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ORIGINAL RESEARCH

Factors Influencing Psychological Insulin Resistance Among Patients with Type 2 Diabetes in China: A Structural Equation Model Analysis

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Purpose: Psychological insulin resistance (PIR) seriously impairs compliance and satisfaction with insulin therapy in patients with type 2 diabetes (T2D). This study aimed to build a structural equation model (SEM) to investigate factors influencing PIR in patients with T2D and the interactions between them.

Patients and Methods: A cross-sectional study was conducted with 289 patients with T2D at the endocrinology department of the First Affiliated Hospital of Anhui Medical University in China between March and September 2023. Demographic characteristics, self-efficacy (SE), social support (SS), diabetes distress (DD), diabetes stigma (DS), and PIR were evaluated using questionnaires, and the pathways were validated by SEM.

Results: The participants had an average PIR score of 56.74 (standard deviation: 11.44). The final model fit well (CMIN/DF = 1.564, GFI = 0.960, AGFI = 0.933, RMSEA = 0.044, NFI = 0.948, TLI = 0.972, IFI = 0.981, CFI = 0.980). In patients with T2D, SE ($\beta = -0.610$, $P < 0.001$), DD ($\beta = 0.613$, $P < 0.01$), SS ($\beta = -0.386$, $P = 0.001$), and DS ($\beta = 0.284$, $P = 0.001$) were significantly associated with PIR.

Conclusion: The PIR scores of patients with T2D were moderate in this study. PIR was linked to SE, SS, DD, and DS in patients with T2D. Among T2D patients, greater SE and lower DD were linked to lower PIR. The direct and indirect correlations between the structural variables in this study offer a good basis for the creation of focused interventions that lower PIR levels.

Keywords: psychological insulin resistance, self-efficacy, structural equation model, social support, diabetes distress, diabetes stigma

Introduction

Diabetes is one of the most common chronic diseases, affecting people of all ages worldwide. According to the latest data for 2021 released by the International Diabetes Federation, there were approximately 537 million cases of diabetes worldwide; 140 million of these were in China, with type 2 diabetes (T2D) accounting for more than 90%, ranking first in the world.[1] Patients with T2D require long-term medication to maintain stable blood glucose control; however, as T2D worsens, insulin production gradually declines, and insulin therapy becomes a major cornerstone of treatment.[2] Although insulin therapy has health benefits, many patients fail to initiate appropriate intensive insulin therapy in time due to various reasons, including weight gain, the need for education, titration for optimal efficacy, the risk of hypoglycaemia, the necessity of regular glucose monitoring, and the expense of insulin therapy.[3,4]

Psychological insulin resistance (PIR) is the term used to describe a patient's reluctance to initiate insulin therapy.[5] The negative effects of PIR are complex and multi-dimensional, involving multiple aspects such as psychology, behavior, and clinical outcomes. PIR may cause the best time for patients with T2D to begin insulin therapy to be missed, as well as affect compliance and satisfaction.[6] Previous studies have shown that even in the presence of diabetes-related

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complications, 50% of patients who fail to control their blood glucose with oral hypoglycemic drugs only start insulin therapy after a delay of nearly 5 years due to PIR.[7] Likewise, a study in South Korea showed that due to the impact of RIP, the insulin refusal rate reached 37.5%, and patients in the refusal group had a longer disease duration, more comorbidities, and greater difficulty in maintaining stable blood glucose control.[8] PIR plays a crucial role in blood glucose control. Poor blood glucose control may reduce patients' ability to engage in important activities and actions, lower their treatment confidence, and affect their mental health, ultimately leading to a vicious cycle that impacts various aspects of their quality of life.[9] Therefore, it is necessary to explore the influencing factors of PIR in patients with T2D in order to take targeted measures to reduce the incidence of PIR.

Diabetes stigma (DS) usually refers to the negative emotional experience of DM patients, including labelling, stereotypes, separation, loss of status, and differential treatment.[10] Stigmatisation is a risk factor for PIR, caused primarily by the lack of private injection areas, and may lead to injections being too early or omitted, which may affect treatment compliance.[9,11]

Diabetes distress (DD) mostly consists of distress related to lifestyle changes, heightened emotional burden, medical care, and interpersonal communication.[12] Besides increasing the psychological pressure of patients, DD also leads to a decline in the ability of T2D patients to manage their diseases on their own, especially concerns and refusals regarding insulin use, namely PIR, which has an impact on blood glucose regulation.[13] Furthermore, previous studies displayed that through experiential avoidance,[14] Among patients with T2D, DD has a positive alleviating effect on DS in patients with T2D; that is, a high level of DD is associated with a high level of DS.[15] From another perspective, a study found that DS may also aggravate DD by reducing self-care, self-efficacy and increasing perceived burden.[16] Relevant evidence indicates a close connection between DD and DS. An increase in DD may intensify the perception of DS, and DS would also be magnified over time due to DD.

The belief that one can impact events and subsequently modify conduct is known as self-efficacy (SE).[17] Based on the evidence, SE is an invaluable resource for predicting intention and behaviour related to diabetic self-management, which in turn helps patients adhere to their treatment plans and medication schedules.[18] Research indicates that there may be a relationship between DD and SE, indicating that high SE is a major protective factor against DD and may be able to predict low DD in individuals with T2D.[19,20] SE may be able to alleviate the stigma associated with patients by modulating DD, which in turn lowers PIR.

