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Application of structural equation modeling in assessing the self-management activities of patients with type 2 diabetes

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Abstract

Objective: This study aimed at assessing the self-management activities of type 2 diabetes patients using Structural Equation Modeling (SEM) which measures and analyzes the correlations between observed and latent variables. This statistical modeling technique explored the linear causal relationships among the variables and accounted for the measurement errors. **Methods:** A sample of 200 patients was recruited from the middle-aged population of rural areas of Pakistan to explore the self-management activities of type 2 diabetes patients using the validated version of the Urdu Summary of Diabetes Self-care Activities (U-SDSCA) instrument. The structural modeling equations of self-management of diabetes were developed and used to analyze the variation in glycemic control (HbA1c). **Results:** The validated version of U-SDSCA instrument showed acceptable psychometric properties throughout a consecutive reliability and validity evaluation including: split-half reliability coefficient 0.90, test-retest reliability ($r = 0.918$, $P \leq .001$), intra-class coefficient (0.912) and Cronbach's alpha (0.79). The results of the analysis were statistically significant ($\alpha = 0.05$, P-value $< .001$), and showed that the model was very well fitted with the data, satisfying all the parameters of the model related to confirmatory factor analysis with chi-squared = 48.9, CFI = 0.94, TLI = 0.95, RMSEA = 0.065, SPMR = 0.068. The model was further improved once the items related to special diet were removed from the analysis, chi-squared value (30.895), model fit indices (CFI = 0.98, TLI = 0.989, RMSEA = 0.045, SPMR = 0.048). A negative correlation was observed between diabetes self-management and the variable HbA1c ($r = –0.47$; $P < .001$). **Conclusions:** The Urdu Summary of Diabetes Self-Care Activities (U-SDSCA) instrument was used for the patients of type 2 diabetes to assess their diabetes self-management activities. The structural equation models of self-management showed a very good fit to the data and provided excellent results which may be used in future for clinical assessments of patients with suboptimal diabetes outcomes or research on factors affecting the associations between self-management activities and glycemic control

Keywords

type 2 diabetes, self-management, structural equation, Urdu SDSCA, factor analysis, instrument, hemoglobin HbA1c

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Introduction

The use of Structural Equation Modeling (SEM) covers various domains of public health and epidemiology.[1] The applications of SEM have been applied from a simple relationship between variables to complex analyses.[2] The application allows to develop complex relationships among multiple variables, therefore this technique is most suitable to manage the measurement errors.[3] These models are also very useful to be used to study the chronic diseases and to develop the model of health education and health behaviors.[4] The other task in SEM is to determine the "Goodness

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of Fit" of the model. This estimation procedure determines how accurate is the model to fit the required data. The model is represented as:

$$\Sigma = \Sigma(\theta) \quad 1$$

Where "Σ is denoted as the population covariance matrix of observed variables, θ is a vector that contains the model parameters, and Σ (θ) is the covariance matrix written as a function of θ". The function to be minimized is given by:

$$Q = [s - \sigma(\theta)]' W [s - \sigma(\theta)] \quad 2$$

The model vector s is a function of parameters θ, s = f (θ), that are to be estimated so as to minimize Q and W is the weight matrix. The model output provides many indices to check the goodness of fit of the model.[5]

In Pakistan, diabetes is the main threat to the middle-aged population[6] and poses a great challenge to the health-care system.[7] The population of Pakistan is at a high risk of type 2 diabetes due to lack of exercise, non-adherence to medicines, and avoiding a healthy diet.[8–11]

In Pakistan, the psychometric validated instrument was not developed to date to assess the self-management of type 2 diabetes in patients.[11] This type of instrument was developed by Toobert et al[12] which was used in English speaking countries. Bukhsh et al[13,14] have reported the standard forward-backward translation of diabetes self-management questionnaire (DSMQ) in Urdu and applied it to a convenience sample of 130 patients with type 2 diabetes and assessed the psychometric properties of this Urdu-version of the instrument. They have found high internal consistency for all the sub-scales of DSMQ.[14]

