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# Relationship Between Blood Glucose Level and Prevalence and Frequency of Stress Urinary Incontinence in Women

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**Objectives:** The purpose of this study was to evaluate the relationship between blood glucose level and the prevalence and frequency of stress urinary incontinence (SUI) in women.

**Methods:** We conducted a cross-sectional study of female participants in the National Health and Nutrition Examination Survey database between 2007 and 2016. Dose-response analysis curves and univariate and multivariate logistic regressions were used to determine the relationship between blood glucose level and the prevalence and frequency of SUI.

**Results:** A total of 10,771 participants were included in this study, of which 6,466 (60.0%) reported no SUI, 4,305 (31.1%) reported monthly SUI, and 953 (8.8%) reported weekly SUI. We found that the blood glucose levels were higher in the weekly SUI group than in the monthly SUI and no SUI groups. Based on blood glucose levels, participants were divided into 3 groups:  $\leq 86.0$  mg/dL group,  $>86.0$  to  $98.0$  mg/dL group, and  $>98.0$  mg/dL group. Dose-response curves showed a nonlinear positive correlation between blood glucose levels and the prevalence and extent of SUI, and participants in the glucose  $>98.0$  mg/dL group had a 15.2% higher risk (adjusted odds risk, 1.152; 95% confidence interval, 1.027–1.293;  $P = 0.016$ ) of SUI prevalence and 12.5% higher risk (adjusted odds risk 1.125; 95% confidence interval, 1.009–1.255;  $P = 0.034$ ) of SUI frequency than participants in the glucose  $\leq 86.0$  mg/dL group.

**Conclusions:** We found that the prevalence and frequency of SUI in women were positively correlated with blood glucose levels, and these findings warrant further study and application to clinical practice to control SUI in women.

**Key Words:** stress urinary incontinence, blood glucose, prevalence, NHANES

(*Female Pelvic Med Reconstr Surg* 2022;28: 304–310)

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This article was published online ahead of print on September 27, 2021.

The authors have declared they have no conflicts of interest.

The methodology of this study followed the criteria outlined in the Declaration of Helsinki (as revised in 2013). This study used previously collected deidentified data, which was deemed exempt from review by the Ethics Committee of The First People's Hospital of Yongkang.

Y.Y. and L.T. studied the concept and design. Y.Y. and L.X. collected the data. Y.Y. and R.H. analyzed and interpreted the data. Y.Y. and L.T. drafted the manuscript. T.C., X.W., and K.L. critically revised the manuscript for important intellectual content. Y.Y. and L.T. performed the statistical analysis.

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DOI: 10.1097/SPV.0000000000001112

Stress urinary incontinence (SUI) is one of the most common diseases in urogynecology, a condition in which involuntary urine leaks from the external orifice of the urethra because of increased abdominal pressure such as exertion, physical activity, sneezing, or coughing.<sup>1</sup> Stress urinary incontinence is a common disease in women. It mostly occurs in the middle-aged and elderly female population, and its prevalence ranges between 18.6% and 75%.<sup>2</sup> It has been pointed out that the high incidence age of SUI is bimodal, with the main age of onset being 40–59 years and 80 years or older, respectively, and the incidence is positively correlated with age.<sup>3</sup> According to the European Prospective Investigation into Cancer study, the number of women affected by SUI increased from 54 million in 2008 to 60 million in 2013 (11.6% increase) and 66 million in 2018 (23.6% increase).<sup>4</sup> Stress urinary incontinence has become the fifth most common chronic disease affecting women's quality of life worldwide.<sup>5</sup> It is a costly and disturbing problem that has a tremendous impact on the quality of life of women, including their mental and physical health.<sup>6</sup> A study in the United States reported that women with SUI pay approximately \$750 per year out-of-pocket for routine care and nearly \$1,400 per year for treatment.<sup>7</sup>

Risk factors for SUI include age, childbearing status, obesity, diabetes, menopause, and parities.<sup>8,9</sup> Diabetes is a chronic disease with a high incidence, which can cause many serious complications, such as neuropathy, nephropathy, and retinopathy.<sup>10</sup> The relationship between abnormal blood glucose levels and SUI has attracted widespread attention in recent years. One study showed that the risk of SUI was 2.5-fold higher in diabetic women than in nondiabetic women, and the incidence of SUI in diabetic and nondiabetic patients was 41.0% and 22.1%, respectively.<sup>11</sup> This suggests an association between blood glucose levels and SUI. However, no previous studies have directly compared the relationship between blood glucose levels and the incidence and frequency of SUI. Fasting blood glucose and HbA<sub>1c</sub> are the most commonly used indicators to assess blood glucose levels. The purpose of this study was to determine whether blood glucose levels were related to the incidence and frequency of SUI.