Social support (SS) is a multifaceted framework that encompasses informational, instrumental, and emotional support.[21] According to a study of low-income individuals with T2D, low satisfaction with SS was linked to severe DD compared to moderate to high satisfaction.[22] A study has shown that high levels of SS can help patients with T2D live an active life, which reduces their PIR.[23]

The majority of earlier research on patients with T2D only described the direct relationship between several variables and PIR. Only the direct correlation between various variables and PIR can be evaluated through correlation or regression methods. However, observing indirect effects can provide us with a new perspective on how these different influencing factors interact with each other, better helping prevent PIR. Overall, the directionality and magnitude of some relationships remain uncertain and rarely adjust for socio-economic confounders. To the best of our knowledge, this study is the first to utilise a structural equation model (SEM) to explore the pathways between DS, DD, SE, SS, and PIR in patients with T2D, as well as the direct and indirect effects between variables. The results provide a theoretical basis and intervention strategies to improve PIR in patients with T2D.

Materials and Methods

Study Design and Participants

This study employed a cross-sectional design. In accordance with the STROBE guidelines, convenience sampling was used to select outpatients and inpatients in the Department of Endocrinology of the First Affiliated Hospital of Anhui Medical University (a comprehensive Grade 3A hospital in Hefei, Anhui Province, China) between March and September 2023. The inclusion criteria were age ≥ 18 years old, diagnosed with T2D, willing to give written informed consent, and no mental illness or cognitive impairment. Based on the sampling calculation method of the structural

equation model, the study's sample size should be at least 10 observations per free parameter in the model, or more than 200 cases.[24] This research was conducted in accordance with the principles of the Declaration of Helsinki. The Ethics Committee of the First Affiliated Hospital of Anhui Medical University granted consent for this study (approval No. 84230040).

Measurements

Demographic Characteristics

The survey encompassed both general demographic data such as age, sex, residence, educational attainment, marital status, employment status, monthly income, and medical insurance payment, as well as disease-specific data such as duration of diabetes, family history of diabetes, therapeutic method, diabetes-related education, comorbidities, and complications. In this study, the duration of diabetes was measured in years, referring to the period from the first clinical diagnosis of T2D to the date of the survey. The therapeutic method included none, oral hypoglycemic agents (OHA), injection of insulin, or OHA plus injection of insulin.

Insulin Treatment Appraisal Scale (ITAS)

The ITAS was developed by Snoek et al to assess the appraisal of insulin therapy in patients with T2D.[25] The scale was fully translated into Chinese by Chen et al, which showed good internal consistency and satisfactory validity in the Chinese population.[26] The ITAS consists of two dimensions: Positive Attitude (PA) and Negative Attitude (NA), with a total of 20 items. It is scored using the Likert 5-point method, ranging from 1 (strongly oppose) to 5 (strongly agree). The four positive items scores were reversed when calculating the overall score, ranging from 20 to 100. A higher total score correlated with a more negative evaluation of insulin therapy. The Cronbach's alpha coefficient of ITAS was 0.86 in this study.

Self-Efficacy for Diabetes Scale (SED)

The SED, created by Lorig et al, aims to assess self-efficacy in diabetic patients.[27] It was translated into Chinese by Sun et al, with good reliability and validity.[28] 8 items in total were rated on a 10-point response scale from 1 (not at all confident) to 10 (totally confident). The average of the evaluated items determined the final score, ranging from 1 to 10 points, and high scores indicate a high level of self-efficacy. In this study, Cronbach's α reliability coefficient was found to be 0.98.

Social Support Rating Scale (SSRS)

The SSRS was developed and validated by Xiao, a Chinese researcher, and has been widely used among the Chinese population.[29] The scale has been proved to have good reliability and validity in patients with T2D.[30] The scale consisted of 10 items composed of three dimensions: objective support (OS), subjective support (SubS), and utilisation of support (US). The total score was the sum of all items and represented the level of social support. The SSRS yielded a total score ranging from 12 to 66 points; scores $\leq$ 22, 23−44, and 45−66 were classified as low, moderate, and high levels of perceived social support, respectively.[31] The Cronbach's alpha for this research scale was 0.86.

Diabetes Distress Scale (DDS)

The DDS was developed by Polonsky et al in 2005 to assess diabetes-related distress.[12] And then Yang and Liu translated it into Chinese and reported Cronbach's alphas and test-retest reliability.[32] The 17-item measure was divided into four categories: emotional burden (EB), interpersonal distress (ID), regimen distress (RD), and physician distress (PD). Distress experienced during the previous month was measured on a 6-point Likert scale, with 1 representing no distress and 6 representing severe distress, ranging from 17 to 102 points. Using the item mean as the cutoff, < 2 were classified as indicating little or no distress, 2−2.9 as moderate distress, and ≥ 3 as high distress.[33] The Cronbach's alpha for this research scale was 0.91.

Stigma Scale for Chronic Illness (SSCI)

The SSCI was created by Rao et al in 2009 to assess stigma in patients with chronic diseases.[34] And the scale was translated into Chinese by Lu et al, showed good internal consistency and convergent validity.[35] The scale consisted of 24

items composed of two dimensions: internalized stigma (IS) and enacted stigma (ES). The score ranged from 24 to 120 points, with 1 representing never and 5 representing always. The higher the score, the higher the level of stigma. The Cronbach's alpha for this research scale was 0.87.

