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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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Manuscripts

## 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

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3 with preterm birth, population well-being may provide a promising novel target for  
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5 reducing preterm birth rates. No study, however, has examined whether the average  
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7 well-being of the population in which a woman lives relates to her risk of preterm  
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9 delivery. To address this gap, we utilized a comprehensive, multi-dimensional  
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11 assessment of well-being across the United States, the Gallup-Sharecare Well-being  
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13 Index™, previously known as the Gallup-Healthways Well-Being Index prior to  
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15 rebranding following Sharecare's 2016 acquisition of Healthways (Gallup-Sharecare,  
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17 2011), and data on all live births in the United States in 2011 (National Center for Health  
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19 Statistics, 2011) to examine whether the rate of preterm birth varies with the overall  
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21 well-being of the population within which the pregnant woman lives.(13-14) We  
22  
23 hypothesized that risk of preterm birth is lower for pregnant women who live in higher  
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25 well-being populations, even when accounting for known individual maternal risk  
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27 factors. Such work lays the groundwork for testing whether society-wide interventions to  
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29 improve well-being might have broad beneficial health effects.  
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## 38 **METHODS**

### 39 *Overview*

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41 We conducted a cross-sectional study in which we linked data on all live births in the  
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43 U.S. in 2011 to area-level data on population well-being. Because county was the  
44  
45 smallest geographic area available for each mother, we aggregated well-being at the  
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47 county level as well; moreover, county-level results also may have important policy  
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49 implications and can inform local communities in developing targeted programs to  
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51 enhance well-being. Well-being was measured at the level of county (or county  
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3 equivalent) and births were linked to the mother's county of residence. We summarized  
4 rates of preterm birth by quintile of county well-being, and tested for associations  
5 between population well-being and gestational age using hierarchical generalized linear  
6 models that adjusted for maternal risk factors.  
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### 14 *Birth Data*

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

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

48 Our primary outcome was preterm delivery, defined as gestational age <37 weeks.(16)  
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### *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.<sup>(14)</sup> The survey comprised 55 self-reported items organized into 6 domains: life evaluation; emotional health; physical health; healthy behaviors; basic access and work environment.<sup>(17)</sup> 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

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3 independent variable; in secondary analyses, we used county-level quintiles for each of  
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5 the individual domain scores.  
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### 8 9 10 *Other Independent Variables*

11 From the NCHS birth dataset we included the following known maternal risk factors for  
12 preterm delivery: age (categorized as <=19, 20-24, 25-29, 30-34, 35-39, 40+); race  
13 (White, Black, Asian, American Indian/Alaska Native); Hispanic ethnicity; smoking  
14 status; start of prenatal visits (1st trimester, 2nd trimester, 3rd trimester, none, not  
15 known); and multiparity (single birth versus multiple). We also included infant sex, and,  
16 as a marker of socioeconomic status, we included the maternal insurance payer  
17 (Medicaid, private, self, other, unknown).  
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### 30 31 *Statistical Analysis*

32 We summarized the outcome and all maternal risk factors by quintile of population WBI,  
33 reporting frequency and percent of births in each category. To assess the association  
34 between population well-being and preterm birth, we estimated two hierarchical linear  
35 models. These models included random effects for county, and were specified using a  
36 linear response; such linear probability models are appropriate when the outcome rate  
37 is not close to 0 or 1, and the predicted values from the model are also between 0 and  
38 1. The first “unadjusted” model included only county quintile of population well-being.  
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40 The second adjusted for maternal age, race, ethnicity, smoking status, trimester during  
41 which prenatal care was initiated, single or multiple birth, and insurance payer. For both  
42 we calculated the Wald P-value for the overall effect of WBI and a separator test for  
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3 trend across WBI quintiles. In secondary analyses we replicated the main analyses  
4 using each of the 6 subdomain scores of the well-being index.  
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10 We also estimated a reference model which included no independent variables, and  
11 used the county level variance from this model to calculate the variance explained at the  
12 county level for each of the models described above, using  $R^2 = (\tau^2 - \tau^{*2})/\tau^2$ , where  $\tau^{*2}$   
13 is the county level variance for the model with independent variables.(18)  
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### 22 *Missing data*

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24 In 2011, fifteen states did not collect information on prenatal visits or payer (AK, AL, AR,  
25 AZ, CT, HI, MA, ME, MN, MS, NJ, RI, VA, WV). We did not impute missing data due to  
26 nonrandom missingness and likely confounding with the outcome. These missing  
27 variables were instead coded as unknown; in sensitivity analyses we omitted these  
28 states.  
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38 All analyses were performed using Stata 14.2 (2016 StataCorp, College Station, TX).

39 The Yale University Institutional Review Board approved this study.  
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## 44 **RESULTS**

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46 We used data from 3,938,985 births across 2,989 counties. The mean (SD) county-level  
47 preterm birth rate was 11.7% (2.2%) preterm births. Table 1 shows numbers and  
48 percentages of children born before and after 37 weeks' gestation, maternal  
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3 characteristics, and infant sex by quintile of average well-being of the maternal county  
4 of residence.  
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10 In the unadjusted model, pregnant women living in counties with higher population well-  
11 being had a significantly lower risk of preterm birth. This finding was consistent across  
12 all WBI quintiles with an absolute difference between the percentage of preterm births in  
13 the highest well-being quintile (10.9%) and the lowest well-being quintile (13.1%) of  
14 2.2% (95% CI: [1.8%,2.6%];  $p<0.001$ ) (Table 2). After adjusting for maternal risk factors  
15 for preterm birth, the trend remained consistent across the quintiles; the absolute  
16 difference between the highest and lowest quintiles was attenuated to 1.9% (95% CI:  
17 [1.7%, 2.1%];  $P<0.001$ ). In sensitivity analyses, results were similar.  
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30 In secondary analyses, independent associations between quintiles of each well-being  
31 domain and preterm birth are reported in Table 3. Similar to the composite WBI score,  
32 all domain scores were significantly associated with maternal risk of preterm birth, in the  
33 unadjusted model and the model adjusting for individual maternal risk factors. Different  
34 domains, however, explained different amounts of variance of well-being, with the basic  
35 access index explaining 14.6% of the county variance. After adjusting for maternal risk  
36 factors, women in counties with the highest basic access score experienced an absolute  
37 difference in preterm birth rates of 2.4% (95%CI: [2.2%,2.6%];  $p<0.001$ ) when  
38 compared with women in counties with the lowest basic access score. Similarly, the  
39 average physical health score of the county within which a pregnant woman resided  
40 was associated with lower rates of preterm birth, in both unadjusted and adjusted  
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3 models (absolute difference in preterm birth rate: 1.9%, 95%CI: [1.7%, 2.1%];  $p < 0.001$ ).  
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5 In the models adjusted for maternal risk factors, healthy behaviors (1.5%, 95%CI:  
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7 [1.3%, 1.7%];  $p < 0.001$ ), emotional health (1.0%, 95%CI: [0.6%, 1.4%];  $p < 0.001$ ), and  
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9 life evaluation (1.1%, 95%CI: [0.9%, 1.3%];  $p < 0.001$ ) of the county population negatively  
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11 correlated with risk of preterm birth.  
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## 16 17 **DISCUSSION**

