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PATHWAYS TO WELLNESS: SUPPORTING HEALTHY BEHAVIORS AFTER GESTATIONAL DIABETES

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Abstract: *Gestational diabetes mellitus (GDM) poses a significant risk factor for the development of type 2 diabetes mellitus (T2DM) in affected females. To mitigate this risk, it is crucial for individuals with GDM to maintain healthy behaviors postpartum, both for diabetes prevention and blood glucose control during pregnancy. However, challenges such as childcare responsibilities and inadequate support from the surrounding environment often hinder the continuation of health-maintaining behaviors among females with a history of GDM. This review examines the barriers faced by these individuals in sustaining healthy behaviors postpartum and explores strategies to overcome these challenges, thereby promoting long-term diabetes prevention and management.*

Keywords: *Gestational diabetes mellitus (GDM), Type 2 diabetes mellitus (T2DM), Postpartum health behaviors Diabetes prevention, Support interventions*

INTRODUCTION

Females with gestational diabetes mellitus (GDM) are a future high-risk group for type 2 diabetes (Ballamy et al., 2009). This makes it important for GDM females to continue health-maintaining behaviors to prevent diabetes during the postpartum period of childcare as well as to achieve blood glucose control during pregnancy (Aroda et al., 2015). However, it has long been reported that it is difficult for females with a history of GDM to continue health maintaining behaviors due to childcare and lack of support from the surrounding environment (Zehle et al., 2008; England et al., 2009; Koh et al., 2010; Razee et al., 2010). A randomized controlled trial of interventions aiming at improving diet, increasing physical activity, changing lifestyle, and promoting breastfeeding to prevent the onset of diabetes in females with a history of GDM has suggested that intensive lifestyle interventions by professionals have some effect on weight loss and prevention of type – 2 diabetes (Guo et al., 2016). However, the effectiveness of their interventions has been small to moderate, the sustainability of the effects of these programs has not been fully evaluated, and the optimal timing and intensity of the interventions have not been determined. In the systematic review of interventions such as diet, exercise, breastfeeding, and reminders, Miyazaki et al. (2017) noted that a combination of diet, exercise, and breastfeeding may be effective in reducing postpartum weight. But most of the evidence was subject to obscure biases and concluded that there was no strong evidence to support the hypothesis that these interventions are

effective in reducing the risk of type 2 diabetes. These findings suggest that intervention programs aimed at preventing type 2 diabetes in women with pre-existing GDM that have been practiced to date have some short-term benefits, but have yet to identify optimal intervention methods.

Furthermore, compared to study populations in Europe and the USA, whose leading cause of diabetes is increased insulin resistance due to obesity, many Japanese and others of Asian heritage are thought to have a genetic predisposition to potential insulin deficiency (Tanaka et al., 1998; Cho et al., 2012), and in Japan, it is not uncommon for GDM pregnant females to have standard or thin body appearances (Chan et al., 2009; Tanaka et al., 2014). This suggests that interventions to improve the lifestyle by losing weight may not necessarily be suitable for such GDM-afflicted Japanese. Considering the characteristics of Japanese who are prone to developing type 2 diabetes, it is very important for Japanese females with a history of GDM to undergo regular glucose tolerance testing as well as to improve their lifestyle.

A study of postpartum diabetes development rates among females with a history of GDM in Japan reported that 20% had developed diabetes by five years postpartum (Waguri, 2011), and it is important to continue health-maintaining behaviors for diabetes prevention and early detection during the childcare period of infants. In Japan, however, although there are strict guidelines for the management of GDM during pregnancy (Japan Society of Obstetrics and Gynecology, Japan Association of Obstetricians and Gynecologists, 2020), there are no available postnatal follow-up programs and postpartum health behaviors are left to the initiative of the mothers themselves. For this reason, it is necessary to develop specific support measures for promoting postpartum health maintenance behaviors appropriate for Japanese GDM females. It is meaningful to share the results of this study with international researchers since there are many Asian heritage people in Europe, the USA, and various other countries due to internationalization.

The Theory of Planned Behavior (TPB), developed to clarify the focus of interventions in the development of health behavior intervention programs, has been supported by meta-analyses for its validity (Montano and Kasprzyk, 2018). Using TPB it is possible to identify the structure of the various factors related to specific behaviors. The TPB distinguishes between “behavior,” which refers to the practice of health behavior, and “behavioral intention,” which refers to the intention to follow practices of the behavior. Behavioral intentions are defined by “attitude (thoughts about the behavior),” “subjective norms (expectations of the surroundings for the behavior),” and “perceived behavioral control (perceptions of the difficulty of the behavior). The “perceived behavioral control” is thought to have a direct influence on behaviors as well as behavioral intentions.

The study aims to build a health behavior model taking into account the characteristics of this population in order to clarify the direction of interventions needed to promote these health maintenance behaviors. In the present study, we focus on two health maintenance behaviors, healthy dietary habits and glucose tolerance testing, which are considered to be particularly important for Japanese females with a history of GDM. Developed the hypothetical model based on the TPB framework, then the model will be validated by structural analysis of covariance to clarify the factors influencing the health behaviors of females with a history of GDM, the relationship between these factors and “behavioral intentions” and “behavior,” with the aim of constructing a health behavior model based on the characteristics of the target population.

CONCEPTUAL FRAMEWORK

This study distinguished healthy dietary habits and taking a glucose tolerance test, as different health maintenance behaviors.

A conceptual framework was established as a hypothesis referring to the results of previous studies, based on the framework of the theory of planned behaviors. When using TPB, it is important to conduct qualitative research on the population being surveyed to determine the consequences of the behavior as perceived by the surveyed population and the factors that influence the behavior (Montano and Kasprzyk, 2018). In a previous study the authors conducted an interview survey with the participants using an interview guide developed based on the findings of previous studies (Zehle et al., 2008; Graco et al., 2009; Jones et al., 2009; Koh et al., 2010; Razee et al., 2010) to extract the factors affecting dietary maintenance and glucose tolerance test-taking behaviors among females with a history of GDM, and the data were qualitatively analyzed using TPB as a theoretical premise (Yamanami et al., 2023). The results showed the following factors affecting healthy dietary practices: 'Finding positive implications for healthy dietary habits' and 'Psychological burden associated with healthy dietary practices', which correspond to the "attitude" component of the TPB. Also, 'Dealing with practical challenges associated with balancing family life and healthy diets' and 'Establishing dietary habits that enable being maintained without difficulty', which comprises the specifics of the "perceived behavioral control" component of the TPB. As factors affecting taking the glucose tolerance test, we extracted 'Finding positive implications for taking the test' and the 'Psychological burden of taking the test', which correspond to "attitude" in TPB, and 'Dealing with practical challenges associated with taking the test while raising children', which is comprised of the specifics of "perceived behavioral control" component of the TPB. For the factors affecting both healthy dietary habits and glucose tolerance testing, 'Thoughts on the health of their own and family' was extracted which correspond to "attitude" in TPB, and 'Attitude of healthcare professionals toward patient diabetes risk' and 'Family understanding and support', which correspond to the "subjective norms" of TPB, were extracted. Furthermore, 'daily life where children and family are prioritized', which comprises the specifics of the "perceived behavioral control" component of the TPB. In this study, "behaviors" to maintain a healthy diet and take a glucose tolerance test, and "behavioral intentions" to enable to conduct these behaviors, were used as the objective variables. The factors affecting these health behaviors extracted in previous studies were used as explanatory variables for each health maintenance behavior (Figures 1 and 2).