Data Collection

Two skilled investigators collected face-to-face data. Face-to-face data collection was standardized in three steps: (1) pre-collection—participants received standardised instructions, provided informed consent, and were explicitly assured of anonymity and confidentiality; (2) during collection—participants self-completed the questionnaire; clarifications, when requested, were given verbatim from a neutral script. For illiterate or visually impaired individuals, items were read aloud verbatim without prompting, and responses were transcribed exactly; (3) post-collection—each questionnaire was immediately screened for completeness, and any missing data were rectified on site. And the questionnaires were sealed in opaque envelopes. Before the official survey, a pre-survey was conducted to identify potential issues and evaluate the reliability of the scales. Participants were given standardised instructions that helped them overcome their reading challenges, and the goals of the study were explained. Each participant signed an informed consent form and completed the questionnaire anonymously.

Statistical Analysis

All data were independently entered and coded by two researchers using Epidata 3.1. Statistical descriptions, reliability analyses, and correlation analyses were performed utilizing SPSS 26.0. Means and standard deviations were used to convey continuous data, whereas the frequencies and percentages were used to express categorical data. Univariate analysis was conducted using independent sample t-tests and one-way analysis of variance. Pearson's correlation coefficient was used to show the association between two variables. Significant factors associated with PIR were included in multiple linear regression analysis for further analysis.

PIR, SS, DD, and DS were regarded as latent variables, whereas SE and the linked dimensions of the latent variables were considered observable variables. An SEM was constructed using AMOS 24.0 to determine the total, indirect, and direct effects among the variables. The overall fitness of the model was assessed using the model-fit indices, which includes CMIN/DF, root mean square error of approximation (RMSEA), comparative fit index (CFI), goodness-of-fit index (GFI), adjusted goodness-of-fit index (AGFI), normed fit index (NFI), Tucker-Lewis Index (TLI), and incremental fitting index (IFI). The effects and significance of statistical results among various variables were evaluated using the bootstrap bias-corrected percentile method. A total of 5000 repeated samples were selected to test whether the mediating effect was significant (95% confidence interval does not include zero). Statistical significance was defined as a P value < 0.05.

Results

Basic Participant Characteristics

A total of 306 qualified patients were surveyed, of which 17 questionnaires were excluded due to an inability to complete or invalid answers; the overall response rate was 94.4%. The respondents' characteristics are presented in Table 1. The

Table 1 Baseline Characteristics and Differences in PIR Level (n=289)

Characteristics	Categories	N (%)	Mean (SD)	t or *F* (*P*)
Age (years)	18~40	61 (21.1)	58.11 (9.96)	0.877 (0.417)
	41~60	162 (56.1)	56.76 (12.03)	
	≥ 61	66 (22.8)	55.42 (11.23)	
Sex	Male	178 (61.6)	54.40 (11.08)	−4.556 (<0.001)
	Female	111 (38.4)	60.50 (11.04)	
Residence	Urban	204 (70.6)	55.37 (11.23)	−3.200 (0.002)
	Rural	85 (29.4)	60.02 (11.33)	

(*Continued*)

Table 1 (Continued).

Characteristics	Categories	N (%)	Mean (SD)	t or *F* (*P*)
Educational attainment	Elementary or less	80 (27.7)	59.14 (11.85)	2.495 (0.060)
	Middle school	82 (28.4)	57.05 (11.61)	
	High school	60 (20.8)	56.08 (10.75)	
	College or above	67 (23.2)	54.09 (10.94)	
Marital status	Single (unmarried/divorced/widowed)	31 (10.7)	58.16 (9.27)	0.731 (0.465)
	Married	258 (89.3)	56.57 (11.68)	
Employment status	Employed	132 (45.7)	54.85 (11.04)	14.657 (<0.001)
	Retired	50 (17.3)	52.34 (11.35)	
	Not employed	107 (37.0)	61.13 (10.59)	
Monthly income (CNY)	< 1000	27 (9.3)	64.44 (9.51)	8.073 (<0.001)
	1000~2999	71 (24.6)	58.54 (11.07)	
	3000~4999	104 (36.0)	56.51 (10.84)	
	≥ 5000	87 (30.1)	53.16 (11.67)	
Medical insurance payment	UWBHI	110 (38.1)	53.36 (11.77)	6.560 (<0.001)
	URBHI	116 (40.1)	57.72 (10.66)	
	NRCMS	48 (16.6)	60.54 (10.93)	
	Self-funded	15 (5.2)	61.73 (10.25)	
Duration of diabetes (years)	< 1	69 (23.9)	60.35 (10.22)	7.614 (<0.001)
	1~5	74 (25.6)	59.01 (10.00)	
	5~10	41 (14.2)	56.27 (12.55)	
	> 10	105 (36.3)	52.95 (11.68)	
Family history of diabetes	Yes	121 (41.9)	55.21 (11.75)	−1.944 (0.053)
	No	168 (58.1)	57.85 (11.11)	
Therapeutic method	None	15 (5.2)	66.20 (7.89)	14.920 (<0.001)
	Oral antidiabetic drug (OAD)	51 (17.6)	63.90 (9.51)	
	Injection of insulin	73 (25.3)	54.29 (10.04)	
	Injection of insulin plus OAD	150 (51.9)	54.55 (11.56)	
Diabetes-related education	Yes	171 (59.2)	52.13 (10.52)	−9.410 (<0.001)
	No	118 (40.8)	63.42 (9.24)	
Comorbidity	Yes	138 (47.8)	54.09 (12.05)	−3.849 (<0.001)
	No	151 (52.2)	59.16 (10.31)	
Complication	Yes	74 (25.6)	55.51 (12.02)	−1.070 (0.285)
	No	215 (74.4)	57.16 (11.23)	