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19 In this study of all births in the United States in 2011, we found that pregnant women  
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21 who lived in counties with higher average well-being had significantly lower risk of  
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23 preterm birth. After accounting for known maternal risk factors, including age, race,  
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25 ethnicity, smoking status, timing of initiation of prenatal care, multiparity, and payer type,  
26  
27 the absolute difference in maternal risk for preterm delivery between the highest well-  
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29 being counties and the lowest well-being counties was 1.9%. Reducing preterm birth  
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31 rates by this absolute amount would result in substantial maternal and infant benefits: if  
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33 the lowest well-being counties experienced this reduced rate, they would have had  
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35 3,077 fewer preterm births in 2011 alone, yielding an estimated financial savings of  
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37 nearly \$160 million (19), in addition to fewer long-term consequences of preterm birth  
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39 such as infant mortality and long-term neurological disabilities. Additional reductions in  
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41 preterm birth risk in counties from the middle well-being quintiles, which contributed  
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43 greater total numbers of births in 2011, would only augment these benefits.  
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51 Decades of research have delineated a variety of maternal-level risk factors for preterm  
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53 delivery, including maternal age, smoking status, history of preterm delivery, and  
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3 socioeconomic status (SES) (2, 3, 20), while recent studies of environmental factors  
4 suggest that features of where a pregnant woman lives, including neighborhood  
5 poverty, local access to healthy foods, and environmental exposures, additionally  
6 influence her risk of preterm delivery (21-24). Our study extends the existing literature  
7 by leveraging unique large national data sources to assess how a comprehensive,  
8 multi-dimensional measure of population well-being and its various domains relate to  
9 individual preterm birth risk across the United States. In completing this study, we found  
10 that pregnant women were at lower risk of preterm delivery when living in higher well-  
11 being populations than when living in lower well-being populations, even when we  
12 accounted for maternal risk factors that are highly correlated with SES , such as  
13 insurance payer, age at time of delivery, smoking status, and timing of first prenatal visit  
14 (25, 26). This finding adds to the growing literature describing the complex interactions  
15 between individuals and their local environment, including natural, built, and social  
16 environments, and their combined effects on health outcomes.

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38 Living in a higher well-being population may result in lower risk of preterm delivery for a  
39 myriad of reasons, including reasons related to the social environment. Pregnant  
40 women who live in higher well-being populations may experience less toxic stress,  
41 greater access to social resources, higher levels of trust and tolerance, and/or a greater  
42 perception of safety.(11) Prior research has shown that exposure to toxic stress  
43 increases the risk of preterm delivery,(30-33) while stronger social support, lesser social  
44 isolation, and greater social connectedness are associated with lower risk of preterm  
45 delivery, perhaps by reducing the allostatic load or chronic stress experienced by  
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3 pregnant women.(34-37) Additionally, while experiences of perceived discrimination are  
4 associated with increased risk of preterm delivery, experiences of trust and tolerance as  
5 well as a greater perception of safety may foster healthier pregnancies and term  
6 deliveries.(38-39)  
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14 According to our results, pregnant women with the same individual maternal risk profile,  
15 including factors associated with SES, experience lower risk of preterm delivery when  
16 living in higher well-being populations than when living in lower well-being populations.  
17 This finding is consistent with emerging epigenetics (23, 27, 28) and maternal  
18 weathering (24, 29) literature. Maternal weathering is a potential explanatory model for  
19 well-described race-based disparities in preterm birth risk that attributes increased risk  
20 of preterm delivery in certain populations of women to “accelerated aging” from greater  
21 exposure to hardship. This model suggests that living in better neighborhoods might  
22 attenuate the increased risk associated with these weathering effects.(29) It is possible  
23 that the observed risk contributed by weathering and the risk mitigated by living in  
24 higher well-being populations are actually related to underlying exposure to toxic stress  
25 and buffering from factors such as trust, tolerance, social support, and perceived safety,  
26 as described above.  
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47 Our study also builds on prior literature that found links between living in areas of  
48 greater poverty and preterm birth risk. In the domain analyses, the basic access domain  
49 demonstrated the strongest relationship with maternal risk of preterm delivery, even  
50 after adjusting for individual maternal risk factors, including insurance provider and  
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3 smoking, and explained nearly 15% of county-level variance in preterm birth rates. The  
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5 basic access index domain includes items that assess perceived access to healthcare,  
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7 clean water, fresh produce, and safe public space as well as ability to afford basic  
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9 needs such as food and shelter. This finding affirms prior literature reporting that access  
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11 to basic needs is strongly correlated with health outcomes. Importantly, however, all  
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13 domains contributed independently to the inverse association between population well-  
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15 being and maternal risk of preterm delivery. In particular, average county-level physical  
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17 health, healthy behaviors, and emotional health scores were inversely associated with  
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19 maternal risk of preterm delivery.  
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26 The results of our study have several potential policy implications. Our findings suggest  
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28 that effective investments in well-being may not only improve overall health and quality  
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30 of life for populations, but also result in reduced rates of preterm birth for pregnant  
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32 women living in those populations, an idea worth pursuing. Our domain analyses  
33  
34 suggest that improving aggregate basic access in particular could plausibly result in not  
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36 only greater well-being but also fewer preterm births, though targeting other domains,  
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38 such as physical health, healthy behaviors, and emotional health, may also yield  
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40 additional valuable results. Importantly, the effectiveness of various interventions will  
41  
42 most likely depend on the contexts within which they are implemented. Currently, efforts  
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44 are underway across the globe to track and improve population well-being through  
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46 programmatic and policy-based interventions.(40-43) While some interventions involve  
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48 multi-sector, community-based programs, many of which are government supported,  
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50 other interventions involve changes in economic and social policies, such as those  
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3 aimed at affordable housing, employment, and access to public spaces for physical  
4 fitness or social connection.(11, 44-45) Given the relationship between population well-  
5 being and preterm birth risk, examining how programs and policies influence not only  
6 well-being but also preterm birth could be informative and allow for spread of  
7 interventions that effectively increase well-being and reduce preterm birth.  
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17 Our study has limitations. First, as a cross-sectional study, it cannot assess causation.  
18 However, determining whether a relationship exists between population well-being and  
19 risk of preterm birth is an essential first step. Second, this study specifically examines  
20 how the average well-being of the adult population within which a pregnant woman lives  
21 correlates with her risk of preterm delivery. Because we do not have an assessment of  
22 the well-being of the individual pregnant women, we cannot determine how population  
23 well-being may moderate the effect of women's own well-being or other related  
24 individual factors on their risk of preterm delivery. Nevertheless, the results of this  
25 nationwide study of nearly 4 million births demonstrates a clear association between the  
26 well-being context within which women live and the risk of preterm delivery. Finally,  
27 geographically smaller units (e.g., neighborhood or city) for population well-being may  
28 be more relevant to describing the community context for an individual pregnant  
29 woman. Nevertheless, the county is a relevant geographic unit in that policies and  
30 programs are often enacted at the county level.  
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51 Pregnant women who live in populations with higher well-being have lower risk of  
52 preterm delivery, even after accounting for known individual maternal risk factors. The  
53 well-being of a population is an important end itself, but if causal pathways exist  
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3 between population well-being and other valued outcomes, investments in population  
4 well-being may yield other benefits, potentially including fewer preterm births.  
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6 Understanding the full effects of population well-being can inform the emerging dialogue  
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8 about its value as a health investment.  
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15 **Contributors:** CR and BR participated in the initial conception of this study. JH  
16 performed all analyses. All authors (CR, BR, JH, ES, MS, AA, KK, ER, and HK)  
17 contributed to the study design, interpretation of data, drafting and revising the article,  
18 and its final approval. All authors are guarantors.  
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28 manuscript.  
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44 publicly available site. Birth data are available with permission from the National Center  
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46 for Health Statistics (<http://www.cdc.gov/nchs/>).  
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53 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)
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)

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Timing of 1st prenatal visit, N (%)						
1 <sup>st</sup> -3 <sup>rd</sup> 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)
4 <sup>th</sup> -6 <sup>th</sup> 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)
7 <sup>th</sup> 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						
1 <sup>st</sup> - 3 <sup>rd</sup> month				ref		
4 <sup>th</sup> - 6 <sup>th</sup> month				-0.014 (0.000)	<0.001	
7 <sup>th</sup> 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 <sup>2</sup>	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
<b>Basic Access Index (BAI)</b>			<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 <sup>2</sup>	0.146			0.656		
<b>Physical Health Index (PHI)</b>			<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 <sup>2</sup>	0.059			0.657		
<b>Healthy Behaviors Index (HBI)</b>			<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 <sup>2</sup>	0.039			0.654		
<b>Emotional Health Index (EHI)</b>			<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 <sup>2</sup>	0.032			0.656		
<b>Life Evaluation Index (LEI)</b>			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 <sup>2</sup>	0.004			0.653		
<b>Work Environment Index (WEI)</b>			<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 <sup>2</sup>	0.016			0.653		