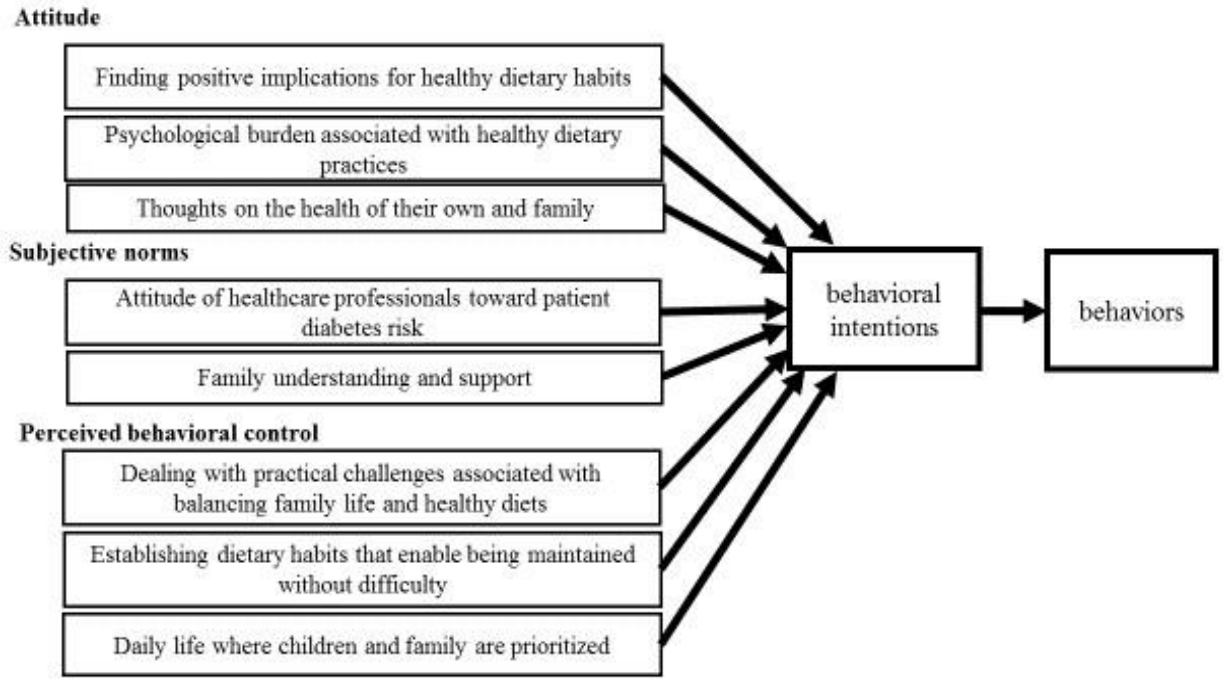

Figure 1. Conceptual framework of healthy dietary habits.

METHODS

Study design

This study is cross-sectional study with a questionnaire.

Participants

The participants in this study were females diagnosed with GDM and currently raising preschool children. Exclusion criteria were females who needed ongoing therapeutic behavior treatment other than glucose intolerance.

Study tool

Draft question items were created based on the results of a previous study by the authors that identified components of dietary and glucose tolerance test-taking behaviors (Yamanami et al., 2023). Question items to measure healthy dietary practices were developed based on a review of the Japanese literature on dietary habits of pregnant females with diabetes and abnormal glucose metabolisms (Fukui, 2018; Yahata and Honda, 2017), as well as the results related to what females with GDM actually practiced as a healthy diet in the previous study by the authors. The questions to measure healthy dietary habits consist of the following four items: “Do you devise ways of eating that prevent blood glucose levels from rising?”, “Do you include foods in your diet that prevent blood glucose levels from rising?”, “Do you eat with attention to nutritional balance?”, and “Do you avoid overeating?”

The questions to measure behavioral intentions for healthy dietary habits consist of the following four items: “Do you try to eat in a way that does not raise blood glucose levels?”, “Do you try to include foods in your diet that do not raise blood glucose levels?”, “Do you try to pay attention to balance of the nutrition in your diet?”, and "Do you try not to overeat?”. The questions about taking a glucose tolerance test were created with one item for behavioral intentions and one item for behaviors: “Do you wish to

take a diabetes test regularly (75g Oral Glucose Tolerance Test (OGTT))?" and "Do you regularly take a diabetes test (75g OGTT)?"

All questions asked the participants to answer with a five-point scale ranging from 5 as fully applicable, to 1 not applicable. For the behavior related to taking a glucose tolerance test, the option "The time for a regular checkup has not come yet" was added. The contents of the questionnaire items were discussed among the researchers and developed with the supervision of a midwife who is a certified diabetes nurse.