Abbreviations: SD, standard deviation; CNY, Chinese yuan; UWBHI, Urban Workers Basic Health Insurance; URBHI, Urban Residents Basic Health Insurance; NRCMS, New Rural Cooperative Medical System.

average age of the 289 patients was 51.53 years old (standard deviation: 12.61, range: 18–77 years). More than half of the patients were male (n = 178, 61.6%). The majority were urban residents (n = 204, 70.6%), had a family history of diabetes (n = 121, 41.9%), had completed elementary school or less (n = 80, 27.7%), were married (n = 258, 89.3%), were employed (n = 132, 45.7%), had a monthly income of 3000–4999 CNY (n = 104, 36.0%), and had urban residents' basic health insurance (n = 116, 40.1%). The duration of diabetes was > 10 years (n = 105, 36.3%); most were treated with oral hypoglycaemic drugs combined with insulin injections (n = 150, 51.9%), received diabetes-related education (n = 171, 59.2%), had comorbidities (n = 138, 47.8%), and had complications (n = 74, 25.6%).

Sex, residence, employment status, monthly income, medical insurance payment, duration of diabetes, therapeutic method, diabetes-related education, and comorbidity showed statistically significant differences in PIR levels in patients with T2D ($P < 0.05$). Compared with participants who had low PIR, those with high PIR were significantly more likely to be female, reside in rural areas, be unemployed, have lower monthly income, pay out-of-pocket, have a shorter diabetes duration, use oral antidiabetic drugs only, lack diabetes-related education, and have no comorbidities. There were no

significant differences in the effects of age, educational attainment, marital status, family history of diabetes, or complications ($P \geq 0.05$).

Descriptive Statistics for Measured Variables

Table 2 presents the descriptive statistics of the measured variables. The average SE was 7.07 ± 1.56. The average scores of OS, SubS, and US were 9.98 ± 3.08, 24.25 ± 4.08, and 6.64 ± 2.22, respectively. In addition, the average scores of DD and DS were 44.47 ± 17.75 and 35.25 ± 8.64, respectively. The average PIR score was 56.74 ± 11.44. Furthermore, the absolute values of skewness and kurtosis were less than 2 and 4, respectively, which met the conditions of normal distribution.[36]

The Relationships Between SE, SS, DD, DS and PIR

The correlation analyses results for SE, SS, DD, DS, and PIR are presented in Table 3. There was a negative association between SE and PIR (r = −0.430, $P < 0.01$), DD (r = −0.346, $P < 0.01$), and DS (r = −0.350, $P < 0.01$). SS showed

Table 2 Descriptive Statistical Results for the Measurement Variables (n=289)

Variables	Mean	SD	Range	Skewness	Kurtosis
SE	7.07	1.56	2~10	−0.27	−0.22
SS					
OS	9.98	3.08	2~20	0.38	0.46
SubS	24.25	4.08	13~32	−0.33	−0.48
US	6.64	2.22	3~12	0.46	−0.25
DD					
EB	12.19	4.90	5~28	0.75	0.25
PD	11.94	3.97	4~22	0.25	−0.35
RD	14.26	4.94	5~27	0.30	−0.52
ID	6.09	2.76	3~18	1.33	2.29
DS					
IS	21.99	6.70	13~42	0.85	0.12
ES	13.27	2.80	11~26	1.87	3.79
PIR					
PA	9.45	2.17	4~16	0.53	0.55
NA	47.29	10.69	16~69	−0.19	−0.44

Abbreviations: SE, self-efficacy; SS, social support; DD, diabetes distress; DS, diabetes stigma; PIR, psychological insulin resistance; SD, standard deviation; OS, objective support; SubS, subjective support; US, utilization of support; EB, emotional burden; PD, physician distress; RD, regimen distress; ID, interpersonal distress; IS, internalized stigma; ES, enacted stigma; PA, positive attitude; NA, negative attitude.

Table 3 The Relationships Between SE, SS, DD, DS and PIR (n=289)

Variables	SE	SS	DD	DS	PIR
SE	1				
SS	0.097	1			
DD	−0.346**	−0.164**	1		
DS	−0.350**	−0.260**	0.467**	1	
PIR	−0.430**	−0.295**	0.509**	0.468**	1

Notes: **$P<0.01$.
Abbreviations: SE, self-efficacy; SS, social support; DD, diabetes distress; DS, diabetes stigma; PIR, psychological insulin resistance.

a negative correlation with DD (r = −0.164, $P < 0.01$), DS (r = −0.260, $P < 0.01$), and PIR (r = −0.295, $P < 0.01$). DD was positively correlated with DS (r = 0.467, $P < 0.01$) and PIR (r = 0.509, $P < 0.01$). The DS and PIR scores were significantly associated (r = 0.468, $P < 0.01$). Multicollinearity was not an issue in this study because the correlation coefficient between the absolute values of the variables ranged from 0.164 to 0.509.