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

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

Continued on next page

<b>Results</b>		
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 – <i>Page 9</i> (b) Give reasons for non-participation at each stage – <i>N/A, this was a population based study at the county level</i> (c) Consider use of a flow diagram – <i>N/A</i>
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders – <i>N/A unit of analysis was the county</i> (b) Indicate number of participants with missing data for each variable of interest – <i>N/A</i> (c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time <i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure <i>Cross-sectional study</i> —Report numbers of outcome events or summary measures – <i>Pages 9-11 and Tables 1-3</i>
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 – <i>Page 10-11 and Table 2</i> (b) Report category boundaries when continuous variables were categorized – <i>All tables</i> (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period – <i>N/a</i>
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses – <i>N/A</i>
<b>Discussion</b>		
Key results	18	Summarise key results with reference to study objectives – <i>Page 11</i>
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 – <i>Page 15</i>
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence – <i>Page 11-15</i>
Generalisability	21	Discuss the generalisability (external validity) of the study results – <i>Page 11-15</i>
<b>Other information</b>		
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— <i>Page 16</i>

\*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](http://www.strobe-statement.org).

# BMJ Open

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

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2018-024143.R1
Article Type:	Research
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<b>Primary Subject Heading</b>:	Public health
Secondary Subject Heading:	Health policy
Keywords:	Maternal medicine < OBSTETRICS, Community child health < PAEDIATRICS, PUBLIC HEALTH

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Manuscripts

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3 1 **Do pregnant women living in higher well-being populations in the US experience**  
4 2 **lower risk of preterm delivery?: A cross-sectional study**  
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6 3

7 4 Carley Riley, MD, MPP, MHS,<sup>1,2</sup> Brita Roy, MD, MPH, MHS,<sup>3</sup> Jeph Herrin, PhD,<sup>4</sup>  
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40 35 **References:** 54  
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42 37 **Word Count:** 3,276  
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## 1 ABSTRACT

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

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

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

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

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12 **Results:** Women living in counties with higher population well-being had a lower rate of  
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14 preterm delivery. The rate of preterm birth in counties in the lowest WBI quintile was  
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16 13.1%, while the rate of preterm birth in counties in the highest WBI quintile was 10.9%.  
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18 In the model adjusted for maternal risk factors (age, race, Hispanic ethnicity, smoking  
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20 status, timing of initiation of prenatal visits, multiparity, maternal insurance payer), the  
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22 association was slightly attenuated with an absolute difference of 1.9% (95% CI 1.7% -  
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24 2.1%; P<0.001).

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19 **Conclusions:** Pregnant women who live in areas with higher population well-being  
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21 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.

## 1 INTRODUCTION

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

9  
10 Research has shown that where a woman lives affects her risk of preterm birth.

11 Decades of study have demonstrated that specific features of the local environment,  
12 including neighborhood poverty, local access to healthy foods, and environmental  
13 exposures, influence a pregnant woman's risk of preterm delivery.(10-14) In addition to  
14 these features, the way that the community views the overall quality of life in their  
15 community is another important, yet often unconsidered, feature of the community.

16 Population well-being is a comprehensive construct that captures these contextual  
17 factors and incorporates community members' perceptions of the quality of their life in  
18 their community (15,16). Well-being at the population or community level influences  
19 health and well-being at the individual level, with a change in well-being of individuals in  
20 a community having an effect on others (17). As such, the population well-being of a  
21 community within which pregnant women live – defined as a broader, multi-dimensional,  
22 self-reported context of the physical, mental, and social health of the geographic  
23 community, including the overall life evaluation of its residents – may constitute a more

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3 1 complete and accurate conceptualization of the environment that influences the  
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5 2 women's risk of preterm delivery.  
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10 4 Higher population well-being is not only an outcome worth achieving for its own sake,  
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12 5 but also has been associated with other desirable health outcomes, such as greater life  
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14 6 expectancy.<sup>(18)</sup> If also associated with preterm birth, population well-being may  
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16 7 provide a promising novel target for reducing preterm birth rates. Prior studies have  
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18 8 examined the relationship of socioeconomic factors with preterm birth, but community  
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20 9 well-being is a distinct construct and no study has examined whether the average well-  
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22 10 being of the population in which a woman lives relates to her risk of preterm delivery. To  
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24 11 address this gap, we utilized a comprehensive, multi-dimensional assessment of well-  
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26 12 being across the United States, the Gallup-Sharecare Well-being Index™, previously  
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28 13 known as the Gallup-Healthways Well-Being Index prior to rebranding following  
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30 14 Sharecare's 2016 acquisition of Healthways (Gallup-Sharecare, 2011), and data on all  
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32 15 live births in the United States in 2011 (National Center for Health Statistics, 2011) to  
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34 16 examine whether the rate of preterm birth varies with the overall well-being of the  
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36 17 population within which the pregnant woman lives (19, 20). We hypothesized that risk of  
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38 18 preterm birth is lower for pregnant women who live in higher well-being populations,  
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40 19 even when accounting for known individual maternal risk factors. Such work lays the  
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42 20 groundwork for testing whether society-wide interventions to improve well-being might  
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44 21 have broad beneficial health effects.  
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## 54 23 **METHODS**

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## 1 *Overview*

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

## 10 11 *Birth Data*

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

## 19 20 *Study Sample*

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

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

### 6 *Outcome*

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

### 9 *Population Well-being Data*

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

1 individual well-being. The individual well-being measure has acceptable reliability,  
2 internal and external validity (28).

3  
4 In 2011, the WBI comprised 55 self-reported items organized into 6 domains: life  
5 evaluation; emotional health; physical health; healthy behaviors; basic access and work  
6 environment.(24) The Life Evaluation Index measures life satisfaction and optimism  
7 about the future. The Emotional Health Index measures daily emotions and the  
8 presence or absence of depression. The Physical Health Index assesses the burden of  
9 chronic disease and recent illness. The Healthy Behaviors Index assesses the  
10 prevalence of smoking, exercising, and eating fruit and vegetables. The Basic Access  
11 Index includes perception of safety and access to housing and health care. The Work  
12 Environment Index assesses job satisfaction, trust and respect in the workplace and,  
13 unlike the other domains, it is collected only from the subset of respondents who report  
14 being employed. Each domain is represented by an index, measured on a scale of 0 to  
15 100. A composite score, the Well-Being Index (WBI), was calculated as the unweighted  
16 mean of the 6 domain scores, and is reported on a scale of 0-100. Gallup surveyed a  
17 unique sample of nearly 1000 individuals 18 years and older every day for  
18 approximately 350 days during 2011. A structured sampling design was used with  
19 respondents surveyed from all 50 states and the District of Columbia. The survey was  
20 administered in both English and Spanish, using both land lines and cell phones. We  
21 aggregated individual WBI responses into county scores based the maternal county of  
22 residence. For our primary analyses, we used quintiles of county WBI scores as our

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

### 3 4 *Other Independent Variables*

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

### 12 13 *Statistical Analysis*

14 We summarized the outcome, WBI score, and all maternal risk factors by quintile of  
15 population WBI, reporting frequency and percent of births in each category. To assess  
16 the association between population well-being and preterm birth, we estimated two  
17 individual level mixed effects linear models. Both models had the same dichotomous  
18 outcome (preterm birth) and both included a random intercept for county. Though  
19 logistic regression models are conventional used for dichotomous outcomes, linear  
20 probability models such as these are appropriate when the outcome rate is not close to  
21 0 or 1, and the predicted values from the model are also between 0 and 1. One  
22 advantage of using a linear model is that the intercept and coefficients have direct  
23 interpretations as a reference rate and risk differences respectively. The first model

1 was unadjusted, including only county quintile of population well-being. The second  
2 adjusted for maternal age, race, ethnicity, smoking status, trimester during which  
3 prenatal care was initiated, single or multiple birth, and insurance payer. For both  
4 models we calculated the Wald P-value for the overall effect of WBI and a separate test  
5 for trend in effects across WBI quintiles. In secondary analyses we replicated the main  
6 analyses using each of the 6 domain scores of the well-being index.