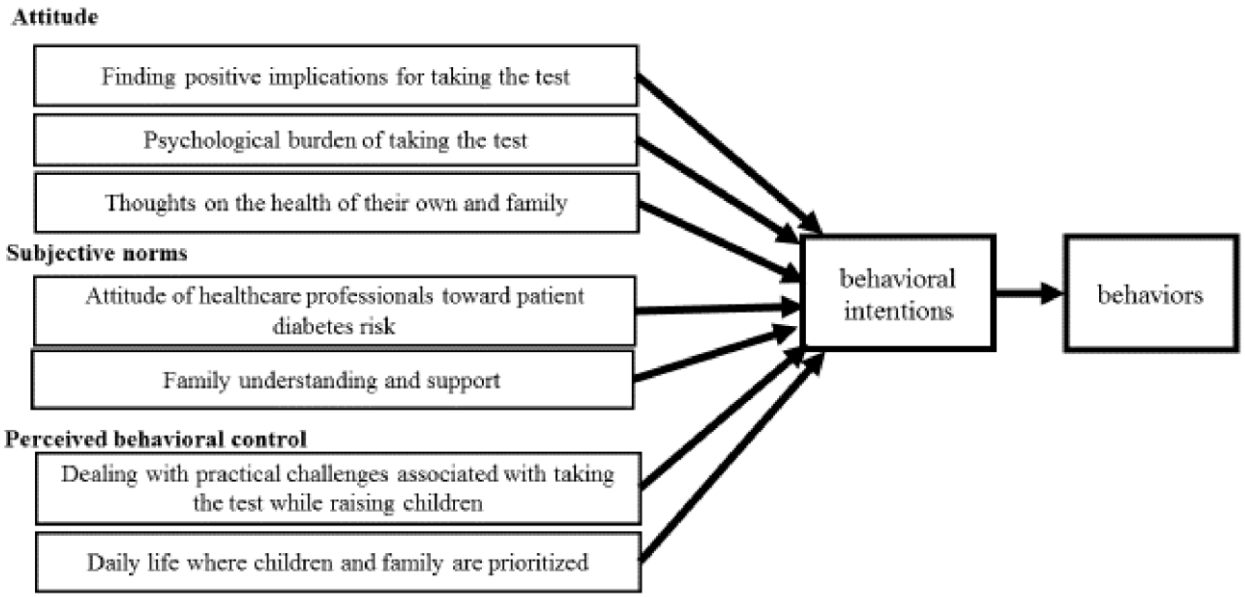

Figure 2. Conceptual framework for glucose tolerance test taking.

Data collection

Data were collected by using Google Forms. First, a preliminary survey was conducted of females with experience in childcare. We controlled for ceiling and floor effects, and excluded three items which showed a ceiling effect. Also, we performed a factor analysis to clarify the outline of the factor structure. Since the purpose of this study was to clarify the structure of influencing factors on health behavior and to examine their relevance, the number of samples required for factor analysis to analyze the structure of influencing factors was assumed to be the necessary number of samples, and a target sample size of 250 samples, which is approximately 10 times the number of items for factor analysis, was set. As for a nationwide questionnaire survey of women with previous GDM in Japan, we could not find any previous studies that could serve as a reference for the collection rate, making it difficult to make a specific estimate. We considered the acceptance of cooperation by institutions to be about 20% of the number of requests, and based on our experience in previous studies, we estimated that each facility would have about 3 to 5 participants in the study. In cases where the number of cooperating institutions was small, we increased the number of institutions to which we requested research cooperation.

Finally, we selected 400 maternal and child health departments of municipalities, 200 medical institutions with diabetes specialists, 500 nursery schools, kindergartens, and childcare center from all over Japan using a multistage sampling method and asked to cooperate in the study. We asked institutions that agreed to cooperate with the survey to display posters and distribute flyers with the

QR code for the survey page of Google Forms to recruit participants. We also requested cooperation from organizations with websites that disseminate information on pregnancy, childbirth, and child rearing, and asked them to post a banner on their websites inviting and linking to the survey page. People who visited the survey page through these were asked to answer questions, and expressed the consent to participate in the study by checking a check box on the survey page. The data collection period was from October 2019 to May 2020.

Survey item

Demographics of the participants

Demographic questions include: age, height, weight, employment status, number and age of children, family structure, who makes the family meals, number of times GDM was diagnosed, family history of DM, nutrition instruction during pregnancy, details of GDM treatment during pregnancy, whether the first postpartum glucose tolerance test was taken and the results, and feeding methods like whether breastfeeding or not.

Questions about health behavior

The participants were asked to answer 44 questions about their behavioral intentions and practices for healthy eating and glucose tolerance, as well as the factors that influence each of these health-maintaining behaviors. The explanatory variable questions included four items related to 'Finding positive implications for healthy dietary habits', and 'Psychological burden associated with healthy dietary practices', respectively, five items related to 'Dealing with practical challenges associated with balancing family life and healthy diets', and two items related to 'Establishing dietary habits that enable being maintained without difficulty', three items related to 'Finding positive implications for taking the test', two items related to 'Psychological burden of taking the test', four items related to 'Dealing with practical challenges associated with taking the test while raising children', three items related to 'Attitude of healthcare professionals toward patient diabetes risk', one item related to 'Family understanding and support', three items related to 'Thoughts on the health of their own and family' and 'Daily life where children and family are prioritized', respectively. The objective variable questions were four items measuring "behavioral intentions" of healthy dietary habits, four items measuring "behaviors," one item measuring "behavioral intentions" for taking periodic glucose tolerance tests, and one item measuring "behaviors."

Statistical analysis

We tabulated the results of survey, calculated frequencies and percentages, means, and standard deviation, and examined the ceiling and floor effects of the questions of variables affecting health behavior. For "healthy dietary habits" and "glucose tolerance test taking," we performed exploratory factor analysis to determine the factor structure of each theoretical variable. Cronbach's α coefficients for each factor obtained by the factor analysis were calculated to examine internal consistency.

Development of a health behavior model in females with a history of GDM

To develop a health behavior model for females with GDM for each of the health behaviors of "healthy dietary habits" and "glucose tolerance test taking," we performed a structural analysis of covariance using each factor extracted from the factor analysis and "behavioral intentions" and "behaviors" as observed variables. After creating the path diagram, we improved the model by referring to the modification index and goodness-of-fit index, and adopted the model with the best fit. For the

goodness-of-fit index, we used GFI (goodness-of-fit index), AGFI (adjusted goodness-of-fit index), CFI (comparative goodness-of-fit index), RMSEA (root mean square error of approximation), and AIC (Akaike's information criterion). For the statistical analysis we used IBM SPSS Statistics ver. 24 Concurrent User License and IBM SPSS Amos Graphics.

Ethics

We used anonymous questionnaires to ensure that individuals could not be identified by their responses. In addition, we clearly stated on the flyer for recruiting study participants and at the beginning of the web-based questionnaire that participation was voluntary and the respondents had the right to refuse further participation, and that they would not suffer any disadvantages by not responding. We limited the number of persons who were able to access and edit the responses to the questionnaires stored in the cloud to the principal researcher to ensure that others could not access the data. This study was conducted with the approval of the Research Ethics Committee of Ibaraki Prefectural University of Health Sciences (Approval numbers: 891, e231, e240; 2019).