Multiple Linear Regression Analysis

Variables that exhibited significant differences in the univariate and correlation analyses were entered as independent variables, with PIR as the dependent variable, and analyzed using multiple linear regression with a stepwise selection procedure. The final model identified employment status, diabetes-related education, SE, SS, DD, and DS as related to PIR in patients with T2D ($P < 0.05$). It was determined that the model was statistically significant and the variables included in the model explained 57.7% of the variance (Adjusted $R^2 = 0.577$; $F = 18.873$; $P < 0.001$). The detailed results are presented in Table 4.

Table 4 Results of Multiple Linear Regression Analysis of PIR (N = 289)

Independent Variables	B	Standard Error	β	T	P	Tolerance	VIF
(Constant)	2.808	0.285		9.851	< 0.001*		
SE	−0.057	0.016	−0.160	−3.623	< 0.001*	0.749	1.355
SS	−0.083	0.036	−0.095	−2.286	0.023*	0.843	1.186
DD	0.206	0.030	0.312	6.791	< 0.001*	0.694	1.441
DS	0.278	0.076	0.175	3.677	< 0.001*	0.649	1.541
Female (Ref: Male)	0.022	0.053	0.019	0.424	0.672	0.722	1.384
Rural (Ref: Urban)	0.082	0.071	0.065	1.157	0.248	0.463	2.160
Employment status (Ref: Employed)							
Retired	0.008	0.068	0.005	0.122	0.903	0.730	1.370
Not employed	0.141	0.065	0.119	2.167	0.031*	0.484	2.068
Monthly income (CNY) (Ref: < 1000)							
1000~2999	−0.032	0.092	−0.204	−0.348	0.728	0.306	3.265
3000~4999	0.088	0.100	0.074	0.878	0.381	0.209	4.788
≥ 5000	0.061	0.107	0.049	0.570	0.569	0.198	5.047
Medical insurance payment (Ref: UWBHI)							
URBHI	0.074	0.059	0.064	1.259	0.636	0.409	2.445
NRCMS	0.044	0.092	0.028	0.474	0.875	0.610	1.640
Self-funded	0.020	0.126	0.008	0.158	0.671	0.546	1.833
Duration of diabetes (years) (Ref: < 1)							
1~5	0.029	0.068	0.022	0.425	0.671	0.546	1.833
5~10	−0.048	0.079	−0.030	−0.610	0.543	0.626	1.587
> 10	0.033	0.070	0.028	0.479	0.632	0.428	2.338
Therapeutic method (Ref: None)							
OAD	0.092	0.116	0.061	0.793	0.429	0.244	4.091
Injection of insulin	−0.198	0.115	−0.150	−1.715	0.088	0.191	5.236
Injection of insulin plus OAD	−0.144	0.112	−0.126	−1.282	0.201	0.152	6.569
Diabetes-related education (Ref: No)	−0.353	0.056	−0.304	−6.352	< 0.001*	0.641	1.560
Comorbidity (Ref: No)	−0.087	0.047	−0.076	−1.852	0.065	0.877	1.140

Notes: Dependent Variable: ITAS. Durbin-Watson = 2.032; $F = 18.873$, $P < 0.001$; $R^2 = 0.610$; Adjusted $R^2 = 0.577$.

Abbreviations: B, regression coefficient; β, standardised regression coefficient; VIF, variance inflation factor; CNY, Chinese yuan; UWBHI, Urban Workers Basic Health Insurance; URBHI, Urban Residents Basic Health Insurance; NRCMS, New Rural Cooperative Medical System; OAD, Oral antidiabetic drug.

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Goodness-of-Fit of the Measurement Model

This study created a preliminary SEM to investigate the relationships between SE, SS, DD, DS, and PIR based on literature reviews, as shown in Figure 1. Path analysis revealed no statistically significant relationship between SS and DS or SE and SS. Given that the model's CMIN/DF value was 3.100, AGFI value was 0.861, RMSEA value was 0.085, NFI value was 0.899, and TLI value was 0.895, the original model required correction.

To enhance the model's fit, the following two routes were eliminated: "SS→DS" ($P = 0.067$), and "SS→SE" ($P = 0.161$). A modification index of 51.094 was used to modify the model and incorporate the covariances of EB and ID. The modified model is shown in Figure 2. Table 5 presents the results of the goodness-of-fit tests for the initial and modified models.

Direct and Indirect Effects of the Structural Model

Eight pathways showed statistically significant differences in the path coefficients of the modified model. Table 6 presents the findings for the direct, indirect, and total effects of DS, SE, DD, SS, and PIR. The results showed that SE has a direct effect on PIR (β = −0.321, $P < 0.001$); DD had the largest positive direct effect on PIR (β = 0.489, $P < 0.001$) and played a partial mediating role between SE and PIR, with a mediating effect value of −0.190, accounting for 31.1% of the total effect; DS had a positive direct effect on PIR (β = 0.284, $P = 0.001$) and played a partial mediating role between SE and PIR, with a mediating effect value of −0.052, accounting for 8.5% of the total effect; DS also played a partial mediating role between DD and PIR, and the mediating effect value was 0.124, accounting for