7  
8 We also estimated a reference model which included no independent variables, and  
9 used the county level variance from this model to calculate the variance explained at the  
10 county level for each of the models described above, using  $R^2 = (\tau^2 - \tau^{*2})/\tau^2$ , where  $\tau^{*2}$   
11 is the county level variance for the model with independent variables.(29)

12  
13 All analyses were performed using Stata 14.2 (2016 StataCorp, College Station, TX).

14 The Yale University Institutional Review Board approved this study.

## 15 16 **RESULTS**

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

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3 1 The observed rate of preterm birth decreased across WBI quintiles from 13.1% in the  
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5 2 lowest quintile to 10.9% in the highest quintile (Table 1). In the unadjusted model,  
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7 3 pregnant women living in counties with higher population well-being had a significantly  
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9 4 lower risk of preterm birth: -2.2% (95% CI: [-2.6%, -1.8%];  $p < 0.001$ ) (Table 2). After  
10  
11 5 adjusting for maternal risk factors for preterm birth, the trend remained consistent  
12  
13 6 across the quintiles; the absolute difference between the highest and lowest quintiles  
14  
15 7 was attenuated to -1.9% (95% CI: [-2.2%, -1.6%];  $P < 0.001$ ). In sensitivity analyses,  
16  
17 8 results were similar.  
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24 10 In secondary analyses, independent associations between quintiles of each well-being  
25  
26 11 domain and preterm birth are reported in Table 3. Similar to the composite WBI score,  
27  
28 12 all domain scores were significantly associated with maternal risk of preterm birth, in the  
29  
30 13 unadjusted model and the model adjusting for individual maternal risk factors. Different  
31  
32 14 domains, however, explained different amounts of variance of well-being, with the basic  
33  
34 15 access index explaining 14.6% of the county variance. After adjusting for maternal risk  
35  
36 16 factors, women in counties with the highest basic access score experienced an absolute  
37  
38 17 difference in preterm birth rates of -2.4% (95%CI: [-2.2%, -2.6%];  $p < 0.001$ ) when  
39  
40 18 compared with women in counties with the lowest basic access score. Similarly, the  
41  
42 19 average physical health score of the county within which a pregnant woman resided  
43  
44 20 was associated with lower rates of preterm birth, in both unadjusted and adjusted  
45  
46 21 models (absolute difference in preterm birth rate: -1.9%, 95%CI: [-1.6%, -2.1%];  
47  
48 22  $p < 0.001$ ). In the models adjusted for maternal risk factors, healthy behaviors (-1.5%,  
49  
50 23 95%CI: [-1.2%, -1.8%];  $p < 0.001$ ), emotional health (-1.0%, 95%CI: [-0.7%, -1.3%];  
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1 p<0.001), and life evaluation (-1.1%, 95%CI: [-0.8%, -1.4%]; p<0.001) of the county  
2 population negatively correlated with risk of preterm birth.

## 4 DISCUSSION

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

18 Decades of research have delineated a variety of maternal-level risk factors for preterm  
19 delivery, including maternal age, smoking status, history of preterm delivery, and  
20 socioeconomic status (SES) (2, 3, 31), while recent studies of environmental factors  
21 suggest that features of where a pregnant woman lives, including neighborhood  
22 poverty, local access to healthy foods, and environmental exposures, additionally  
23 influence her risk of preterm delivery (10, 11, 13, 14). Our study extends the existing

1 literature by leveraging large national data sources to assess how a comprehensive,  
2 multi-dimensional measure of population well-being, including the self-reported overall  
3 quality of life, and its various domains relate to individual preterm birth risk across the  
4 United States. In completing this study, we found that pregnant women were at lower  
5 risk of preterm delivery when living in higher well-being populations than when living in  
6 lower well-being populations, even when we accounted for maternal risk factors that are  
7 highly correlated with SES, such as insurance payer, age at time of delivery, smoking  
8 status, and timing of first prenatal visit (32, 33). This finding adds to the growing  
9 literature describing the complex interactions between individuals and their local  
10 environment, including natural, built, and social environments, and their combined  
11 effects on health outcomes.

12  
13 The relationship will identify could plausibly be causal through several mechanisms,  
14 including reasons related to the social environment. Pregnant women who live in higher  
15 well-being populations may experience less toxic stress, greater access to social  
16 resources, higher levels of trust and tolerance, and/or a greater perception of safety.(16)  
17 Prior research has shown that exposure to toxic stress increases the risk of preterm  
18 delivery,(34-37) while stronger social support, less social isolation, and greater social  
19 connectedness are associated with lower risk of preterm delivery, perhaps by reducing  
20 the allostatic load or chronic stress experienced by pregnant women.(38-43)  
21 Additionally, while experiences of perceived discrimination are associated with  
22 increased risk of preterm delivery, experiences of trust and tolerance as well as a

1 greater perception of safety may foster healthier pregnancies and term deliveries.(44-  
2 46)

3  
4 According to our results, pregnant women with the same individual maternal risk profile,  
5 including factors associated with SES, experience lower risk of preterm delivery when  
6 living in higher well-being populations than when living in lower well-being populations.  
7 This finding is consistent with emerging epigenetics (13, 47, 48) and maternal  
8 weathering (24, 29) literature. The maternal weathering model suggests that certain  
9 populations of women have an increased risk of preterm delivery due to “accelerated  
10 aging” that they experience as a result of greater exposure to hardship. This model  
11 suggests that living in better neighborhoods might attenuate the increased risk  
12 associated with these weathering effects.(49) It is possible that the observed risk  
13 contributed by weathering and the risk mitigated by living in higher well-being  
14 populations are actually related to underlying exposure to toxic stress and buffering  
15 from factors such as trust, tolerance, social support, and perceived safety.

16  
17 Our study also builds on prior literature that found links between living in areas of  
18 greater poverty and increased risk of preterm birth. In the domain analyses, the basic  
19 access domain demonstrated the strongest relationship with maternal risk of preterm  
20 delivery. Even after adjusting for individual maternal risk factors, including insurance  
21 provider and smoking, the basic access domain explained nearly 15% of county-level  
22 variance in preterm birth rates. The basic access index domain includes items that  
23 assess perceived access to healthcare, clean water, fresh produce, and safe public

1 space as well as ability to afford basic needs such as food and shelter. This finding  
2 affirms prior literature reporting that access to basic needs is strongly correlated with  
3 health outcomes. Importantly, however, all domains contributed independently to the  
4 inverse association between population well-being and maternal risk of preterm  
5 delivery, though to varying degrees. Average county-level physical health, healthy  
6 behaviors, and emotional health scores were associated with a one- to two-percent  
7 lower maternal risk of preterm delivery.

8  
9 The results of our study have several potential implications. Our findings suggest the  
10 possibility that effective population- and community-level investments in well-being may  
11 not only improve overall health and quality of life for populations, but also contribute to  
12 reduced rates of preterm birth for pregnant women living in those populations, an idea  
13 worth pursuing. Our domain analyses suggest that improving aggregate basic access,  
14 in particular, could plausibly result in not only greater well-being but also fewer preterm  
15 births. Targeting other domains, such as physical health, healthy behaviors, and  
16 emotional health, may yield additional improvements. Importantly, the effectiveness of  
17 various interventions will most likely depend on the contexts within which they are  
18 implemented. Currently, efforts are underway across the globe to track and improve  
19 population well-being through programmatic and policy-based interventions.(4, 6, 50-52)  
20 While some interventions involve multi-sector, community-based programs, many of  
21 which are government supported, other interventions involve changes in economic and  
22 social policies, such as those aimed at affordable housing, employment, and access to  
23 public spaces for physical fitness or social connection.(16, 53, 54) Given the

1 relationship between population well-being and preterm birth risk, examining the  
2 association of such programs and policies with preterm birth could be informative and  
3 allow for spread of interventions that effectively increase well-being and reduce preterm  
4 birth.