RESULTS

Research cooperating facilities and participants

The facilities cooperating in the study were nine medical institutions, 41 municipalities, 21 nursery schools, kindergartens, and childcare centers, and one Web site. By the end of May 2020, 58 responses were collected. A factor analysis showed that the Kaiser-Mayer-Olkin sample validity measure was about 0.6, and we determined this to have reached the minimum number of participants for the statistical analysis. Due to the COVID-19 pandemic, most of the group health checkups for infants and childcare support events conducted by local governments were also cancelled, many people refraining from non-urgent medical visits, and nursery schools and kindergartens were often closed. Then we concluded that further recruitment of additional participants would be difficult and terminated data collection. There were no missing values in the responses, and all were treated as valid responses.

Characteristics of the participants

The mean age was 36.7 ± 5.9 and the mean number of children was 2.02 ± 0.8. The proportion of those in employment was 60.3%, and of these, 6.9% was on maternity or paternity leave. Fifty-five of the 58 participants were responsible for preparing family meals at home. The number of GDM diagnoses was 1.16 ± 0.4, with 86% of the participants having been diagnosed once. For treatment of GDM during the pregnancy, insulin was used by 44.8% (26 participants). Postpartum glucose tolerance testing was performed with 67.2% (39 patients), and 23 patients having normal results, 12 with borderline results, and 3 diabetics. The mean BMI was 24.0 ± 4.6 (Table 1). **Item and factor analysis of factors affecting health maintaining behaviors**

After converting reverse-scored items to straight items, we examined the score distributions from the mean and standard deviation of each item. Items with means ± SD above five and those below one were included in the analysis after examining the histograms and the meaning of the questions.

Healthy dietary habits

Factor structure and internal consistency of explanatory variables

We performed an exploratory factor analysis using

Promax rotation with the maximum likelihood method on a total of 24 items: four items related to 'Finding positive implications for healthy dietary habits', and 'Psychological burden associated with

healthy dietary practices', respectively, five items related to 'Dealing with practical challenges associated with balancing family life and healthy diets', and two items related to 'Establishing dietary habits that enable being maintained without difficulty , two items related to 'Attitude of healthcare professionals toward patient diabetes risk', one item related to 'Family understanding and support', three items related to 'Thoughts on the health of their own and family' and 'Daily life where children and family are prioritized', respectively. Changes in eigenvalues suggest that a six-factor structure was reasonable. Therefore, assuming six factors, we performed the factor analysis again with Promax rotation using the maximum likelihood method. Considering the interpretability of factors, we repeated the analysis several times, examined the meanings of the items with low commonality or items that did not show high loadings on any of the factors, and excluded three items. We adopted items with factor loadings above 0.40 and the maximum value, resulting in a six-factor structure consisting of 21 items.
The first factor consisted of four items related to stress caused by eating and negative feelings about eating, and it was named psychological burden presented by the eating. The second factor consisted of four items related to the sense of having enough time for oneself and the burden of childcare, and it was named Having spare time in daily life. The third factor consisted of four items, and it was named Feelings of ease about eating because of the high factor loadings of the items related to maintaining a healthy diet without any strain. The fourth factor consisted of four items related to the susceptibility to diabetes among females with a history of GDM explained by healthcare professionals and the awareness of the risk of developing diabetes, and it was named Awareness of the necessity of healthy dietary habits. The fifth factor consisted of two items related to family attitudes toward the risk of developing diabetes in females with a history of
GDM, and it was named Family understanding of postpartum healthcare. The sixth factor consisted of three items related to the effects of healthy eating and it was named Finding positive implications for healthy dietary habits. The Kaiser-Meyer-Olkin measure of sample adequacy was 0.65, and Bartlett's sphericity test was approximate $\chi 2 = 549.710$, $p < 0.001$. The Cronbach coefficient for all 21 items was 0.68, and the Cronbach's α coefficients were 0.81 for factor 1, 0.72 for factor 2, 0.74 for factor 3, 0.71 for factor 4, 0.80 for factor 5, and 0.69 for factor 6

Internal consistency in measures of behavioral intentions and behaviors

Cronbach's α coefficients were obtained for four "behavior" scale items and four "behavioral intention" scale items related to healthy dietary habits. Cronbach's α coefficients for "behavioral intentions" and "behaviors2 for healthy dietary habits were 0.69. These values are somewhat low, but it was decided to adopt them as within the acceptable range, considering the semantic content of the items.

Taking a glucose tolerance test

Factor structure and internal consistency of explanatory variables

We performed an exploratory factor analysis using Promax rotation with the maximum likelihood method on a total of 18 items: Three items related to 'Finding positive implications for taking the test', two items related to 'Psychological burden of taking the test', four items related to 'Dealing with practical challenges associated with taking the test while raising children', Two items related to 'Attitude of healthcare professionals toward patient diabetes risk', 1 items related to 'Family understanding and support', three items related to 'Thoughts on the health of their own and family' and

'Daily life where children and family are prioritized', respectively. Changes in eigenvalues suggest that a four-factor structure was reasonable, and assuming four factors, we performed the factor analysis again with Promax rotation using the maximum likelihood method. Considering the interpretability of factors, we repeated the analysis several times, examined the meanings of the items with low commonality or items that did not show high loadings on any of the factors, and excluded three items. We adopted items with factor loadings of 0.35 or more as the maximum value, resulting in a four-factor structure consisting of 15 items.

The first factor consisted of five items related to the childcare burden and time adjustment, and it was named *Adjustment of daily life to test taking*. The second factor consisted of three items related to negative feelings toward the test and it was named *psychological burden of taking the test*. The third factor consisted of three items related to the benefits of taking the glucose tolerance test, and it was named *finding positive implications for taking the test*. The fourth factor consisted of three items related to the susceptibility to diabetes among females with a history of GDM as explained by healthcare professionals and the awareness of the risk of developing diabetes, and it was named *Awareness of the necessity of taking the test*.

The Kaiser-Meyer-Olkin measure of sample adequacy was 0.65, and Bartlett's sphericity test was approximate $\chi 2 = 549.710$, $p < 0.001$. The Cronbach's α coefficient for all 15 items was 0.62, and the Cronbach's α coefficients were 0.71 for factor 1, 0.78 for factor 2, 0.70 for factor 3, and 0.66 for factor 4 (Table 3).

Table 2. Factor structure of factors affecting healthy dietary habits.