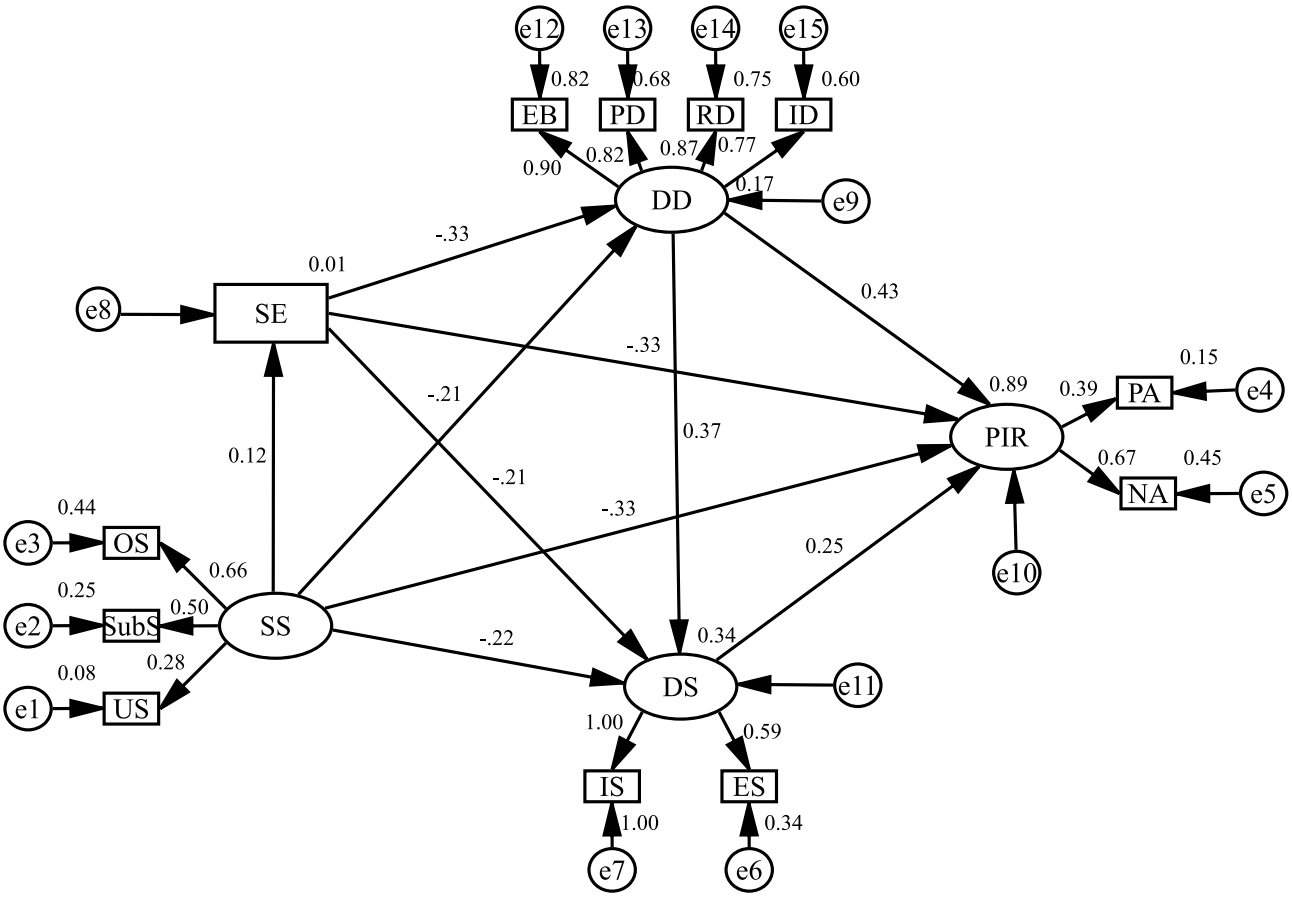

Figure 1 Standardized estimates of relationships and effect sizes in the initial model.