## MATERIALS AND METHODS

### Patients Selection

The participants of this study were from the 2007 to 2016 National Health and Nutrition Examination Survey (NHANES) database ([www.cdc.gov/nchs/nhanes/index.htm](http://www.cdc.gov/nchs/nhanes/index.htm)). The NHANES database is a cross-sectional survey designed to assess the health and nutritional status of noninstitutionalized civilians in 50 states and the District of Columbia. A multistage probability sampling design was used with the goal of obtaining a nationally representative sample.<sup>12</sup> Approximately 5,000 individuals were sampled annually through a multistage stratified probability design, and all participants receive a structured questionnaire at home and a

physical examination at a mobile testing center. Since 1999, most of the data in this representative survey have been published online on a 2-year cycle. The current survey was conducted with NHANES respondents from the 2007 to 2008, 2009 to 2010, 2011 to 2012, 2013 to 2014, and 2015 to 2016 decades. A total of 25,516 female respondents were included in the survey sample.

The exclusion criteria were as follows: (1) unknown blood glucose ( $n = 9,254$ ); (2) age less than 20 years ( $n = 2,710$ ); (3) cancer complications ( $n = 1,287$ ); (4) unknown SUI ( $n = 1,360$ ); (5) unknown HbA<sub>1c</sub> ( $n = 28$ ); and (6) incomplete general survey ( $n = 106$ ) (Fig. 1). After the exclusion of these factors, 10,771 female participants were included in the final study.

## Study Variables and Outcome

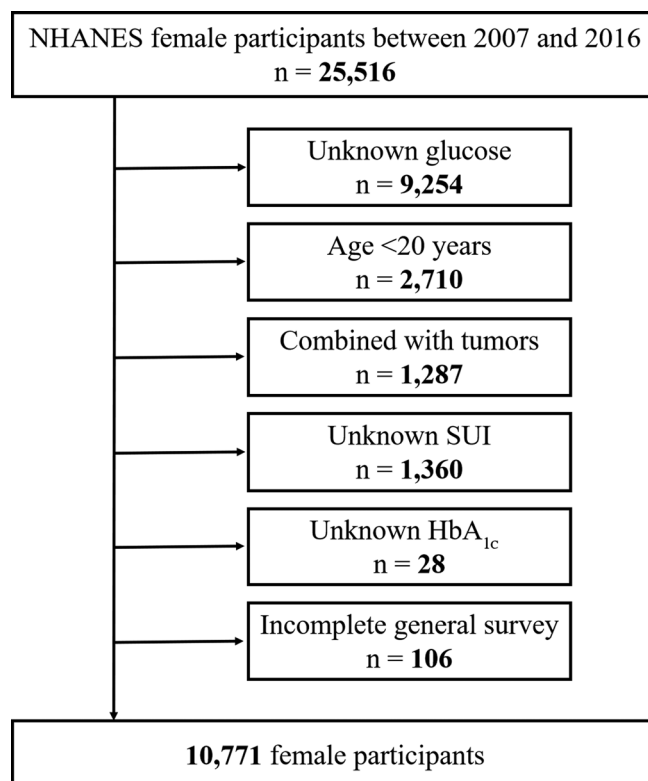
The outcomes of interest were the history of SUI and the frequency of SUI. It could be extracted from the Kidney Conditions—Urology file under Questionnaire Data. For the question “During the past 12 months, have you leaked or lost control of even a small amount of urine with an activity like coughing, lifting, or exercise, or an urge to urinate?”, participants who answered “yes” were considered to have a history of SUI. The frequency of SUI was determined based on the question “How frequently does this occur?”. We defined monthly SUI as self-reported once a month or more, and weekly SUI as self-reported weekly or more incontinence events.<sup>13</sup>

The main indicator of this study was blood glucose levels, which can be obtained from the standard biochemical files of laboratory data. Blood glucose is measured in the fasting state. Specific values for blood glucose were extracted from the Standard Biochemistry Profile data file under Laboratory Data. Other covariates included age (20–39 years, 40–59 years, and

≥60 years), race (non-Hispanic White, non-Hispanic Black, Mexican American, other Hispanic, and other), marital status (married and unmarried/other), education (less than high school, high school or equivalent, college or above, and other), hypertension (no, yes), diabetes (no, yes), vigorous recreational activities (no, yes), moderate recreational activities (no, yes), HbA<sub>1c</sub> (normal [ $<5.7$ ], prediabetes [ $5.7–6.5$ ], diabetes mellitus [ $>6.5$ ]), blood urea nitrogen, creatinine, and uric acid. For the diagnosis of diabetes, it can be obtained from the Diabetes data file under Questionnaire Data. Similarly, hypertension and recreational activity were obtained from the Blood Pressure and Cholesterol and Physical Activity data files, respectively.