5  
6 Our study has limitations. First, as a cross-sectional study, it cannot assess causation.  
7 However, determining whether a relationship exists between population well-being and  
8 risk of preterm birth is an essential first step. Second, this study specifically examines  
9 how the average well-being of the adult population within which a pregnant woman lives  
10 correlates with her risk of preterm delivery. Because we do not have an assessment of  
11 the well-being of the individual pregnant women, we cannot determine how population  
12 well-being may moderate the effect of women's own well-being or other related  
13 individual factors on their risk of preterm delivery. Additionally, we did not have data on  
14 maternal income, wealth, or education level, so we could not directly adjust for these  
15 socioeconomic variables. Nevertheless, we utilized available maternal-level variables  
16 that are known to be associated with socioeconomic status as proxies in order to control  
17 for the effect of socioeconomic status on preterm birth and isolate the effect of  
18 community well-being. Finally, we did not have well-being data available at  
19 geographically smaller units (e.g., neighborhood or city), which may be more relevant  
20 than county well-being in describing the community context for an individual pregnant  
21 woman. While counties are distinct from the smaller, often more homogeneous,  
22 geographic units of neighborhoods and census tracts, policies and programs are often  
23 enacted at the county level. Thus, results may drive action at the county-level, while

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3 1 also informing local communities in developing targeted programs to enhance well-  
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5 2 being.  
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10 4 Pregnant women who live in populations with higher well-being have lower risk of  
11  
12 5 preterm delivery, even after accounting for known individual maternal risk factors. The  
13  
14 6 well-being of a population is an important end itself, but if causal pathways exist  
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16 7 between population well-being and other valued outcomes, investments in population  
17  
18 8 well-being may yield other benefits, potentially including fewer preterm births.  
19  
20  
21 9 Understanding the full effects of population well-being can inform the emerging dialogue  
22  
23 10 about its value as a health investment.  
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29  
30 13 performed all analyses. All authors (CR, BR, JH, ES, MS, AA, KK, ER, and HK)  
31  
32 14 contributed to the study design, interpretation of data, drafting and revising the article,  
33  
34 15 and its final approval. All authors are guarantors.  
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54 23

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18 measures; chairs a cardiac scientific advisory board for UnitedHealth; is a  
19 participant/participant representative of the IBM Watson Health Life Sciences Board; is  
20 a member of the Advisory Board for Element Science and the Physician Advisory Board  
21 for Aetna; and is the founder of Hugo, a personal health information platform.



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3 1 **Data Sharing:** If the paper is accepted for publication, we will post a de-identified data  
4  
5 2 set with county resident well-being data from Gallup-Sharecare on ICSPR Open, a  
6  
7 3 publicly available site. Birth data are available with permission from the National Center  
8  
9 4 for Health Statistics (<http://www.cdc.gov/nchs/>).  
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15 6 **Ethics Approval:** This study was approved by the Yale University Institutional Review  
16  
17 7 Board.  
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22 9 **Patient and Public Involvement:** No patients were involved in this study.  
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1 Table 1. Gestational age at birth and maternal characteristics by maternal county quintile of composite Gallup-  
 2 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 (%)						
1 <sup>st</sup> - 3 <sup>rd</sup> 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)
4 <sup>th</sup> - 6 <sup>th</sup> 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)
7 <sup>th</sup> 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)

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1 Table 2. Maternal risk of preterm delivery: overall and by county of residence aggregated by quintile of composite  
 2 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						
1 <sup>st</sup> - 3 <sup>rd</sup> month				ref		
4 <sup>th</sup> - 6 <sup>th</sup> month				-0.019 [-0.020,-0.018]	<0.001	
7 <sup>th</sup> 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	
Unknown				-0.004 [-0.006,-0.003]	<0.001	
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 <sup>2</sup>	0.078			0.656		

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1 Table 3. Maternal risk of preterm delivery by county of residence aggregated by quintile of individual Gallup-  
 2 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
<b>Basic Access Index (BAI)</b>			<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 <sup>2</sup>	0.146			0.656		
<b>Physical Health Index (PHI)</b>			<0.001			<0.001
Q1	ref			ref		
Q2	-	<0.001		-0.007 [-0.010,-0.005]	<0.001	
Q3	0.009 [-0.012,-0.005]	<0.001		-0.013 [-0.015,-0.010]	<0.001	
Q4	-0.013 [-0.016,-0.009]	<0.001		-0.017 [-0.019,-0.014]	<0.001	
Q5	-0.017 [-0.020,-0.013]	<0.001		-0.019 [-0.021,-0.016]	<0.001	
R <sup>2</sup>	0.059			0.657		
<b>Healthy Behaviors Index (HBI)</b>			<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 <sup>2</sup>	0.039			0.654		
<b>Emotional Health Index (EHI)</b>			<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 <sup>2</sup>	0.032			0.656		
<b>Life Evaluation Index (LEI)</b>			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 <sup>2</sup>	0.004			0.653		
<b>Work Environment Index (WEI)</b>			<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 <sup>2</sup>	0.016			0.653		

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

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

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 – <i>Page 9</i> (b) Give reasons for non-participation at each stage – <i>N/A, this was a population based study at the county level</i> (c) Consider use of a flow diagram – <i>N/A</i>
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders – <i>N/A unit of analysis was the county</i> (b) Indicate number of participants with missing data for each variable of interest – <i>N/A</i> (c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time <i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure <i>Cross-sectional study</i> —Report numbers of outcome events or summary measures – <i>Pages 9-11 and Tables 1-3)</i>
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 – <i>Page 10-11 and Table 2</i> (b) Report category boundaries when continuous variables were categorized – <i>All tables</i> (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period – <i>N/a</i>
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses – <i>N/A</i>

**Discussion**

Key results	18	Summarise key results with reference to study objectives – <i>Page 11</i>
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 – <i>Page 15</i>
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence – <i>Page 11-15</i>
Generalisability	21	Discuss the generalisability (external validity) of the study results – <i>Page 11-15</i>

**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— <i>Page 16</i>
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\*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](http://www.strobe-statement.org).

# BMJ Open

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

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2018-024143.R2
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Complete List of Authors:	Riley, Carley; Cincinnati Children's Hospital Medical Center, Roy, Brita; Yale University School of Medicine, Internal Medicine Herrin, Jeph; Yale University School of Medicine, Spatz, Erica; Yale University School of Medicine, Cardiology Silvestri, Mark; Yale University School of Medicine Arora, Anita; Yale University School of Medicine Kell, Kenneth; Tivity Health Rula, Elizabeth; Tivity Health Krumholz, Harlan; Yale University, Medicine
<b>Primary Subject Heading</b>:	Public health
Secondary Subject Heading:	Health policy
Keywords:	Maternal medicine < OBSTETRICS, Community child health < PAEDIATRICS, PUBLIC HEALTH

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## 1 2 Do pregnant women living in higher well-being populations in the US experience 3 lower risk of preterm delivery?: A cross-sectional study

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35  
36 **References:** 54

37  
38 **Word Count:** 3,290

## 1 ABSTRACT

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

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

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

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

12 **Results:** Women living in counties with higher population well-being had a lower rate of  
13 preterm delivery. The rate of preterm birth in counties in the lowest WBI quintile was  
14 13.1%, while the rate of preterm birth in counties in the highest WBI quintile was 10.9%.  
15 In the model adjusted for maternal risk factors (age, race, Hispanic ethnicity, smoking  
16 status, timing of initiation of prenatal visits, multiparity, maternal insurance payer), the  
17 association was slightly attenuated with an absolute difference of 1.9% (95% CI 1.7% -  
18 2.1%;  $P < 0.001$ ).

