,480 (6.5)	55,444 (9.2)	136,276 (11.2)	165,157 (12.6)	95,301 (14.7)
≥ 40	116,218 (3.0)	2,472 (1.5)	13,152 (2.2)	34,270 (2.8)	41,864 (3.2)	24,460 (3.8)
Maternal race, N (%)						
White	3,010,346 (76.4)	134,126 (82.8)	437,875 (72.9)	923,217 (76.2)	1,027,093 (78.1)	488,035 (75.2)
Black	629,998 (16.0)	21,510 (13.3)	124,793 (20.8)	214,219 (17.7)	188,715 (14.3)	80,761 (12.4)
American Indian/Alaskan Native American	45,035 (1.1)	4,896 (3.0)	9,839 (1.6)	10,900 (0.9)	12,770 (1.0)	6,630 (1.0)
Asian	253,606 (6.4)	1,432 (0.9)	27,866 (4.6)	63,985 (5.3)	86,969 (6.6)	73,354 (11.3)
Mother is Hispanic, N (%)						
No	2,996,684 (76.1)	146,500 (90.5)	492,335 (82.0)	897,455 (74.0)	940,278 (71.5)	520,116 (80.2)
Yes	942,301 (23.9)	15,464 (9.5)	108,038 (18.0)	314,866 (26.0)	375,269 (28.5)	128,664 (19.8)
Maternal smoking, N (%)						
No	3,400,601 (92.4)	123,008 (83.0)	475,937 (88.5)	1,066,051 (92.4)	1,175,513 (94.2)	560,092 (94.8)
Yes	278,922 (7.6)	25,218 (17.0)	61,999 (11.5)	88,132 (7.6)	72,718 (5.8)	30,855 (5.2)
Missing	259,462 (7.1)	13,738 (9.3)	62,437 (11.6)	58,138 (5.0)	67,316 (5.4)	57,833 (9.8)
Payer, N (%)						
Medicaid	1,462,567 (43.3)	72,640 (55.6)	265,707 (50.8)	487,403 (46.2)	451,382 (40.6)	185,435 (33.1)
Private	1,559,450 (46.1)	45,482 (34.8)	202,817 (38.8)	451,072 (42.8)	537,882 (48.4)	322,197 (57.6)
Self	135,125 (4.0)	5,327 (4.1)	19,694 (3.8)	43,835 (4.2)	46,824 (4.2)	19,445 (3.5)
Other	165,507 (4.9)	5,623 (4.3)	23,798 (4.6)	54,736 (5.2)	57,700 (5.2)	23,650 (4.2)
Unknown	57,360 (1.7)	1,575 (1.2)	10,515 (2.0)	18,064 (1.7)	18,085 (1.6)	9,121 (1.6)
Missing	558,976 (16.5)	31,317 (24.0)	77,842 (14.9)	157,211 (14.9)	203,674 (18.3)	88,932 (15.9)

Timing of 1st prenatal visit, N (%)						
1st- 3rd month	2,417,154 (71.5)	88,922 (68.1)	357,044 (68.3)	750,727 (71.2)	807,186 (72.6)	413,275 (73.8)
4th- 6th month	657,371 (19.4)	29,131 (22.3)	114,187 (21.9)	204,381 (19.4)	210,748 (19.0)	98,924 (17.7)
7th month-term	144,107 (4.3)	6,899 (5.3)	25,691 (4.9)	44,460 (4.2)	46,204 (4.2)	20,853 (3.7)
No prenatal visit	47,479 (1.4)	1,854 (1.4)	9,102 (1.7)	14,963 (1.4)	16,223 (1.5)	5,337 (1.0)
Unknown	113,898 (3.4)	3,841 (2.9)	16,507 (3.2)	40,579 (3.8)	31,512 (2.8)	21,459 (3.8)
Missing	558,976 (16.5)	31,317 (24.0)	77,842 (14.9)	157,211 (14.9)	203,674 (18.3)	88,932 (15.9)
Infant sex, N (%)						
Female	1,922,350 (48.8)	79,125 (48.9)	293,350 (48.9)	591,407 (48.8)	642,544 (48.8)	315,924 (48.7)
Male	2,016,635 (51.2)	82,839 (51.1)	307,023 (51.1)	620,914 (51.2)	673,003 (51.2)	332,856 (51.3)
Multiple births, N (%)						
Yes	136,209 (3.5)	4,789 (3.0)	19,735 (3.3)	41,606 (3.4)	45,599 (3.5)	24,480 (3.8)
No	3,802,776 (96.5)	157,175 (97.0)	580,638 (96.7)	1,170,715 (96.6)	1,269,948 (96.5)	624,300 (96.2)