## Statistical Analysis

We divided the study population into 3 groups based on blood glucose levels: ≤86.0 mg/dL (tertile 1), >86.0 to 98.0 mg/dL (tertile 2), and >98.0 mg/dL (tertile 3). Continuous variables were represented by interquartile range, whereas classification variables were represented by proportions. For categorical variables,  $P$  values were analyzed by  $\chi^2$  tests, and for continuous variables, the  $t$  test for slope was used in generalized linear models. Univariate and multivariate logistic regressions were used to evaluate the correlation between blood glucose levels and the prevalence and frequency of SUI, and the adjusted odds ratio (aOR) and 95% confidence interval (CI) were calculated. We constructed 3 models: (1) in the basic model, we did not adjust any variables; (2) in the core model, we adjusted for participant-related clinically relevant variables such as age, race, marital status, education, hypertension, diabetes, and vigorous and moderate recreational activities; (3) in the extended model, we adjusted for the variables in the core model plus laboratory



**FIGURE 1.** Flowchart of participant selection in this study. NHANES, National Health and Nutrition Examination Survey; SUI, stress urinary incontinence.

**TABLE 1.** Baseline Characteristics of All Patients in Study

| Characteristic                   | All Patients      | SUI               |                   |                   |                   | P*     | P†     |
|----------------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|--------|--------|
|                                  |                   | No SUI<br>n (%)   | Total<br>n (%)    | Monthly<br>n (%)  | Weekly<br>n (%)   |        |        |
| Total patients                   | 10,771            | 6,466 (60.0)      | 4,305 (40.0)      | 3,352 (31.1)      | 953 (8.8)         |        |        |
| Age, y                           |                   |                   |                   |                   |                   | <0.001 | <0.001 |
| Median (IQR)                     | 47.0 (33.0–62.0)  | 44.0 (30.0–61.0)  | 51.0 (40.0–63.0)  | 50.0 (39.0–62.0)  | 57.0 (45.0–68.0)  | <0.001 | <0.001 |
| 20–39                            | 3,814 (35.4)      | 2,762 (42.7)      | 1,052 (24.4)      | 889 (26.5)        | 163 (17.1)        |        |        |
| 40–59                            | 3,702 (34.4)      | 1,909 (29.5)      | 1,793 (41.6)      | 1,426 (42.5)      | 367 (38.5)        |        |        |
| ≥60                              | 3,255 (30.2)      | 1,795 (27.8)      | 1,460 (33.9)      | 1,037 (30.9)      | 423 (44.4)        |        |        |
| Race                             |                   |                   |                   |                   |                   | <0.001 | <0.001 |
| Non-Hispanic White               | 4,308 (40.0)      | 2,404 (37.2)      | 1,904 (44.2)      | 1,471 (43.9)      | 433 (45.4)        |        |        |
| Non-Hispanic Black               | 2,279 (21.2)      | 1,601 (24.8)      | 678 (15.7)        | 551 (16.4)        | 127 (13.3)        |        |        |
| Mexican American                 | 1,786 (16.6)      | 965 (14.9)        | 821 (19.1)        | 636 (19.0)        | 185 (19.4)        |        |        |
| Other Hispanic                   | 1,295 (12.0)      | 760 (11.8)        | 535 (12.4)        | 393 (11.7)        | 142 (14.9)        |        |        |
| Other                            | 1,103 (10.2)      | 736 (11.4)        | 367 (8.5)         | 301 (9.0)         | 66 (6.9)          |        |        |
| Marital status                   |                   |                   |                   |                   |                   | <0.001 | <0.001 |
| Married                          | 5,034 (46.7)      | 2,797 (43.3)      | 2,237 (52.0)      | 1,787 (53.3)      | 450 (47.2)        |        |        |
| Unmarried/others                 | 5,737 (53.3)      | 3,669 (56.7)      | 2,068 (48.0)      | 1,565 (46.7)      | 503 (52.8)        |        |        |
| Education                        |                   |                   |                   |                   |                   | <0.001 | <0.001 |