19 **Conclusions:** Pregnant women who live in areas with higher population well-being  
20 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.

## 1 INTRODUCTION

2 Despite considerable efforts, preterm birth remains a substantial public health problem  
3 in the United States.(1-3) With one in ten babies born at less than 37 weeks gestation,  
4 preterm birth is the greatest contributor to infant mortality and a leading cause of long-  
5 term neurological disabilities in children, resulting in considerable mortality, morbidity,  
6 and long-term costs in the US.(4-6) Research has demonstrated that while individual  
7 factors such as maternal age and smoking status influence a pregnant woman's risk of  
8 preterm delivery,(3) community environment has additional influence.(7-9)  
9  
10 Research has also shown that where a woman lives affects her risk of preterm birth.  
11 Decades of study have demonstrated that specific features of the local environment,  
12 including neighborhood poverty, local access to healthy foods, and environmental  
13 exposures, influence a pregnant woman's risk of preterm delivery.(10-14) In addition to  
14 these features, the way that the community views the overall quality of life in their  
15 community is another important, yet often unconsidered, feature of the community.  
16 Population well-being is a comprehensive construct that captures these contextual  
17 factors and incorporates community members' perceptions of the quality of their life in  
18 their community (15, 16). Well-being at the population or community level influences  
19 health and well-being at the individual level, with a change in well-being of individuals in  
20 a community having an effect on others(17). As such, the population well-being of a  
21 community within which pregnant women live – defined as a broader, multi-dimensional,  
22 self-reported context of the physical, mental, and social health of the geographic  
23 community, including the overall life evaluation of its residents – may constitute a more

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3 1 complete and accurate conceptualization of the environment that influences the  
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5 2 women's risk of preterm delivery.  
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10 4 Higher population well-being is not only an outcome worth achieving for its own sake,  
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12 5 but also has been associated with other desirable health outcomes, such as greater life  
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14 6 expectancy.(18) If also associated with preterm birth, population well-being may  
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16 7 provide a promising novel target for reducing preterm birth rates. Prior studies have  
17  
18 8 examined the relationship of socioeconomic factors with preterm birth, but community  
19  
20 9 well-being is a distinct construct and no study, has examined whether the average well-  
21  
22 10 being of the population in which a woman lives relates to her risk of preterm delivery. To  
23  
24 11 address this gap, we utilized a comprehensive, multi-dimensional assessment of well-  
25  
26 12 being across the United States, the Gallup-Sharecare Well-being Index™, previously  
27  
28 13 known as the Gallup-Healthways Well-Being Index prior to rebranding following  
29  
30 14 Sharecare's 2016 acquisition of Healthways (Gallup-Sharecare, 2011), and data on all  
31  
32 15 live births in the United States in 2011 (National Center for Health Statistics, 2011) to  
33  
34 16 examine whether the rate of preterm birth varies with the overall well-being of the  
35  
36 17 population within which the pregnant woman lives(19, 20). We hypothesized that risk of  
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38 18 preterm birth is lower for pregnant women who live in higher well-being populations,  
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40 19 even when accounting for known individual maternal risk factors. Such work lays the  
41  
42 20 groundwork for testing whether society-wide interventions to improve well-being might  
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44 21 have broad beneficial health effects.  
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## 54 23 **METHODS**

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## 1 *Overview*

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

## 11 *Birth Data*

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

## 20 *Study Sample*

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



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

### 6 *Outcome*

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

### 9 *Population Well-being Data*

10 Our primary independent variable was population well-being. Data on population well-  
11 being were obtained from the Gallup-Sharecare Well-being Index (WBI) survey for  
12 2011.(19) To develop the WBI, survey items that aligned with prior research on well-  
13 being were compiled by experts in the field (23-25). Based on the existing literature,  
14 items were selected so that the survey would include both hedonic well-being (i.e.,  
15 people's feelings and thoughts about their lives) and eudemonic well-being (i.e., an  
16 individual's judgments about the meaning and purpose in one's life) (26). The survey  
17 therefore includes items assessing daily emotional experience and a wide variety of  
18 evaluative domains, such as overall life, standard of living, and satisfaction with  
19 community, work, relationships, and personal health. Data from a large, representative  
20 national sample was then used to perform factor analysis to determine the final set of  
21 questions. Criterion validity of geographically aggregated data was established by  
22 examining correlations with health and socioeconomic indicators (27). Principal  
23 component and confirmatory factor analyses were then used to create an instrument

1 valid for measuring individual well-being. The individual well-being measure has  
2 acceptable reliability, internal and external validity (28).

3  
4 In 2011, the WBI comprised 55 self-reported items organized into 6 domains: life  
5 evaluation; emotional health; physical health; healthy behaviors; basic access and work  
6 environment.(24) The Life Evaluation Index measures life satisfaction and optimism  
7 about the future. The Emotional Health Index measures daily emotions and the  
8 presence or absence of depression. The Physical Health Index assesses the burden of  
9 chronic disease and recent illness. The Healthy Behaviors Index assesses the  
10 prevalence of smoking, exercising, and eating fruit and vegetables. The Basic Access  
11 Index includes perception of safety and access to housing and health care. The Work  
12 Environment Index assesses job satisfaction, trust and respect in the workplace and,  
13 unlike the other domains, it is collected only from the subset of respondents who report  
14 being employed. Each domain is represented by an index, measured on a scale of 0 to  
15 100. A composite score, the Well-Being Index (WBI), was calculated as the unweighted  
16 mean of the 6 domain scores, and is reported on a scale of 0-100. Gallup surveyed a  
17 unique sample of nearly 1000 individuals 18 years and older every day for  
18 approximately 350 days during 2011. A structured sampling design was used with  
19 respondents surveyed from all 50 states and the District of Columbia. The survey was  
20 administered in both English and Spanish, using both land lines and cell phones. We  
21 aggregated individual WBI responses into county scores based the maternal county of  
22 residence. For our primary analyses, we used quintiles of county WBI scores as our

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

### 3 4 *Other Independent Variables*

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

### 12 13 *Statistical Analysis*

14 We summarized the outcome, WBI score, and all maternal risk factors by quintile of  
15 population WBI, reporting frequency and percent of births in each category. To assess  
16 the association between population well-being and preterm birth, we estimated two  
17 individual level mixed effects linear models. Both models had the same dichotomous  
18 outcome (preterm birth) and both included a random intercept for county) Though  
19 logistic regression models are conventional used for dichotomous outcomes, linear  
20 probability models such as these are appropriate when the outcome rate is not close to  
21 0 or 1, and the predicted values from the model are also between 0 and 1. One  
22 advantage of using a linear model is that the intercept and coefficients have direct  
23 interpretations as a reference rate and risk differences respectively. The first model

1 was unadjusted, including only county quintile of population well-being. The second  
2 adjusted for maternal age, race, ethnicity, smoking status, trimester during which  
3 prenatal care was initiated, single or multiple birth, and insurance payer. For both  
4 models we calculated the Wald P-value for the overall effect of WBI and a separate test  
5 for trend in effects across WBI quintiles. In secondary analyses we replicated the main  
6 analyses using each of the 6 domain scores of the well-being index.

7  
8 We also estimated a reference model which included no independent variables, and  
9 used the county level variance from this model to calculate the variance explained at the  
10 county level for each of the models described above, using  $R^2 = (\tau^2 - \tau^{*2})/\tau^2$ , where  $\tau^{*2}$   
11 is the county level variance for the model with independent variables.(29)

12  
13 All analyses were performed using Stata 14.2 (2016 StataCorp, College Station, TX).

14 The Yale University Institutional Review Board approved this study.

15  
16 **Patient and Public Involvement:** No patients or the public were involved in the  
17 planning and design of this study.