Variable				Factor 1	Factor 2	Factor 3
Think about what to eat that won't raise my blood glucose levels is stressful (R)	0.95	-0.01	-0.11	-0.09	-0.03	-0.02
feel stressed because I need to pay attention to my blood glucose levels (R)	0.83	0.10	0.31	0.01	-0.09	-0.07
Feeling depressed after eating due to concerns about elevated blood glucose levels (R)	0.68	-0.03	0.30	0.05	0.04	0.03
Worrying about my blood glucose levels makes it impossible to eat freely what I like (R)	0.58	-0.07	-0.19	-0.08	0.17	0.03
Factor 2: Having spare time in daily life I try to have	0.14	-0.74	-0.02	0.18	0.04	-0.12

my own time.						
Heavy burden of housework and childcare on me (R)	0.08	0.68	0.13	-0.04	-0.27	-0.09
don't have the time to preparing healthy meals that do not raise blood glucose levels (R)	0.06	0.61	-0.09	0.08	0.10	-0.02
My children need much care (R)	-0.01	0.55	-0.08	0.16	0.14	-0.06
Factor 3: Feelings of ease about eating						
keep on a diet that does not raise blood glucose levels as best I can	0.10	0.04	0.93	-0.04	0.04	0.02
naturally eat a diet that does not raise my blood glucose levels	0.05	-0.14	0.70	0.02	0.04	-0.07
I'm not mentally able to prepare healthy meals that do not raise blood glucose levels (R)	0.37	0.37	-0.48	0.01	-0.02	-0.02
like cooking	0.09	0.05	0.44	-0.14	-0.08	0.12
Factor 4: Awareness of the necessity of healthy dietary habits						
My healthcare professionals told me that I was prone to diabetes and that I should be careful not to get diabetes	0.02	0.12	-0.09	0.79	-0.14	-0.14
think I am prone to diabetes	0.17	-0.19	-0.01	0.74	-0.05	-0.03
have been advised by my healthcare professionals to continue eating a diet that will not raise my blood glucose levels after childbirth	-0.35	0.27	-0.22	0.58	-0.06	0.08
worry about my blood glucose levels	-0.15	-0.24	0.11	0.48	0.20	0.23
Factor 5: Family understanding of postpartum healthcare My family cares about my dietary habits	0.03	-0.06	-0.12	-0.11	1.05	-0.08
My family is supportive of my diabetes prevention	-0.12	0.08	0.22	-0.07	0.65	0.06
Factor 6: Finding positive implications for healthy dietary habits						
believe that a diet that does not raise my blood glucose levels will have a positive effect on my weight control	-0.07	0.07	-0.09	-0.19	-0.09	1.03
believe that a diet that does not raise my blood glucose levels will have a positive impact on my family's health	0.07	-0.04	0.10	0.05	0.05	0.52

believe that my diabetes can be prevented by eating a diet that does not raise blood sugar levels	0.17	-0.04	0.15	0.36	0.00	0.45
Factor correlation	1.00	0.42	-0.24	0.20	-0.01	0.21
		1.00	-0.22	0.12	-0.22	0.15
			1.00	0.28	0.23	0.10

Factor 1: Psychological burden toward eating

Table 2. Contd.

Extraction: Maximum likelihood, Rotation: Promax rotation, KMO measure of sampling adequacy: 0.60; R = reversal items; α = 0.68; (n = 58).

Table 3. Factor structure of factors affecting taking a glucose tolerance test.

Factor 1: Adjustment of daily life to test taking				
Heavy burden of housework and childcare for me (R)	0.88	-0.13	0.13	0.03
My children need much care (R)	0.71	-0.11	-0.03	-0.11
I try to have my own time	0.61	0.04	-0.02	0.18
I don't have the time to go to taking a glucose tolerance test (75 g OGTT) (R)	0.42	0.34	-0.05	0.01
I have a place to leave my child when I have to run errands	0.38	0.30	-0.02	0.09
Factor 2: Psychological burden of taking the test				
I'm not motivated to taking a glucose tolerance test (75g OGTT) (R)	-0.04	0.80	0.05	-0.06
I find it painful to take a glucose tolerance test (75 g OGTT) (R)	-0.15	0.79	0.11	0.02
I feel stressed because I need to pay attention to my blood glucose level (R)	0.16	0.48	-0.10	-0.12
Reliability coefficient (Cronbach's α)	0.81	0.72	0.74	0.71
Factor 3: Finding positive implications for taking the test				
I think taking a glucose tolerance test (75 g OGTT) will increase my awareness of my own diabetes prevention	0.07	-0.01	0.99	0.00
I believe that by taking a glucose tolerance test (75 g OGTT), treatment of diabetes can be started earlier	-0.03	0.25	0.68	0.16
Taking a glucose tolerance test (75 g OGTT) provides relief that I don't have diabetes	0.01	-0.10	0.61	-0.24
Factor 4: Awareness of the necessity of taking the test				
I think I am prone to diabetes	-0.06	-0.05	-0.09	0.81
My healthcare professionals told me that I was prone to diabetes and that I should be careful not to get diabetes.	0.13	0.12	-0.07	0.74
I worry about my blood glucose levels	-0.13	-0.30	0.16	0.46

	1.00	0.18	0.26	0.80
		1.00	0.20	0.69
			1.00	

I have been advised by my healthcare professionals to regularly take a diabetes test (75 g OGTT)	0.11	-0.12	0.04	0.36
Factor correlation	1.00	0.39	0.06	-0.17
		1.00	-0.08	-0.22
			1.00	0.10
				1.00
Reliability coefficient (Cronbach's α)	0.71	0.78	0.70	0.66

Variable	Factor 1	Factor 2	Factor 3	Factor 4

Extraction: Maximum likelihood, Rotation: Promax rotation, KMO measure of sampling adequacy: 0.60; R = reversal items; α = 0.62; (n = 58)

Table 4. Scores of factors affecting healthy dietary habit.

Factor	Factor name	Mean	SD
1	Psychological burden toward eating	3.62	1.04
2	Having spare time in daily life	2.25	0.90
3	Feelings of ease about eating	2.65	0.97
4	Awareness of the necessity of taking the test	3.52	0.98
5	Family understanding of postpartum healthcare	2.69	1.23
6	Finding positive implications for healthy dietary habits	4.28	0.72

Table 5. Scores of factors affecting glucose tolerance test taking.