| Less than high school            | 2,624 (24.4)      | 1,444 (22.3)      | 1,180 (27.4)      | 838 (25.0)        | 342 (24.4)        |        |        |
| High school or equivalent        | 2,323 (21.6)      | 1,411 (21.8)      | 912 (21.2)        | 722 (21.5)        | 190 (19.9)        |        |        |
| College or above                 | 5,813 (54.0)      | 3,607 (55.8)      | 2,206 (51.2)      | 1,786 (53.3)      | 420 (44.1)        |        |        |
| Other                            | 11 (0.1)          | 4 (0.1)           | 7 (0.2)           | 6 (0.2)           | 1 (0.1)           |        |        |
| Hypertension                     |                   |                   |                   |                   |                   | <0.001 | <0.001 |
| No                               | 6,993 (64.9)      | 4,473 (69.2)      | 2,520 (58.5)      | 2,060 (61.5)      | 460 (48.3)        |        |        |
| Yes                              | 3,778 (35.1)      | 1,993 (30.8)      | 1,785 (41.5)      | 1,292 (38.5)      | 493 (51.7)        |        |        |
| Diabetes                         |                   |                   |                   |                   |                   | <0.001 | <0.001 |
| No                               | 9,509 (88.3)      | 5,841 (90.3)      | 3,668 (85.2)      | 2,921 (87.1)      | 747 (78.4)        |        |        |
| Yes                              | 12,62 (11.7)      | 625 (9.7)         | 637 (14.8)        | 431 (12.9)        | 206 (21.6)        |        |        |
| Vigorous recreational activities |                   |                   |                   |                   |                   | <0.001 | <0.001 |
| No                               | 8,867 (82.3)      | 5,208 (80.5)      | 3,659 (85.0)      | 2,804 (83.7)      | 855 (89.7)        |        |        |
| Yes                              | 1,904 (17.7)      | 1,258 (19.5)      | 646 (15.0)        | 548 (16.3)        | 98 (10.3)         |        |        |
| Moderate recreational activities |                   |                   |                   |                   |                   | 0.042  | <0.001 |
| No                               | 6,428 (59.7)      | 3,808 (58.9)      | 2,620 (60.9)      | 1,958 (58.4)      | 662 (69.5)        |        |        |
| Yes                              | 4,343 (40.3)      | 2,658 (41.1)      | 1,685 (39.1)      | 1,394 (41.6)      | 291 (30.5)        |        |        |
| HbA <sub>1c</sub>                |                   |                   |                   |                   |                   | <0.001 | <0.001 |
| Median (IQR)                     | 5.50 (5.20–5.90)  | 5.40 (5.20–5.80)  | 5.60 (5.30–6.00)  | 5.60 (5.30–5.90)  | 5.70 (5.40–6.20)  | <0.001 | <0.001 |
| Normal (<5.7)                    | 6,693 (62.1)      | 4,291 (66.4)      | 2,402 (55.8)      | 1,979 (59.0)      | 423 (44.4)        |        |        |
| Prediabetes (5.7–6.5)            | 3,053 (28.3)      | 1,674 (25.9)      | 1,379 (32.0)      | 1,012 (30.2)      | 367 (38.5)        |        |        |
| Diabetes mellitus (>6.5)         | 1,025 (9.5)       | 501 (7.7)         | 524 (12.2)        | 361 (10.8)        | 163 (17.1)        |        |        |
| Glucose, mg/dL                   | 91.0 (84.0–102.0) | 90.0 (83.0,100.0) | 93.0 (86.0–106.0) | 93.0 (85.0–104.0) | 97.0 (88.0–117.0) | <0.001 | <0.001 |
| Blood urea nitrogen, mmol/L      | 12.0 (9.0–15.0)   | 11.0 (9.0–15.0)   | 12.0 (9.0–15.0)   | 12.0 (9.0–15.0)   | 13.0 (10.0–17.0)  | <0.001 | <0.001 |
| Creatinine, mg/dL                | 0.73 (0.63–0.84)  | 0.72 (0.64,0.83)  | 0.73 (0.63–0.85)  | 0.73 (0.63–0.84)  | 0.73 (0.63–0.87)  | 0.599  | 0.280  |
| Uric acid, mg/dL                 | 4.7 (4.0–5.6)     | 4.6 (3.9–5.5)     | 4.8 (4.0–5.7)     | 4.7 (4.0–5.6)     | 5.0 (4.1–5.9)     | <0.001 | <0.001 |

For categorical variables, *P* values were analyzed by  $\chi^2$  tests. For continuous variables, the *t* test for slope was used in generalized linear models.

Continuous data are presented as the median (IQR), and categorical data as n (%).

\* $\chi^2$  detected the difference between no SUI group and SUI group.

† $\chi^2$  detected the difference between no SUI group, monthly SUI group, and weekly SUI group.