## 18 19 **RESULTS**

20 We used data from 3,938,985 births across 2,989 counties, representing 99.6% of all  
21 US births in 2011. The mean (SD) county-level preterm birth rate was 11.7% (2.2%)  
22 preterm births. Table 1 shows numbers and percentages of children born before and

1 after 37 weeks' gestation, maternal characteristics, and infant sex by quintile of average  
2 well-being of the maternal county of residence.

3  
4 The observed rate of preterm birth decreased across WBI quintiles from 13.1% in the  
5 lowest quintile to 10.9% in the highest quintile (Table 1). In the unadjusted model,  
6 pregnant women living in counties with higher population well-being had a significantly  
7 lower risk of preterm birth. -2.2% (95% CI: [-2.6%, -1.8%];  $p < 0.001$ ) (Table 2). After  
8 adjusting for maternal risk factors for preterm birth, the trend remained consistent  
9 across the quintiles; the absolute difference between the highest and lowest quintiles  
10 was attenuated to -1.9% (95% CI: [-2.2%, -1.6%];  $P < 0.001$ ). In sensitivity analyses,  
11 results were similar.

12  
13 In secondary analyses, independent associations between quintiles of each well-being  
14 domain and preterm birth are reported in Table 3. Similar to the composite WBI score,  
15 all domain scores were significantly associated with maternal risk of preterm birth, in the  
16 unadjusted model and the model adjusting for individual maternal risk factors. Different  
17 domains, however, explained different amounts of variance of well-being, with the basic  
18 access index explaining 14.6% of the county variance. After adjusting for maternal risk  
19 factors, women in counties with the highest basic access score experienced an absolute  
20 difference in preterm birth rates of -2.4% (95%CI: [-2.2%, -2.6%];  $p < 0.001$ ) when  
21 compared with women in counties with the lowest basic access score. Similarly, the  
22 average physical health score of the county within which a pregnant woman resided  
23 was associated with lower rates of preterm birth, in both unadjusted and adjusted

1 models (absolute difference in preterm birth rate: -1.9%, 95%CI: [-1.6%, -2.1%];  
2 p<0.001). In the models adjusted for maternal risk factors, healthy behaviors (-1.5%,  
3 95%CI: [-1.2%, -1.8%]; p<0.001), emotional health (-1.0%, 95%CI: [-0.7%, -1.3%];  
4 p<0.001), and life evaluation (-1.1%, 95%CI: [-0.8%, -1.4%]; p<0.001) of the county  
5 population negatively correlated with risk of preterm birth.

## 6 7 **DISCUSSION**

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

20  
21 Decades of research have delineated a variety of maternal-level risk factors for preterm  
22 delivery, including maternal age, smoking status, history of preterm delivery, and  
23 socioeconomic status (SES) (2, 3, 31), while recent studies of environmental factors

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

15  
16 The relationship will identify could plausibly be causal through several mechanisms,  
17 including reasons related to the social environment. Pregnant women who live in higher  
18 well-being populations may experience less toxic stress, greater access to social  
19 resources, higher levels of trust and tolerance, and/or a greater perception of safety.(16)  
20 Prior research has shown that exposure to toxic stress increases the risk of preterm  
21 delivery,(34-37) while stronger social support, less social isolation, and greater social  
22 connectedness are associated with lower risk of preterm delivery, perhaps by reducing  
23 the allostatic load or chronic stress experienced by pregnant women.(38-43)

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3 1 Additionally, while experiences of perceived discrimination are associated with  
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5 2 increased risk of preterm delivery, experiences of trust and tolerance as well as a  
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7 3 greater perception of safety may foster healthier pregnancies and term deliveries.(44-  
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9 4 46)  
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15 6 According to our results, pregnant women with the same individual maternal risk profile,  
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17 7 including factors associated with SES, experience lower risk of preterm delivery when  
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19 8 living in higher well-being populations than when living in lower well-being populations.  
20  
21 9 This finding is consistent with emerging epigenetics (13, 47, 48) and maternal  
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23 10 weathering (24, 29) literature. The maternal weathering model suggests that certain  
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25 11 populations of women have an increased risk of preterm delivery due to “accelerated  
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27 12 aging” that they experience as a result of greater exposure to hardship. This model  
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29 13 suggests that living in better neighborhoods might attenuate the increased risk  
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31 14 associated with these weathering effects.(49) It is possible that the observed risk  
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33 15 contributed by weathering and the risk mitigated by living in higher well-being  
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35 16 populations are actually related to underlying exposure to toxic stress and buffering  
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37 17 from factors such as trust, tolerance, social support, and perceived safety.  
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45 19 Our study also builds on prior literature that found links between living in areas of  
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47 20 greater poverty and increased risk of preterm birth. In the domain analyses, the basic  
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49 21 access domain demonstrated the strongest relationship with maternal risk of preterm  
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51 22 delivery. Even after adjusting for individual maternal risk factors, including insurance  
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53 23 provider and smoking, the basic access domain explained nearly 15% of county-level  
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3 1 variance in preterm birth rates. The basic access index domain includes items that  
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5 2 assess perceived access to healthcare, clean water, fresh produce, and safe public  
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7 3 space as well as ability to afford basic needs such as food and shelter. This finding  
8  
9 4 affirms prior literature reporting that access to basic needs is strongly correlated with  
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11 5 health outcomes. Importantly, however, all domains contributed independently to the  
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13 6 inverse association between population well-being and maternal risk of preterm  
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15 7 delivery, though to varying degrees. Average county-level physical health, healthy  
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17 8 behaviors, and emotional health scores were associated with a one- to two-percent  
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19 9 lower maternal risk of preterm delivery.  
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26 11 The results of our study have several potential implications. Our findings suggest the  
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28 12 possibility that effective population- and community-level investments in well-being may  
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30 13 not only improve overall health and quality of life for populations, but also contribute to  
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32 14 reduced rates of preterm birth for pregnant women living in those populations, an idea  
33  
34 15 worth pursuing. Our domain analyses suggest that improving aggregate basic access,  
35  
36 16 in particular, could plausibly result in not only greater well-being but also fewer preterm  
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38 17 births. Targeting other domains, such as physical health, healthy behaviors, and  
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40 18 emotional health, may yield additional improvements. Importantly, the effectiveness of  
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42 19 various interventions will most likely depend on the contexts within which they are  
43  
44 20 implemented. Currently, efforts are underway across the globe to track and improve  
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46 21 population well-being through programmatic and policy-based interventions.(4, 6, 50-52)  
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48 22 While some interventions involve multi-sector, community-based programs, many of  
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50 23 which are government supported, other interventions involve changes in economic and  
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1 social policies, such as those aimed at affordable housing, employment, and access to  
2 public spaces for physical fitness or social connection.(16, 53, 54) Given the  
3 relationship between population well-being and preterm birth risk, examining the  
4 association of such programs and policies with preterm birth could be informative and  
5 allow for spread of interventions that effectively increase well-being and reduce preterm  
6 birth.

7  
8 Our study has limitations. First, as a cross-sectional study, it cannot assess causation.  
9 However, determining whether a relationship exists between population well-being and  
10 risk of preterm birth is an essential first step. Second, this study specifically examines  
11 how the average well-being of the adult population within which a pregnant woman lives  
12 correlates with her risk of preterm delivery. Because we do not have an assessment of  
13 the well-being of the individual pregnant women, we cannot determine how population  
14 well-being may moderate the effect of women's own well-being or other related  
15 individual factors on their risk of preterm delivery. Additionally, we did not have data on  
16 maternal income, wealth, or education level, so we could not directly adjust for these  
17 socioeconomic variables. Nevertheless, we utilized available maternal-level variables  
18 that are known to be associated with socioeconomic status as proxies in order to control  
19 for the effect of socioeconomic status on preterm birth and isolate the effect of  
20 community well-being. Finally, we did not have well-being data available at  
21 geographically smaller units (e.g., neighborhood or city), which may be more relevant  
22 than county well-being in describing the community context for an individual pregnant  
23 woman. While counties are distinct from the smaller, often more homogeneous,

1 geographic units of neighborhoods and census tracts, policies and programs are often  
2 enacted at the county level. Thus, results may drive action at the county-level, while  
3 also informing local communities in developing targeted programs to enhance well-  
4 being.