The English version of Summary of Diabetes Self-care Activities (SDSCA) instrument[12] has been extensively used in various diabetes-related studies[14] and was translated into other languages such as Chinese by Xu et al,[15] Spanish by Vincent et al,[16] Arabic by Aljohani et al,[17] German by Kamradt et al[18] and Urdu by Ansari et al.[19]

This study used a validated Urdu version of the SDSCA instrument[19] and applied it to the assessment of self-management activities of type 2 diabetes patients. When we compare DSMQ and SDSCA, there is a major overlap in the contents or items of both the instruments. The estimation approach of SDSCA is different as it asks for the number of days per week on which a certain behavior was carried out. Therefore, it depends on the professional's hands and has to be focused on the particular regimen of the patient. The DSMQ on the other hand requires the self-rating of the patient's self-management, and the rating is carried out with respect to a more general duration of 8 weeks. The findings could be more representative, but also likely to be more vulnerable to memory bias.[20]

The large sample size of 200 patients with type 2 diabetes was used to assess their diabetes self-management activities as using a large sample reduces the likelihood of random variation that can occur in small samples.[12] The structural equation model of self-management was developed to identify the factors affecting the associations between self-management activities and glycemic control. This study also examined the possible association between participants' demographic variables and diabetes-related self-management activities. The present study hypothesizes that, as the self-management activities increase with the time, the levels of HbA1c decrease as well.

Methods

Study Design

The 2 samples of participants were purposively recruited from the medical clinics of Al-Rehman Hospital, Pakistan, which provides primary health-care services. For the first sample, about 50 patients were approached, and 30 agreed to participate in the study. Participants recruited for the first sample of 30 were asked to complete the questionnaire, and their informed consent was obtained. This small sample was used to assess instrument reliability and validity. However, factor analysis on small sample size (n = 30) was not possible to perform as the results obtained from the small sample would have been unstable and might not be replicable.[12] The larger sample of 200 participants was used to do the factor analysis to get a good model to assess the factors associated with the self-management activities and the model can also be used for future research in this area.

Participants (inclusion/exclusion criteria)

The participants aged 40-60 years were included in this sample with poorly controlled type 2 diabetes with the latest HbA1c lab test, taking medications prescribed by the general practitioner, and excellent communication skills in the Urdu language. The patients with diabetes having HbA1c $>$ 7% were included in this study, and patients having coexisting liver, kidney, or thyroid disorder were excluded.

Ethics Approval

The ethics committee of the University of New South Wales, Australia approved this study on 6 April 2017, (HC 16882). The Ayub Medical Institution, Abbottabad, Pakistan approved this study on 31 October 2016.

Table 1. Patients' Characteristics and Their Association with Glycemic Control (n = 200).

Parameters	Male (n)	Female (n)	Mean ± SD	*P*-value	Total
Age (in years)	51	53	51.40 ± 6.42	.25	52
<60 years	85	87			172
≥60 years	15	13			28
Diabetes patients	100	100		.20	200
Marital status					
Single	15	5			20
Married	75	85			160
Divorced	10	2			12
Widowed	0	8			8
Education					
<grade 9	16	50			66
High school	65	40			105
College degree	10	7			17
Professional	9	3		.70	12
Employment					
Full/part time	75	65		.05	140
Unemployed	10	35			45
Retired	15	0			15
Diabetes duration					
<8 years	36	42	7.72 ± 2.38		78
≥8 years	64	58	8.1 ± 2.30	.048	122
HbA1c (%)					
Uncontrolled (>7%)	91	91	9.03 ± 1.52	.051	182
Controlled (≤7%)	9	9			18

n, number of patients; SD, standard deviation.
P-values are two tailed t-test values.