Factor	Factor name	Mean	SD
1	Adjustment of daily life to test taking	2.53	0.86
2	Psychological burden of taking the test	3.59	1.11
3	Finding positive implications for taking the test	4.20	0.83
4	Awareness of the necessity of taking the test	3.82	0.97

Table 6. Scores of "behavioral intentions" and "behaviors" of healthy dietary habits.

Variable	Mean	SD
Healthy dietary habits "Behavioral Intentions"	3.85	0.79
Healthy dietary habits "Behaviors"	3.17	0.89

Table 7. Scores of "behavioral intentions" and "behaviors" for taking the glucose tolerance test.

Variable	Mean	SD
Taking the glucose tolerance test "Behavioral Intentions"	3.03	1.47
Taking the glucose tolerance test "Behaviors"	1.57	1.12

Subscale analysis

For the six factors of healthy dietary habits (Table 4) and the four factors of regular glucose tolerance test taking (Table 5) extracted by the factor analysis, we calculated the mean scores of the items comprising each factor and the mean scores of the four "behavioral intention" and four "behavior" items regarding healthy dietary habits, and used these as subscale scores (Table 6). Because the first factor affecting the healthy dietary habits and the second factor affecting the regular glucose tolerance test taking were comprised of reverse-scored items alone, we used the unprocessed mean scores so that the higher the burden, the higher the score, to fit the meaning of the names. For the "behaviors" and "behavioral intentions" of the regular glucose tolerance test taking, we used a score of "Do you wish to take a diabetes test regularly (75g OGTT)?" and a score of "Do you regularly take a diabetes test (75g OGTT)?" as the scale of the score (Table 7).

Health behavior model for healthy dietary habits

We used a total of 58 samples for the analysis. *Feelings of ease about eating* was significant at 0.01% for both "behavioral intentions" and "behaviors, with a path coefficient for "behavioral intentions" of 0.57 ($p < 0.001$) and for "behaviors" of 0.46 ($p < 0.001$). Other "behavioral intention" items with significance were *Finding positive implications for healthy dietary habits* (path coefficient 0.28, $p = 0.005$), *having spare time in daily life* (path coefficient 0.29, $p < 0.01$), and *Family understanding of postpartum healthcare* (path coefficient 0.19, $p = 0.004$).

The path to "behavioral intentions" was not significant for *Awareness of the necessity of healthy dietary habits* ($p = 0.050$), but significance estimates were found for the paths to *psychological burden presented by the eating* (path coefficient 0.25, $p = 0.048$) and to *Finding positive implications for healthy dietary habits* (path coefficient 0.27, $p = 0.045$). The path coefficient from "behavior intentions" to "behaviors" was 0.46, $p < 0.001$. The coefficients of determination for "behavioral intentions" and "behaviors" in this model were 0.49 and 0.63, respectively. The goodness-of-fit index for the model was CMIN = 10.935, p = 0.683, GFI = 0.955, AGFI = 0.900, CFI = 1.000, RMSEA = 0.000, AIC = 50.935, indicating that the model fits the data (Figure 3).

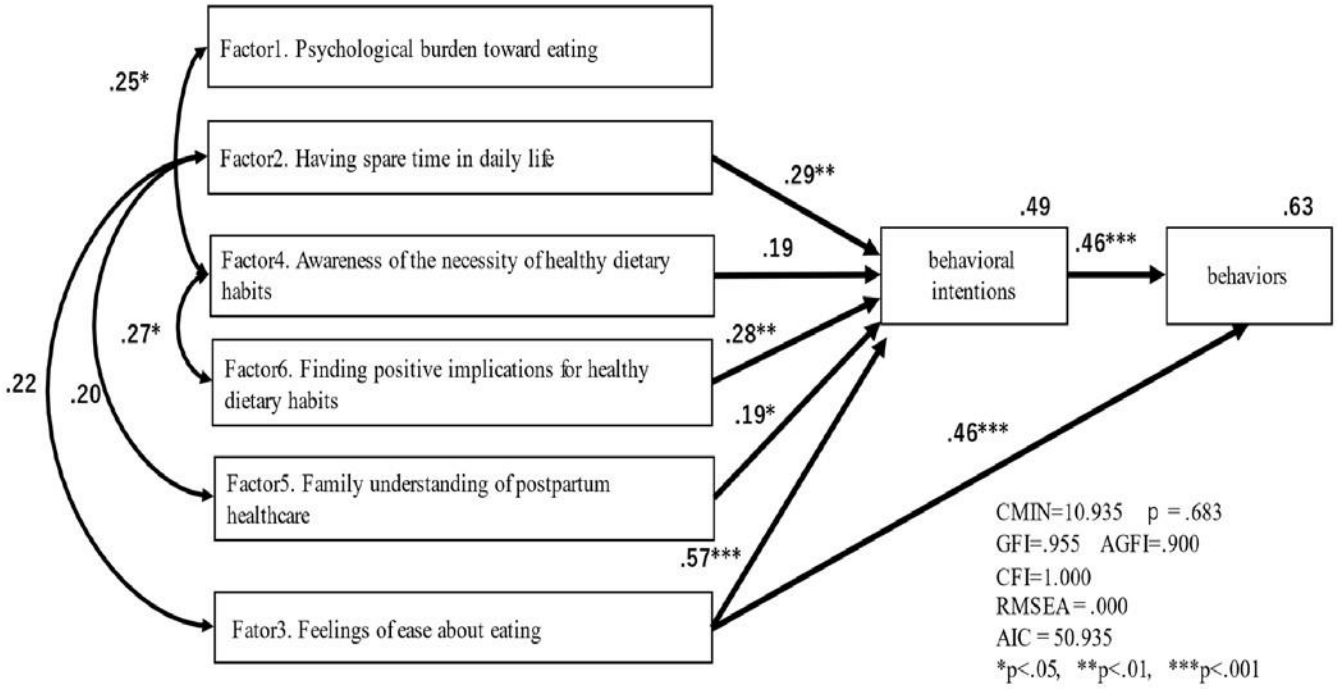

Figure 3. Health behavior model of healthy dietary habits.

Health behavior model for glucose tolerance test taking

Excluding seven samples that chose the answer option "The time for a regular checkup has not come yet" for the question "Do you regularly take a diabetes test (75 g OGTT)?", 51 samples were included in the analysis. Factors that had significant estimates on the path to "behavioral intentions" were *Awareness of the necessity of taking the test* (path coefficient 0.47, $p < 0.001$), *Finding positive implications for taking the test* (path coefficient 0.25, $p = 0.033$), and *psychological burden of taking the test* (path coefficient -0.29, $p = 0.030$).