IQR, interquartile range; SUI, stress urinary incontinence.

test indicators such as blood urea nitrogen, creatinine, uric acid, and HbA<sub>1c</sub>.

To further understand whether there was a nonlinear trend in the relationship between blood glucose levels and the prevalence and frequency of SUI, the restricted cubic model was used to draw the dose-response curve. The restricted cubic spline function is a powerful tool for describing dose-response relationships between continuous variables and outcomes and can describe the relationship between the independent and dependent variables quite clearly.<sup>14</sup> All analyses were performed using R studio software (version 1.2.5033) and SPSS software (version 24.0), and differences were considered statistically significant at  $P < 0.05$ .

### RESULTS

In our study, 10,771 female participants were enrolled in the final study, 6,466 (60.0%) reported no SUI and 4,305 (40.0%) reported SUI (of which 3,352 [31.1%] reported monthly SUI, and 953 [8.8%] reported weekly SUI). The demographic and clinical characteristics of all participants were shown in Table 1. There were significant differences among the 3 groups in age, race, marital status, education, hypertension, diabetes, vigorous recreational activities, moderate recreational activities, HbA<sub>1c</sub>, blood glucose, urea nitrogen, and uric acid. We found a higher proportion of participants in the weekly SUI group who were 60 years or older (44.4% vs 30.9%, 27.8%), with hypertension (51.7% vs 38.5%, 30.8%), with diabetes (21.6% vs 12.9%, 9.7%), with no strenuous recreational activity (89.7% vs 83.7%, 80.5%), and with no moderate recreational activity (69.5% vs 58.4%, 58.9%) than in the monthly SUI and no SUI groups. In addition, there was a trend toward higher levels of age, glucose (Fig. 2A), HbA<sub>1c</sub> (Fig. 2B), urea nitrogen, and uric acid in no SUI, monthly SUI, and weekly SUI.

Based on blood glucose levels, we divided all participants into 3 groups:  $\leq 86.0$  mg/dL group (tertile 1, [T1]),  $>86.0$  to  $98.0$  mg/dL group (tertile 2 [T2]), and  $>98.0$  mg/dL group (tertile 3 [T3]) (Table 2). We found that there were statistical differences in age, race, marital status, education, hypertension, diabetes, vigorous recreational activities, moderate recreational activities, HbA<sub>1c</sub>, urea nitrogen, creatinine, uric acid, SUI prevalence, and frequency among the 3 groups. In addition, we found that the prevalence of SUI increased (T3 group, 46.5%; T2 group, 40.0%; T1 group, 33.7%) with increasing blood glucose and that there was an increasing trend in the frequency of SUI (monthly SUI: T3 group, 33.6%; T2 group, 31.8%; T1 group, 28.0%; weekly SUI: T3 group, 12.9%; T2 group, 8.2%; T1 group, 5.7%).

The restricted cubic spline model showed that there was a nonlinear positive correlation between blood glucose level and the prevalence (Fig. 3A) and frequency (Fig. 3B) of SUI, with a subsequent increase in the prevalence and frequency of SUI as

blood glucose increased. After adjusting for age, race, marital status, education, hypertension, diabetes, vigorous and moderate recreational activities, blood urea nitrogen, creatinine, uric acid, and HbA<sub>1c</sub> variables, multivariate logistic regression analysis showed that participants in the glucose  $>98.0$  mg/dL group had a 15.2% higher risk (aOR, 1.152; 95% CI 1.027–1.293;  $P = 0.016$ ) of SUI prevalence and 12.5% higher risk (aOR, 1.125; 95% CI 1.009–1.255;  $P = 0.034$ ) of SUI frequency than participants in the glucose  $\leq 86.0$  mg/dL group (Table 3).

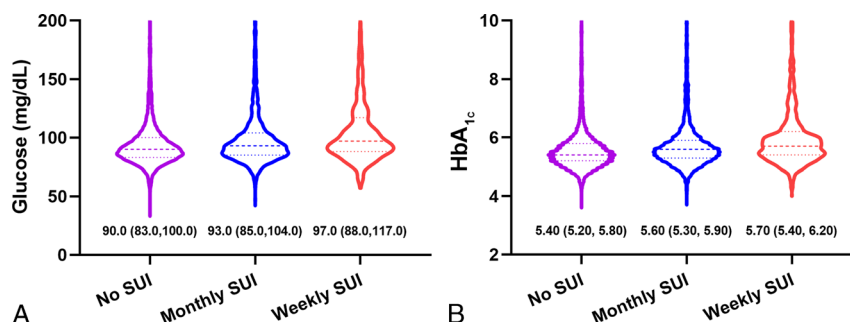
### DISCUSSION

In this retrospective study, we found that higher blood glucose levels were associated with the prevalence of SUI and that blood glucose levels increased with increasing frequency of SUI. In addition, the dose-response curves showed a nonlinear positive correlation between blood glucose and the prevalence and frequency of SUI. This suggests that elevated blood glucose levels may be a strong indicator for diagnosing the prevalence of SUI and the severity of SUI in women.