Statistical Analysis

The Statistical analysis was carried out by using IBM SPSS 25. The descriptive statistics were calculated from the patients' demographic data. The split-half reliability correlation score was calculated based on the data of 30 participants with equal lengths co-efficient of 0.95.[19] The Urdu version of the instrument (U-SDSCA) questionnaire was administered to the sample of 30 participants twice at least one week apart so that test-retest could be calculated.[21–23] The results of the test were statistically significant reliability score ($r = 0.918$, $P \leq .001$). The internal consistency analysis for the 10 items of the U-SDSCA questionnaire was estimated at 0.79 (Cronbach's alpha).[24] The scores for the sub-scale were also calculated, and all these results were in agreement with the English version of SDSCA,[12] the Arabic version of SDSCA,[17] and the German version of SDSCA.[18]

Results

The mean age of the 200 participants was 52 years (Range: 40-65 years). One hundred participants were male (50%), and 100 participants were female (50%) and the mean duration of time since diagnosis of type 2 diabetes was 8 (Range: 2-13 years). The medical record accessed from the medical centers of the hospital showed the higher values of HbA1c (9%) for both men and women patients ranging between (2 and 13) %. The mean value of the body mass index (BMI) was 29 kg/m^2. All the participants have shown great interest and completed the questionnaire during their visit to the medical centers of the hospital. Table 1 provides details on the patient's characteristics and their association with glycemic control.

Structural Equation Models of Diabetes Self-management

The structural modeling of diabetes self-management analysis was performed using IBM AMOS 25 software. For statistical significance, a *P*-value <.05 was considered. The diabetes self-management models were developed using the validated Urdu version of SDSCA, considering the 2 important variables: diabetes self-management and HbA1c. The self-management activities were modeled as latent variable operationalized by SDSCA's 5 self-management activities or behaviors (Figures 1-3).