5  
6 Pregnant women who live in populations with higher well-being have lower risk of  
7 preterm delivery, even after accounting for known individual maternal risk factors. The  
8 well-being of a population is an important end itself, but if causal pathways exist  
9 between population well-being and other valued outcomes, investments in population  
10 well-being may yield other benefits, potentially including fewer preterm births.  
11 Understanding the full effects of population well-being can inform the emerging dialogue  
12 about its value as a health investment.

13  
14 **Contributors:** CR and BR participated in the initial conception of this study. JH  
15 performed all analyses. All authors (CR, BR, JH, ES, MS, AA, KK, ER, and HK)  
16 contributed to the study design, interpretation of data, drafting and revising the article,  
17 and its final approval. All authors are guarantors.

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6 2 **Competing Interests:** All authors have completed the ICMJE uniform disclosure form  
7  
8 3 at [www.icmje.org/coi\\_disclosure.pdf](http://www.icmje.org/coi_disclosure.pdf) and declare the following competing interests:  
9  
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19  
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21  
22 10 and Translational Science Award; ER and KK are current or former employees and  
23  
24 11 shareholders of the Healthways corporation (acquired by Sharecare), the company that  
25  
26 12 developed the measure of well-being used in this article; ES, JH, and HK also report  
27  
28 13 receiving support from the Centers for Medicare and Medicaid Services; Dr. Krumholz is  
29  
30 14 a recipient of research agreements from Medtronic and Johnson & Johnson (Janssen),  
31  
32 15 through Yale, to develop methods of clinical trial data sharing; is the recipient of a grant  
33  
34 16 from Medtronic and the Food and Drug Administration, through Yale, to develop  
35  
36 17 methods for postmarket surveillance of medical devices; works under contract with the  
37  
38 18 Centers for Medicare & Medicaid Services to develop and maintain performance  
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40 19 measures; chairs a cardiac scientific advisory board for UnitedHealth; is a  
41  
42 20 participant/participant representative of the IBM Watson Health Life Sciences Board; is  
43  
44 21 a member of the Advisory Board for Element Science and the Physician Advisory Board  
45  
46 22 for Aetna; and is the founder of Hugo, a personal health information platform.  
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3 1 **Data Sharing:** If the paper is accepted for publication, we will post a de-identified data  
4  
5 2 set with county resident well-being data from Gallup-Sharecare on ICSPR Open, a  
6  
7 3 publicly available site. Birth data are available with permission from the National Center  
8  
9 4 for Health Statistics (<http://www.cdc.gov/nchs/>).  
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15 6 **Ethics Approval:** This study was approved by the Yale University Institutional Review  
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17 7 Board.  
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1 Table 1. Gestational age at birth and maternal characteristics by maternal county quintile of composite Gallup-  
 2 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 (%)						
1 <sup>st</sup> - 3 <sup>rd</sup> 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)
4 <sup>th</sup> - 6 <sup>th</sup> 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)
7 <sup>th</sup> 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)

1 Table 2. Maternal risk of preterm delivery: overall and by county of residence aggregated by quintile of composite  
 2 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	
<b>GHWBI score</b>			<0.001			<0.001
Q1	ref			ref		
Q2	-	0.001			<0.001	
Q3		<0.001		-0.006 [-0.009,-0.003]	<0.001	
Q4	-0.006 [-0.010,-0.002]	<0.001		-0.013 [-0.016,-0.010]	<0.001	
Q5	-0.013 [-0.017,-0.009]	<0.001		-0.014 [-0.017,-0.012]	<0.001	
	-0.015 [-0.019,-0.012]			-0.019 [-0.022,-0.016]		
	-0.022 [-0.026,-0.018]					
<b>Maternal age</b>						
≤ 19				ref		
20-24					<0.001	
25-29				-0.019 [-0.020,-0.017]	<0.001	
30-34				-0.021 [-0.022,-0.020]	<0.001	
35-39				-0.016 [-0.017,-0.014]	<0.001	
≥ 40				0.002 [0.000,0.003]	<0.001	
				0.023 [0.021,0.025]		
<b>Maternal race</b>						
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	
<b>Mother is Hispanic</b>						
No				ref		
Yes				0.015 [0.014,0.015]	<0.001	
<b>Maternal smoking</b>						
No				ref		
Yes				0.030 [0.029,0.031]	<0.001	
Unknown				0.004 [0.002,0.007]	<0.001	
<b>Payer</b>						
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	
<b>Timing of first prenatal visit</b>						
1 <sup>st</sup> - 3 <sup>rd</sup> month				ref		
4 <sup>th</sup> - 6 <sup>th</sup> month					<0.001	
7 <sup>th</sup> month-term					<0.001	
No prenatal visit				-0.019 [-0.020,-0.018]	<0.001	
Unknown				-0.012 [-0.014,-0.011]	<0.001	
				-0.013 [-0.014,-0.011]		
				-0.005 [-0.008,-0.002]		
				-0.004 [-0.006,-0.003]		

1	Infant sex				ref	
2	Female				0.011	<0.001
3	Male				[0.010,0.011]	
4	Multiple births				ref	
5	No				0.487	<0.001
6	Yes				[0.485,0.489]	
7	R <sup>2</sup>	0.078			0.656	

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1 Table 3. Maternal risk of preterm delivery by county of residence aggregated by quintile of individual Gallup-  
 2 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
<b>Basic Access Index (BAI)</b>			<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 <sup>2</sup>	0.146			0.656		
<b>Physical Health Index (PHI)</b>			<0.001			<0.001
Q1	ref			ref		
Q2	-	<0.001		-0.007 [-0.010,-0.005]	<0.001	
Q3	0.009 [-0.012,-0.005]	<0.001		-0.013 [-0.015,-0.010]	<0.001	
Q4	-0.013 [-0.016,-0.009]	<0.001		-0.017 [-0.019,-0.014]	<0.001	
Q5	-0.017 [-0.020,-0.013]	<0.001		-0.019 [-0.021,-0.016]	<0.001	
R <sup>2</sup>	0.059			0.657		
<b>Healthy Behaviors Index (HBI)</b>			<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 <sup>2</sup>	0.039			0.654		
<b>Emotional Health Index (EHI)</b>			<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 <sup>2</sup>	0.032			0.656		
<b>Life Evaluation Index (LEI)</b>			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 <sup>2</sup>	0.004			0.653		
<b>Work Environment Index (WEI)</b>			<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 <sup>2</sup>	0.016			0.653		

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

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

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 – <i>Page 9</i> (b) Give reasons for non-participation at each stage – <i>N/A, this was a population based study at the county level</i> (c) Consider use of a flow diagram – <i>N/A</i>
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders – <i>N/A unit of analysis was the county</i> (b) Indicate number of participants with missing data for each variable of interest – <i>N/A</i> (c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time <i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure <i>Cross-sectional study</i> —Report numbers of outcome events or summary measures – <i>Pages 9-11 and Tables 1-3</i>
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 – <i>Page 10-11 and Table 2</i> (b) Report category boundaries when continuous variables were categorized – <i>All tables</i> (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period – <i>N/a</i>
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses – <i>N/A</i>

**Discussion**

Key results	18	Summarise key results with reference to study objectives – <i>Page 11</i>
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 – <i>Page 15</i>
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence – <i>Page 11-15</i>
Generalisability	21	Discuss the generalisability (external validity) of the study results – <i>Page 11-15</i>

**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— <i>Page 16</i>
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\*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](http://www.strobe-statement.org).