Stress urinary incontinence is the most common type of urinary incontinence, affecting approximately 50% of women.<sup>15</sup> It is primarily a multifactorial induced alteration in the anatomy of the bladder and urethral tissues that severely impairs the patient's physiological function to control voiding.<sup>16</sup> Furthermore, it is primarily due to a defect in the mechanism of urethral closure without detrusor contraction, which may be related to the excessive activity and loss of support of the urethra or neuromuscular defects in the urethra itself.<sup>17</sup> Diabetes mellitus has also been implicated as a risk factor for the development of SUI. However, the relationship between specific mechanisms have not been elucidated.<sup>18</sup>

Diabetes mellitus is a chronic metabolic disease with a high incidence. It is considered an independent risk factor for female urinary incontinence.<sup>19</sup> Hyperglycemia can cause osmotic diuresis, which leads to urinary frequency and further increases the risk of incontinence.<sup>20</sup> A high percentage of patients with diabetes mellitus develop urinary autonomic lesions or bladder lesions.<sup>21</sup> Animal studies and research data suggest that diabetic bladder disease is caused by ultrastructural and microvascular damage to the detrusor muscle and that changes in its neural component ultimately lead to changes in detrusor function.<sup>22</sup> Patients with diabetes mellitus are at increased risk of bacterial colonization and urinary tract infections, which may exacerbate existing lower urinary tract symptoms, including increased urinary frequency and incontinence.<sup>23</sup>

In epidemiological studies, SUI was found to be positively associated with the duration of diabetes mellitus and hyperglycemia.<sup>24,25</sup> Brown et al<sup>21</sup> analyzed the NHANES database from 2001 to 2002 and found that women with diabetes mellitus had



**FIGURE 2.** Comparison of blood glucose and HbA<sub>1c</sub> levels among the no SUI, monthly SUI, and weekly SUI groups. (A), blood glucose levels; (B), HbA<sub>1c</sub> levels. SUI, stress urinary incontinence.