The path from *Adjustment of daily life to test taking* to "behavioral intentions" had no significant influence, but a significant path coefficient of -0.34, $p = 0.019$ was obtained for the path between *Adjustment of daily life for test taking* and *psychological burden of taking the test*. "Behavioral intentions" alone had a significant path to "behaviors" with a path coefficient of 0.29, $p = 0.042$. The coefficients of determination for "behavioral intentions" and "behaviors" in this model were 0.29 and 0.21, respectively. The goodness-of-fit index for the model was CMIN = 2.164, $p = 0.950$, GFI = 0.986, AGFI = 0.959, CFI = 1.000, RMSEA = 0.000, and AIC = 30.164, indicating that the model fits the data (Figure 4).

DISCUSSION

Characteristics of participants

The mean age of the participants in this study was 36.7 ± 5.9 years. In previous Japanese studies on the clinical profile of pregnant females with GDM (Iida et al., 2016; Yanagisawa et al., 2016), the mean age at delivery was in the early 30s ± 5. Given that this present study focused on GDM in females within a few years of childbirth, the mean age of the participants may be comparable to the average age structure of the population. For employment, data from the Gender Equality Bureau of the Cabinet Office (2018) show that only about 40% of females continue employment after the first childbirth, while

60% of the participants in this study were employed. This may be due to the fact that many of the responses in this study were obtained through day-care centers, and may explain the lower scores on the scales of *Having spare time in daily life* and *Adjustment of daily life to test taking*.

For glucose tolerance, 62.1% of the study participants had a family history of DM and 44.8% used insulin during pregnancy. In the previous studies on the clinical profile of GDM females (Iida et al., 2016; Yanagisawa et al., 2016), a family history of DM was less than half of the subjects and insulin use during pregnancy was about 30-40% of the subjects; compared to the previous studies, a higher percentage of the participants in the study had a family history of DM and had used insulin. Morrison et al. (2010) reported that factors related to higher awareness of risk for DM in GDM females were a family history of DM, insulin use during pregnancy, and BMI 25. Also, more than 50% of the participants in the present study who had experienced postpartum glucose tolerance testing indicated that they were at a borderline-diabetes level. This suggests that the participants may have been a population that has slightly more aware of their own DM risk than the general population of GDM females.

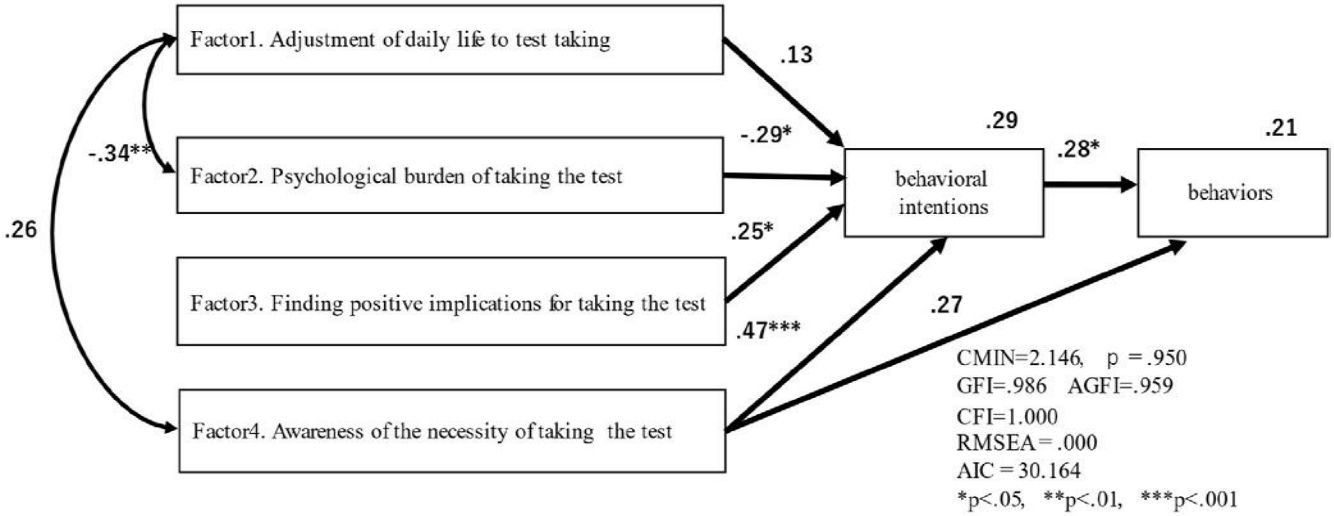

Figure 4. Health behavior model of glucose tolerance test taking.

Structure of the health behavior model in females with a history of GDM

The study identified the factors affecting two health behaviors, healthy dietary habits and glucose tolerance testing, and the strength of the influence of these factors on the behaviors.

Structure of the health behavior model in healthy dietary habits

We believe that the model of the healthy dietary habits can be evaluated as a model that yields adequate goodness-of-fit indices and reflects the commitment of the study participants to healthy behaviors. In this study, the factor most influential on "behavioral intentions" was *Feelings of ease about eating*, followed by *having spare time in daily life*. The *Feelings of ease about eating* affected "behaviors" to the same degree as the influence from "behavioral intentions" to "behaviors" and may be considered an important factor for healthy dietary practices among females with a history of GDM.

Many of the participants in this study were in charge of preparing meals for their families at home. For this reason, it can be inferred that healthy eating habits may be affected by whether these participants have spare time to prepare healthy meals and whether they have relaxed feelings to continue healthy

eating habits without difficulty in their busy schedules. Zehle et al. (2008) reported that postpartum healthy eating among females with a history of GDM was related to self-efficacy to be able to prepare meals, but was also influenced by family preferences and time constraints on preparing healthy meals. Time availability and family understanding also influenced behavioral intentions in the participants in the present study. This result supports the report by Zehle et al. However, the key influencing factor in the present model, *Feelings of ease about eating*, is slightly different from self-efficacy, which is defined as "confidence in one's ability to do it well," because the *Feelings of ease about eating* is related to "doing something naturally not out of sense of duty" and not being bothered by it. Honjo (2010) stated that in the process of creating the Self-Care Capacity Assessment Questionnaire (SCAQ), Japanese participants overwhelmingly used the expression "become" more often than "do" and often described themselves as "naturally able" with regard to self-care. The *Feelings of ease about eating* may reflect such cultural characteristics of the Japanese, and we think that the results indicate that this study has provided indexes for understanding the health maintenance behaviors of Japanese females with GDM.