Table 2. Maternal risk of preterm delivery: overall and by county of residence aggregated by quintile of composite Gallup-Sharecare Well-Being Index (WBI) score, unadjusted and adjusted for maternal risk factors

Variable	Coefficient (95% CI)	P	Wald P	Coefficient (SE)	P	Wald P
Intercept	0.131 [0.128,0.134]	<0.001		0.120 [0.118,0.123]	<0.001	
GHWBI score			<0.001			<0.001
Q1	ref			ref		
Q2	-0.006 [-0.010,-0.002]	0.001		-0.006 [-0.009,-0.003]	<0.001	
Q3	-0.013 [-0.017,-0.009]	<0.001		-0.013 [-0.016,-0.010]	<0.001	
Q4	-0.015 [-0.019,-0.012]	<0.001		-0.014 [-0.017,-0.012]	<0.001	
Q5	-0.022 [-0.026,-0.018]	<0.001		-0.019 [-0.022,-0.016]	<0.001	
Maternal age						
≤ 19				ref		
20-24				-0.019 [-0.020,-0.017]	<0.001	
25-29				-0.021 [-0.022,-0.020]	<0.001	
30-34				-0.016 [-0.017,-0.014]	<0.001	
35-39				0.002 [0.000,0.003]	0.018	
≥ 40				0.023 [0.021,0.025]	<0.001	
Maternal race						
White				ref		
Black				0.051 [0.050,0.052]	<0.001	
American Indian/Native American				0.024 [0.021,0.027]	<0.001	
Asian				0.011 [0.009,0.012]	<0.001	
Mother is Hispanic						
No				ref		
Yes				0.015 [0.014,0.015]	<0.001	
Maternal smoking						
No				ref		
Yes				0.030 [0.029,0.031]	<0.001	
Unknown				0.004 [0.002,0.007]		
Payer						
Medicaid				ref		
Private				-0.019 (0.000)	<0.001	
Self				-0.012 (0.001)	<0.001	
Other				-0.013 (0.001)	<0.001	
Unknown				-0.005 (0.001)	<0.001	
Timing of first prenatal visit						
1st- 3rd month				ref		
4th- 6th month				-0.019 [-0.020,-0.018]	<0.001	
7th month-term				-0.012 [-0.014,-0.011]	<0.001	
No prenatal visit				-0.013 [-0.014,-0.011]	<0.001	
Unknown				-0.005 [-0.008,-0.002]	<0.001	
				-0.004 [-0.006,-0.003]		

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Infant sex					.	
Female				ref		
Male				0.011 [0.010,0.011]	<0.001	
Multiple births						
No				ref		
Yes				0.487 [0.485,0.489]	<0.001	
R^2	0.078			0.656		

Table 3. Maternal risk of preterm delivery by county of residence aggregated by quintile of individual Gallup-Sharecare Well-Being Index (WBI) domain scores, unadjusted and adjusted for maternal risk factors