**TABLE 2.** Characteristics of the SUI Population by Categories of Glucose Levels

| Characteristic                   | Glucose Level    |                  |                  | P      |
|----------------------------------|------------------|------------------|------------------|--------|
|                                  | Tertile 1        | Tertile 2        | Tertile 3        |        |
| Total patients                   | 3,591            | 3,758            | 3,422            |        |
| Age, y                           |                  |                  |                  | <0.001 |
| Median (IQR)                     | 37.0 (27.0–51.0) | 48.0 (35.0–62.0) | 58.0 (45.0–68.0) | <0.001 |
| 20–39                            | 1,976 (55.0)     | 1,251 (33.3)     | 587 (17.2)       |        |
| 40–59                            | 1,075 (29.9)     | 1,391 (37.0)     | 1,236 (36.1)     |        |
| ≥60                              | 540 (15.0)       | 1,116 (29.7)     | 1,599 (46.7)     |        |
| Race                             |                  |                  |                  | <0.001 |
| Non-Hispanic White               | 1,518 (42.3)     | 1,491 (39.7)     | 1,299 (38.0)     |        |
| Non-Hispanic Black               | 817 (22.8)       | 741 (19.7)       | 721 (21.1)       |        |
| Mexican American                 | 508 (14.1)       | 641 (17.1)       | 637 (18.6)       |        |
| Other Hispanic                   | 393 (10.9)       | 475 (12.6)       | 427 (12.5)       |        |
| Other                            | 355 (9.9)        | 410 (10.9)       | 338 (9.9)        |        |
| Marital status                   |                  |                  |                  | 0.028  |
| Married                          | 1,624 (45.2)     | 1,816 (48.3)     | 1,594 (46.6)     |        |
| Unmarried/others                 | 1,967 (54.8)     | 1,942 (51.7)     | 1,828 (53.4)     |        |
| Education                        |                  |                  |                  | <0.001 |
| Less than high school            | 645 (18.0)       | 922 (24.5)       | 1,057 (30.9)     |        |
| High school or equivalent        | 723 (20.1)       | 807 (21.5)       | 793 (23.2)       |        |
| College or above                 | 2,221 (61.8)     | 2,025 (53.9)     | 1,567 (45.8)     |        |
| Other                            | 2 (0.1)          | 4 (0.1)          | 5 (0.1)          |        |
| Hypertension                     |                  |                  |                  | <0.001 |
| No                               | 2,835 (78.9)     | 2,551 (67.9)     | 1,607 (47.0)     |        |
| Yes                              | 756 (21.1)       | 1,207 (32.1)     | 1,815 (53.0)     |        |
| Diabetes                         |                  |                  |                  | <0.001 |
| No                               | 3,466 (96.5)     | 3,611 (96.1)     | 2,432 (71.1)     |        |
| Yes                              | 125 (3.5)        | 147 (3.9)        | 990 (28.9)       |        |
| Vigorous recreational activities |                  |                  |                  | <0.001 |
| No                               | 2,675 (74.5)     | 3,086 (82.1)     | 3,106 (90.8)     |        |
| Yes                              | 916 (25.5)       | 672 (17.9)       | 316 (9.2)        |        |
| Moderate recreational activities |                  |                  |                  | <0.001 |
| No                               | 1,944 (54.1)     | 2,219 (59.0)     | 2,265 (66.2)     |        |
| Yes                              | 1,647 (45.9)     | 1,539 (41.0)     | 1,157 (33.8)     |        |
| HbA <sub>1c</sub>                |                  |                  |                  | <0.001 |
| Median (IQR)                     | 5.30 (5.00–5.50) | 5.50 (5.20–5.70) | 5.90 (5.50–6.70) | <0.001 |
| Normal (<5.7)                    | 2,993 (83.3)     | 2,591 (68.9)     | 1,109 (32.4)     |        |
| Prediabetes (5.7–6.5)            | 546 (15.2)       | 1,123 (29.9)     | 1,384 (40.4)     |        |
| Diabetes mellitus (>6.5)         | 52 (1.4)         | 44 (1.2)         | 929 (27.1)       |        |
| SUI                              |                  |                  |                  | <0.001 |
| No                               | 2,382 (66.3)     | 2,254 (60.0)     | 1,830 (53.5)     |        |
| Yes                              | 1,209 (33.7)     | 1,504 (40.0)     | 1,592 (46.5)     |        |
| Monthly                          | 1,006 (28.0)     | 1,195 (31.8)     | 1,151 (33.6)     |        |
| Weekly                           | 203 (5.7)        | 309 (8.2)        | 441 (12.9)       |        |
| Blood urea nitrogen, mmol/L      | 11.0 (8.0–14.0)  | 12.0 (9.0–15.0)  | 13.0 (10.0–16.0) | <0.001 |
| Creatinine, mg/dL                | 0.72 (0.62–0.82) | 0.72 (0.63–0.83) | 0.75 (0.65–0.88) | <0.001 |
| Uric acid, mg/dL                 | 4.4 (3.8–5.1)    | 4.7 (4.0–5.5)    | 5.1 (4.3–6.1)    | <0.001 |

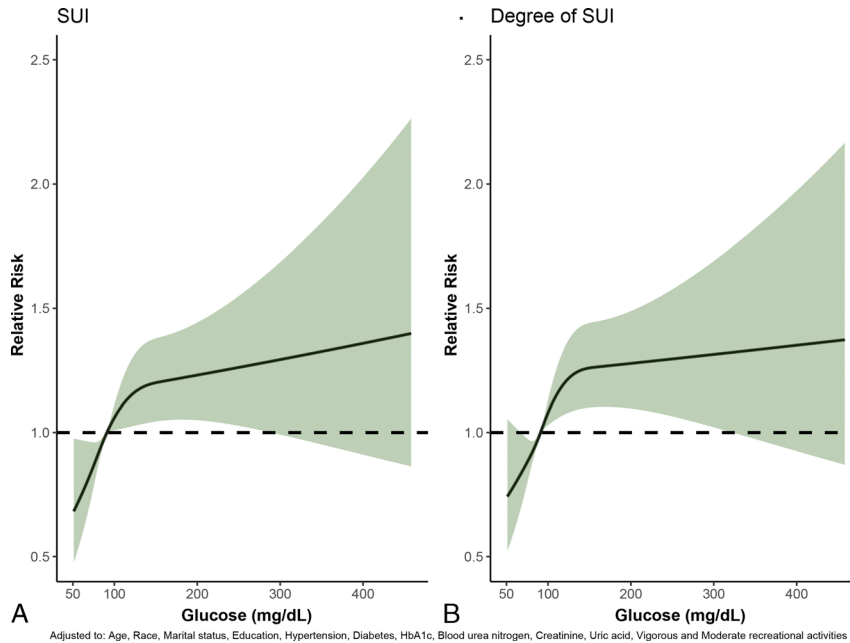
The glucose levels of the tertiles in the study population were ≤86.0 mg/dL (tertile 1), >86.0 to 98.0 mg/dL (tertile 2), and >98.0 mg/dL (tertile 3). IQR, interquartile range; SUI, stress urinary incontinence.