Structure of the health behavior model in glucose tolerance test taking

The model of the taking periodic glucose tolerance tests yielded adequate goodness-of-fit indices. Therefore, it may be stated that the model reflects the efforts of the participants to achieve healthy behaviors. In this study, the most important factor was *Awareness of the necessity of taking the test*. Barriers to regular postpartum follow-up of females with GDM are an issue in the health care system of Japan, for reasons such as lack of staff for this population at medical facilities, lack of standardized care protocols, and problems with healthcare costs, and healthcare collaboration conditions. Also, other personal barriers such as lack of information, education, and family and workplace support are also reported (Nielsen et al., 2014). *Adjustment of daily life to test taking* in this study may represent factors affecting the health behaviors of females with a history of GDM in the childcare stage. Such factors include the high burden of housework and childcare, and the availability of people and services to take care of their children when they need to do everyday chores. However, in the model, *Adjustment of daily life to test taking* had no significant influence on "behavioral intentions" or "behaviors."

The mean score of items in "behaviors" of the glucose tolerance test was very low (1.57 ± 1.1) in this study. Together, the data from the sample in this study that underwent glucose tolerance testing was small, and this makes it difficult to clarify the factors affecting the behaviors. Further studies are needed to examine the factors that affect the "behaviors" of females with GDM and improve the accuracy of the model, by increasing the sample size of females with a history of GDM who continue to be followed up at medical institutions.

Support for promoting health maintenance behaviors for females with a history of GDM

Assistance in maintaining healthy dietary habits

Feelings of ease about eating and *having spare time in daily life* both had a significant influence on healthy dietary habits. However, these were also the two items with the lowest scores on the subscale, suggesting that females with GDM raising children do not have enough time and opportunity to relax in their daily lives. This suggests that it is often difficult for females with GDM raising children to achieve their behavioral intentions toward healthy dietary habits. Takahashi (2005) reported that although the presence of children can be an obstacle to changes in lifestyle, the presence of children

does not mean that lifestyles cannot be changed, and that it is important to take the time together with healthcare professionals to find areas that can be changed, even in the presence of the children. The results of the analysis of this study suggest the usefulness of time management in daily life and clarifying the viewpoints of whether a healthy diet can be practiced without difficulty when assessing the dietary habits of females with GDM raising children.

The results of this study showed that *Awareness of the necessity of healthy dietary habits* did not have a significant direct effect on behavioral intentions, although communicating the need for the healthy behavior is considered to be important in health education. However, *Awareness of the necessity of healthy dietary habits* had significant relationships with *Finding positive implications for healthy dietary habits* and the *psychological burden presented by the eating*. Also, *finding positive implications for healthy dietary habits* had a significant path coefficient toward behavioral intentions. Increasing *Awareness of the necessity of healthy dietary habits* may indirectly increase the behavioral intentions for healthy dietary habits, but it is also related to the *psychological burden presented by the eating*. In the model, there was no relationship between *psychological burden presented by the eating* and health behaviors, and the psychological burden was not a clear inhibitor of health behaviors. However, feeling psychologically burdened by meals that are repeated in daily life is not desirable from the perspective of postpartum mental health. These relationships suggest that it is important for healthcare professionals to place importance on specific dietary methods that would reduce any sense of burden on postpartum females with GDM when communicating the need for healthy dietary habits.

Support for periodic glucose tolerance testing

The most influential factor on taking the glucose tolerance tests was behavioral intentions, and the factor affecting behavioral intentions most was *Awareness of the necessity of taking the test*, which consisted of the explanation or advice from the healthcare professionals as well as the awareness of the own diabetes risk. A previous study conducted in Japan suggests that postpartum follow-ups for females with a history of GDM often lack clear instructions from medical facilities (Arata et al., 2014). However, since many of the participants in this study were insulin users during pregnancy and more than half were diagnosed as borderline-diabetic at postpartum glucose tolerance testing, it is possible that the *Awareness of the necessity of taking the test* was increased by clear instructions from healthcare professionals to take pediatric postpartum checkups. The awareness of the necessity of taking the test was the most important explanatory variable for behavioral intentions. This suggests that test-taking behavior can be promoted by clearly communicating the meaning and necessity of taking regular glucose tolerance tests also after childbirth, and explaining the specific timing and method of taking the test. In the model, *Adjustment of daily life to test taking* had no significant influence on "behavioral intentions" or "behaviors," but this factor had a significant negative relationship with *psychological burden of taking the test*, and then this psychological burden had a significant negative influence on behavioral intentions. These relationships show that females in an environment where it is difficult to adjust their lives to enable the test taking may have an increased feeling of a burden due to the test taking or a heavier psychological burden toward the test, which may make them more reluctant to adjust their lives for the test taking. The findings suggest that test-taking

behavior can be eased along by increasing opportunities for females with a history of GDM to receive medical examinations while raising children if nurses actively intervene during outpatient visits and infant health checkups at health centers and medical institutions. Through such opportunities healthcare professionals can provide consultation and education on specific lifestyle adjustments for this population.

Limitations

In Japan, it was difficult to find and identify females with a history of GDM because they become less focused on life issues after childbirth, and because the survey was conducted during the COVID-19 pandemic, it was impossible to obtain a sufficiently unbiased sample. Therefore, there are limitations in generalizing the results of this study. It will be a challenge to improve the model through further validation with a larger sample size, leading to specific intervention programs in the future.

Conclusions

In this study, we focused on "healthy dietary habits" and "periodic glucose tolerance test taking" among the health maintaining behaviors of females with a history of GDM, and built a health behavior model for females with a history of GDM, based on the framework of TPB. In the healthy eating behavior model, *Feelings of ease about eating*, *Having spare time in daily life*, *finding positive implications for healthy dietary habits*, and *Family understanding of postpartum healthcare* affected "behavioral intentions." The factors that affected "behaviors" included "behavioral intentions" and *Feelings of ease about eating*. In the health behavior model for periodic glucose tolerance testing, *Awareness of the necessity of taking the test*, *finding positive implications for taking the test*, and the *psychological burden of taking the test* affected "behavioral intentions." "Behavior" was also affected by "behavioral intentions," but the degree of influence was weak. Because other factors may strongly affect the test taking behavior, showing the need for further studies to verify the relationships. By adapting the framework of the TPB to the health behavior model of this population, cognitive and environmental factors that affect health maintaining behaviors were extracted, and viewpoints of intervention for promoting health maintaining behavior were found.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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