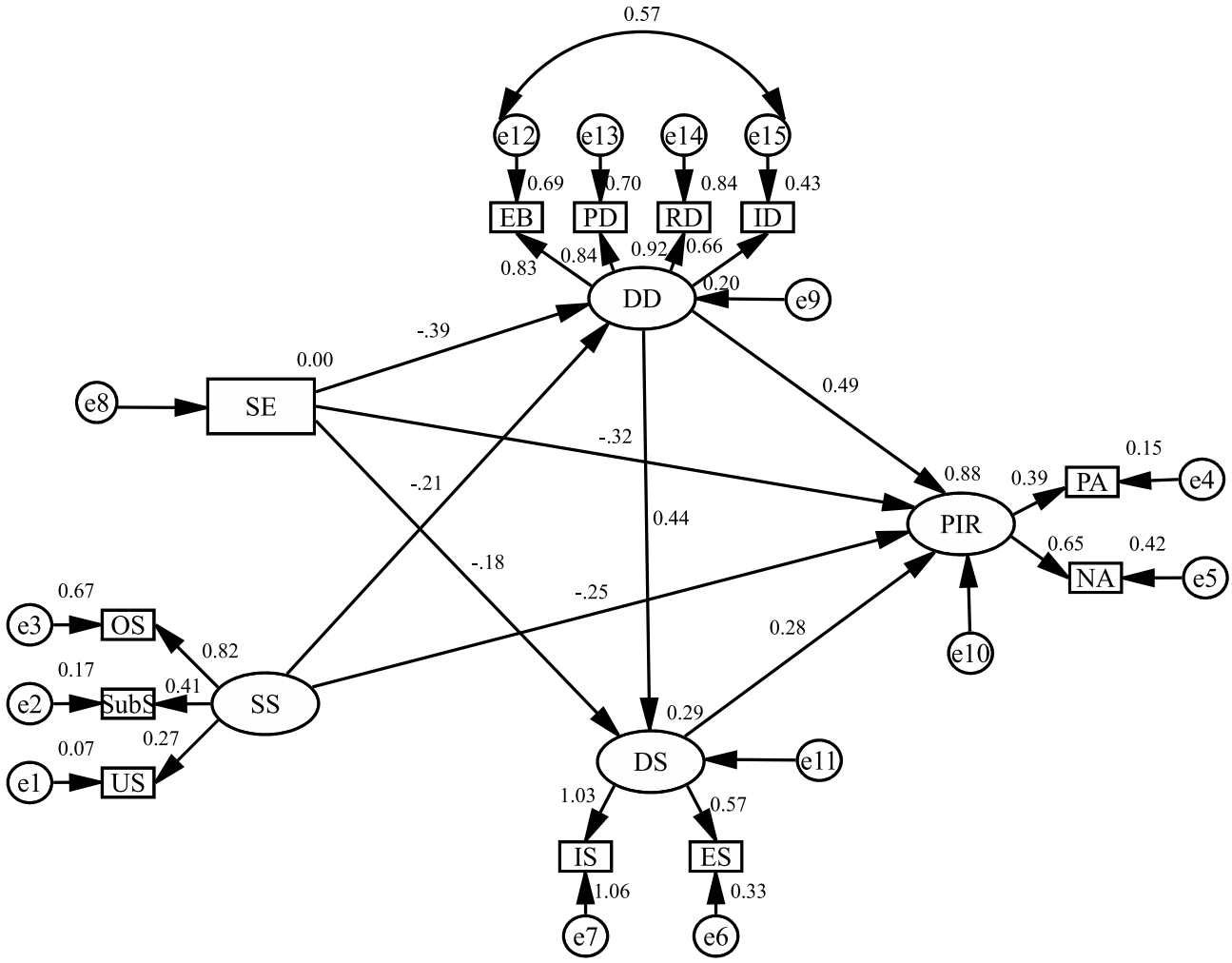

Figure 2 Standardized estimates of relationships and effect sizes in the modified model.

20.2% of the total effect. DD and DS had a chain mediating effect between SE and PIR, with a mediating effect value of −0.048, accounting for 7.9% of the total effect; SS had a direct effect on PIR (β = −0.255, P = 0.007); DD also played a partial mediating role between SS and PIR, with a mediating effect value of −0.105, accounting for 27.2% of the total effect.

Table 5 Goodness-of-Fit Test Results Between the Initial Model and the Modified Model (n=289)

	CMIN/DF	GFI	AGFI	RMSEA	NFI	TLI	IFI	CFI
Reference	≤ 3	> 0.9	> 0.9	< 0.08	> 0.9	> 0.9	> 0.9	> 0.9
Initial model	3.100	0.920	0.861	0.085	0.899	0.895	0.930	0.928
Modified model	1.564	0.960	0.933	0.044	0.948	0.972	0.981	0.980

Abbreviations: CMIN, chi-square; DF, degrees of freedom; GFI, goodness-of-fit index; AGFI, adjusted goodness-of-fit index; RMSEA, root mean square error of approximation; NFI, Normed ft index; TLI, Tucker-Lewis Index; IFI, Incremental fitting index; CFI, comparative norm of fit index.

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Table 6 Standardized Direct, Indirect, and Total Effects in the Modified Model (n=289)

Variables	Standardized Effects	Pathes	Effect Size	Standard Error	Bootstrap 95% CI		Proportion of Total Effect (%)
SE	Direct effects	SE→PIR	−0.321	0.089	−0.509	−0.161	
		SE→DD	−0.388	0.060	−0.501	−0.264	
		SE→DS	−0.183	0.053	−0.291	−0.081	
	Indirect effects	SE→DD→PIR	−0.190	0.055	−0.298	−0.082	31.1
		SE→DS→PIR	−0.052	0.022	−0.095	−0.009	8.5
		SE→DD→DS→PIR	−0.048	0.017	−0.082	−0.015	7.9
	Total effect	SE→PIR	−0.610	0.089	−0.810	−0.459	
SS	Direct effects	SS→PIR	−0.255	0.112	−0.479	−0.049	
		SS→DD	−0.214	0.072	−0.367	−0.081	
	Indirect effect	SS→DD→PIR	−0.105	0.043	−0.189	−0.021	27.2
		SS→DD→DS→PIR	−0.027	0.015	−0.056	0.002	
	Total effect	SS→PIR	−0.386	0.126	−0.622	−0.130	
DD	Direct effects	DD→PIR	0.489	0.120	0.280	0.752	
		DD→DS	0.438	0.065	0.311	0.570	
	Indirect effect	DD→DS→PIR	0.124	0.044	0.057	0.233	20.2
	Total effect	DD→PIR	0.613	0.118	0.409	0.875	
DS	Direct effects	DS→PIR	0.284	0.089	0.131	0.479	

Abbreviations: SE, self-efficacy; SS, social support; DD, diabetes distress; DS, diabetes stigma; PIR, psychological insulin resistance.