Variable	Unadjusted Model Coefficient [95% CI]	P	Wald P	Adjusted Model Coefficient[95% CI]	P	Wald P
Basic Access Index (BAI)			<0.001			<0.001
Q1	ref			ref		
Q2	-0.012 [-0.016,-0.009]	<0.001		-0.009 [-0.012,-0.006]	<0.001	
Q3	-0.021 [-0.024,-0.017]	<0.001		-0.015 [-0.017,-0.012]	<0.001	
Q4	-0.027 [-0.031,-0.024]	<0.001		-0.019 [-0.022,-0.016]	<0.001	
Q5	-0.034 [-0.037,-0.030]	<0.001		-0.024 [-0.027,-0.021]	<0.001	
R^2	0.146			0.656		
Physical Health Index (PHI)			<0.001			<0.001
Q1	ref			ref		
Q2	-0.009 [-0.012,-0.005]	<0.001		-0.007 [-0.010,-0.005]	<0.001	
Q3	-0.013 [-0.016,-0.009]	<0.001		-0.013 [-0.015,-0.010]	<0.001	
Q4	-0.017 [-0.020,-0.013]	<0.001		-0.017 [-0.019,-0.014]	<0.001	
Q5	-0.019 [-0.023,-0.016]	<0.001		-0.019 [-0.021,-0.016]	<0.001	
R^2	0.059			0.657		
Healthy Behaviors Index (HBI)			<0.001			<0.001
Q1	ref			ref		
Q2	-0.003 [-0.007,0.001]	0.130		-0.005 [-0.008,-0.002]	<0.001	
Q3	-0.008 [-0.011,-0.004]	<0.001		-0.010 [-0.013,-0.008]	<0.001	
Q4	-0.013 [-0.017,-0.010]	<0.001		-0.015 [-0.017,-0.012]	<0.001	
Q5	-0.017 [-0.021,-0.013]	<0.001		-0.015 [-0.018,-0.012]	<0.001	
R^2	0.039			0.654		
Emotional Health Index (EHI)			<0.001			<0.001
Q1	ref			ref		
Q2	-0.011 [-0.014,-0.007]	<0.001		-0.010 [-0.013,-0.008]	<0.001	
Q3	-0.012 [-0.015,-0.008]	<0.001		-0.011 [-0.014,-0.009]	<0.001	
Q4	-0.014 [-0.018,-0.010]	<0.001		-0.013 [-0.016,-0.010]	<0.001	
Q5	-0.012 [-0.016,-0.008]	<0.001		-0.010 [-0.013,-0.007]	<0.001	
R^2	0.032			0.656		
Life Evaluation Index (LEI)			0.004			<0.001
Q1	ref			ref		
Q2	-0.005 [-0.009,-0.001]	0.010		-0.005 [-0.008,-0.002]	<0.001	
Q3	-0.006 [-0.009,-0.002]	0.004		-0.008 [-0.011,-0.005]	<0.001	
Q4	-0.006 [-0.009,-0.002]	0.003		-0.010 [-0.013,-0.007]	<0.001	
Q5	-0.008 [-0.011,-0.004]	<0.001		-0.011 [-0.014,-0.008]	<0.001	
R^2	0.004			0.653		
Work Environment Index (WEI)			<0.001			<0.001
Q1	ref			ref		
Q2	-0.007 [-0.011,-0.003]	<0.001		-0.008 [-0.010,-0.005]	<0.001	
Q3	-0.008 [-0.012,-0.004]	<0.001		-0.009 [-0.011,-0.006]	<0.001	
Q4	-0.010 [-0.013,-0.006]	<0.001		-0.007 [-0.010,-0.005]	<0.001	
Q5	-0.006 [-0.010,-0.002]	0.002		-0.003 [-0.006,0.000]	0.001	
R^2	0.016			0.653		

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract – *Abstract (Page 2, "Methods: We performed a cross-sectional study…")*
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found – *Page 2*
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported – *Pages 4-5*
Objectives	3	State specific objectives, including any prespecified hypotheses – *Page 5, "…to examine whether maternal risk of preterm birth varies with the overall well-being.."*
Methods		
Study design	4	Present key elements of study design early in the paper – *Page 5, beginning of methods*
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection – *Pages 5-9*
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants – *Page 5-6*
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable – *Pages 6-9*
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group – *Pages 6-9*
Bias	9	Describe any efforts to address potential sources of bias – *Page 7-9*
Study size	10	Explain how the study size was arrived at -- *Page 6, 1st paragraph of Study Sample*
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why – *Pages 7-9*
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding – *Pages 7-9*
		(*b*) Describe any methods used to examine subgroups and interactions – *pages 7-9*
		(*c*) Explain how missing data were addressed – *Page 9*
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy – *N/A*
		(*e*) Describe any sensitivity analyses – *Page 9*

Continued on next page

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed – *Page* 9
		(b) Give reasons for non-participation at each stage – *N/A, this was a population based study at the county level*
		(c) Consider use of a flow diagram – *N/A*
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders – *N/A unit of analysis was the county*
		(b) Indicate number of participants with missing data for each variable of interest – *N/A*
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures – *Pages 9-11 and Tables 1-3)*
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included – *Page 10-11 and Table 2*
		(*b*) Report category boundaries when continuous variables were categorized – *All tables*
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period – *N/a*
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses – *N/A*
Discussion		
Key results	18	Summarise key results with reference to study objectives – *Page 11*
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias – *Page 15*
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence – *Page 11-15*
Generalisability	21	Discuss the generalisability (external validity) of the study results – *Page 11-15*
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based—*Page 16*

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.