higher rates of SUI than other types of incontinence. Ebbesen et al<sup>26</sup> found that 28.8% of Norwegian women with diabetes mellitus had SUI. In addition, a study of overweight and obese American women found that 38% of 762 women with diabetes mellitus had urinary incontinence at least once a week.<sup>27</sup> In the

current study, more than half (637 [50.5%]) of the 1,262 diabetic participants had combined SUI.

In our study, we found a nonlinear positive association between blood glucose levels and the prevalence and frequency of SUI. A growing number of studies have confirmed that abnormal





**FIGURE 3.** Restricted cubic spline model images of blood glucose and stress urinary incontinence (SUI) prevalence and frequency. (A), SUI prevalence; (B), SUI frequency.

blood glucose levels are closely associated with the development of SUI.<sup>20,28</sup> Zhang et al<sup>29</sup> concluded that urinary incontinence complicated by diabetes mellitus is mainly associated with neuropathy and detrusor myopathy innervating the bladder, and long-term hyperglycemia leads to damage to the nerves innervating the bladder or sphincter, decreased bladder contraction, abnormal detrusor function, and decreased voiding function, which can eventually lead to urinary incontinence. The effect of diabetes mellitus on female urinary incontinence may also be due to microvascular complications. Diabetes-related microvascular damage may affect the pelvic floor muscles, leading to bladder or sphincter dysfunction, which further leads to urinary incontinence.<sup>20,30</sup> Elevated blood glucose levels may affect pelvic floor muscle function and bladder nerves, thereby increasing the incidence and extent of SUI.<sup>2</sup>

Our study also has some limitations. First, our study is a cross-sectional study based on the NHANES database and could not establish a causal relationship between blood glucose levels and SUI, and further studies need to be prospective. Second, blood glucose levels were not necessarily synchronized with the specific time of SUI reporting. Finally, the NHANES findings were based on participant self-reported data, and we were unable to obtain a complete history of SUI.

**CONCLUSIONS**

In summary, we found a nonlinear positive correlation between blood glucose levels and the prevalence and frequency of SUI in women, and higher blood glucose levels indicate a higher risk of SUI. Our findings can guide women, especially those with

**TABLE 3.** Adjusted Odds Ratios for Associations Between the Glucose Level and Prevalence or Frequency Risk of SUI in NHANES 2007 to 2016\*

| Characteristic    | Basic Model         |        | Core Model          |        | Extended Model      |       |
|-------------------|---------------------|--------|---------------------|--------|---------------------|-------|
|                   | aOR (95% CI)        | P      | aOR (95% CI)        | P      | aOR (95% CI)        | P     |
| Prevalence of SUI |                     |        |                     |        |                     |       |
| Glucose, mg/dL    |                     |        |                     |        |                     |       |
| Tertile 1         | 1.00                |        | 1.00                |        | 1.00                |       |
| Tertile 2         | 1.316 (1.197–1.448) | <0.001 | 1.110 (1.004–1.227) | 0.041  | 1.096 (0.991–1.212) | 0.073 |
| Tertile 3         | 1.715 (1.557–1.889) | <0.001 | 1.223 (1.095–1.365) | <0.001 | 1.152 (1.027–1.293) | 0.016 |
| Frequency of SUI  |                     |        |                     |        |                     |       |
| Glucose, mg/dL    |                     |        |                     |        |                     |       |
| Tertile 1         | 1.00                |        | 1.00                |        | 1.00                |       |
| Tertile 2         | 1.327 (1.208–1.458) | <0.001 | 1.108 (1.005–1.223) | <0.001 | 1.038 (0.940–1.147) | 0.448 |
| Tertile 3         | 1.800 (1.637–1.978) | <0.001 | 1.254 (1.126–1.394) | <0.001 | 1.125 (1.009–1.255) | 0.034 |

\*Adjusted covariates. Basic model: univariate analysis; core model: age, race, marital status, education, hypertension, diabetes, and vigorous and moderate recreational activities; extended model: basic model plus blood urea nitrogen, creatinine, uric acid, and HbA<sub>1c</sub>.

aOR, adjusted odds ratio; CI, confidence interval; NHANES, National Health and Nutrition Examination Survey; SUI, stress urinary incontinence.

comorbid diabetes, to better control their blood glucose to reduce the occurrence and frequency of SUI.

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