Discussion

This study identified the relevant variables influencing PIR in patients with T2D based on an SEM built using literature reviews. The SEM demonstrated the mechanism of action between these variables. SE and SS had direct and indirect negative effects on PIR in patients with T2D; and DD had both direct and indirect positive effects; DS had only direct positive effects. These findings highlight the significance of SE, DD, and additional elements that may aid in improving PIR in individuals with T2D.

SEM indicated that SE was the second total effect coefficient, except for DD. As demonstrated by numerous earlier research investigations, there was a statistically significant negative association between SE and PIR, which this study reinforced.[23,37–39] According to social cognitive theory, self-efficacy can be used to predict behavior changes related to health, which include goal-setting, mindset, and strategy.[40] Those with T2D who have high levels of SE tend to view their health changes more positively and have greater adherence to insulin therapy, which helps avoid the development of PIR. As SE is a major factor in lowering PIR, healthcare practitioners should assess and assist patients in enhancing their SE as a preventative measure or educational strategy. A study demonstrated that an eight-week advanced-practice education program for primary-care teams significantly enhanced SE with T2D patients.[41] This suggests that enhancing the training of healthcare professionals to promote SE in T2D patients and alleviating PIR is of great significance.

The results showed that SE can mediate PIR through DD and DS. Therefore, lowering the level of PIR, simultaneously reducing DD and DS, may become an important breakthrough. PIR and DD were positively correlated, indicating that greater PIR corresponded with higher DD levels, in line with prior research.[25,42,43] Research suggests that insulin therapy worsens distress related to emotional burden, such as feeling dazed by injecting oneself, fatigue, and worry about complications, making the disease itself harder to manage.[44,45] Healthcare providers should take proactive steps to check for DD, particularly in the event of complications or changes in therapy.[46] A recent systematic review found that patients can improve mental health and reduce the distress of diabetes through some psychological interventions, such as cognitive behavioural therapy, guided self-determination, and blood glucose awareness training.[47]

There was a strong positive correlation between DS and PIR. Relationships between DD, SE, and PIR can potentially be mediated by DS. In a study of Turkish teenagers with type 1 diabetes, stigma was found to be a predictor of negative perceptions about insulin treatment.[48] To adjust their negative perception of insulin, patients should pay attention to their

psychological state when managing their diabetes. Additionally, it is critical to provide patients with knowledge about their disease to help them better comprehend their condition, which will lessen stigma.

PIR in individuals with T2D was negatively related to SS, and PIR decreased as SS increased. This correlated with similar research results in the literature.[23] Although SS can come from a variety of sources, information support is the most prevalent, according to a study that examined numerous diabetes phases.[49] According to a Japanese study, high levels of SS can even buffer negative physiological changes and lower the incidence of diabetic nephropathy.[50] Our research indicated that SS can also lower DD. A 12-week pilot study noted that SS received during intervention was critical to lowering the stress associated with managing the illness.[51] The pathway analysis of this study showed that SS and PIR were partially mediated by DD. Healthcare professionals considering assessing and identifying as many SS as possible to lower DD levels may be helpful in reducing PIR levels.

Furthermore, advancements in medication and technology may alleviate PIR by reducing the burden of injections and improving adherence. A meta-analysis showed once-weekly basal insulin analogues, such as icodec insulin, significantly reduced the frequency of injection compared with once-daily injections, which may be an important factor in mitigating PIR.[52] Needle-free insulin administration has been widely used by improving insulin injection devices, reducing pain and skin trauma, and supporting better compliance and satisfaction.[6] Therefore, future studies can improve the injection frequency and drug delivery device to reduce PIR.

This study had several limitations. First, the capacity to deduce causation was restricted by the cross-sectional study design. While the SEM is useful in demonstrating associations, the relationships identified do not imply causation. Future longitudinal and experimental research must be designed to further investigate the causal relationships between these variables, especially to further verify the relationship between DD and DS. Because it was a cross-sectional study, the reverse pathway (DS→DD) or the interaction with time cannot be ruled out. Second, convenience sampling was used to select the sample, which meant that it was not representative because it came from a hospital. Consequently, it is essential to perform a multicenter survey utilizing a random sampling method in the future. Finally, there could be subjective bias because the data were gathered using self-reported assessments.

Conclusion

This study is the first to investigate the variables associated with PIR in Chinese patients with T2D using the SEM method. SE, SS, DD, and DS were significant determinants of PIR; among these, SE and DD were the most critical variables linked to PIR in individuals with T2D. Elements influencing SE and DD may aid in the creation of intervention plans, assessing SE and DD before intervention, and boosting patient self-assurance in handling their condition, all of which will reduce the likelihood of PIR. Simultaneously, the effects of SS and DS on the PIR should also be considered.

Data Sharing Statement

The data of the study can be obtained by requesting the corresponding author for reasonable reasons.

Ethics Approval and Informed Consent

This study was approved by the Ethics Committee of the First Affiliated Hospital of Anhui Medical University with an approval number of 84230040 and was conducted according to the Helsinki Declaration.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The author(s) report no conflicts of interest in this work.

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