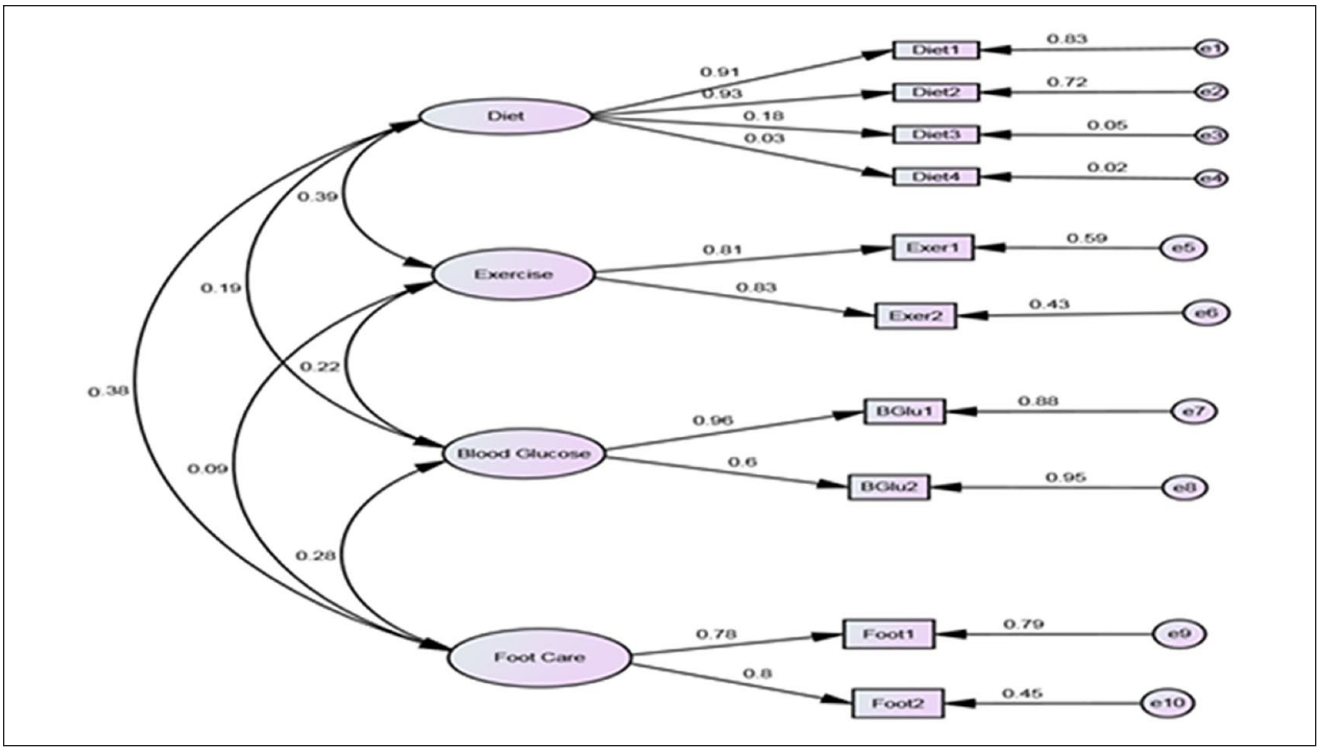

Figure 1. CFA model 1: factor structure of the U-SDSCA (with 10 items): chi-squared = 48.9, sample size = 200, CFI = 0.94, TLI = 0.95, RMSEA = 0.065, SPMR = 0.068, *P* = .018 (<0.05), (95% CI = 0.01-0.06). For path arrows, the data are standardized regression coefficients and correlation coefficients for double arrows. The ovals indicate latent variables and boxes represent measurement variables.

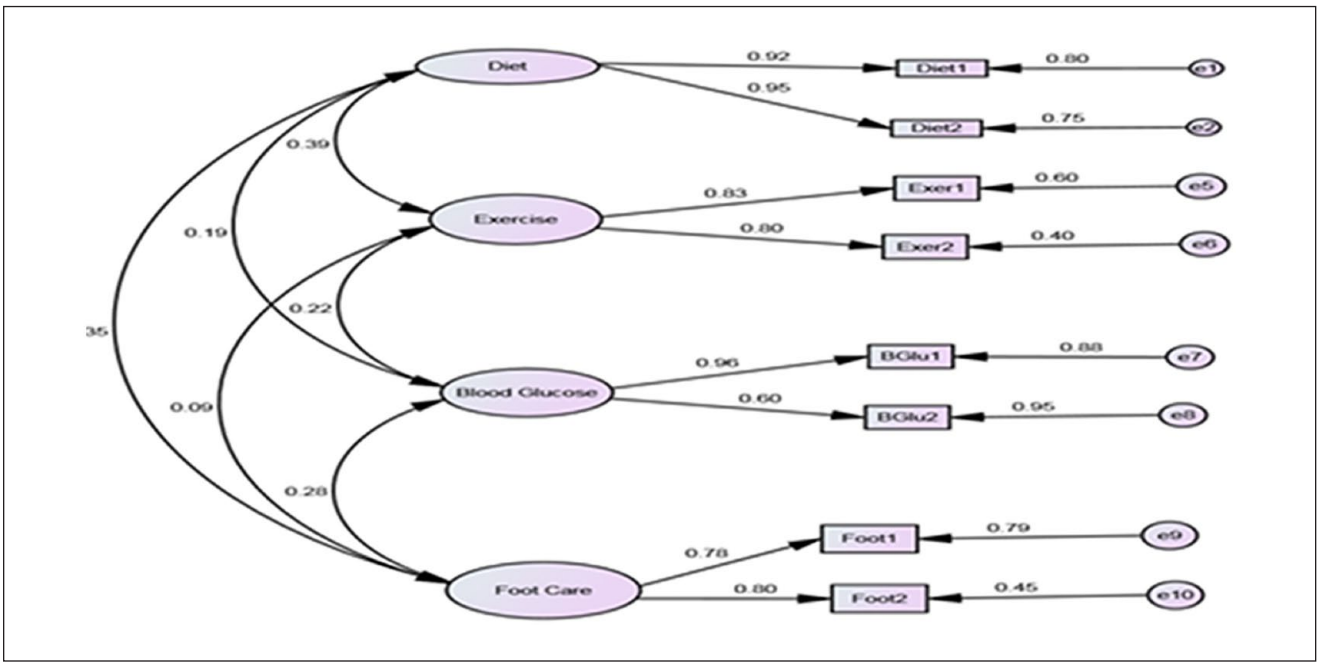

Figure 2. CFA model 2: factor structure of the U-SDSCA (with 8 items): chi-squared = 30.89, sample size = 200, CFI = 0.98, TLI = 0.99, RMSEA = 0.045, SPMR = 0.048, *P* = 0.011 (<0.05), (95% CI = 0.02-0.07). For path arrows, the data are standardized regression coefficients and correlation coefficients for double arrows. The ovals indicate latent variables and boxes represent measurement variables.

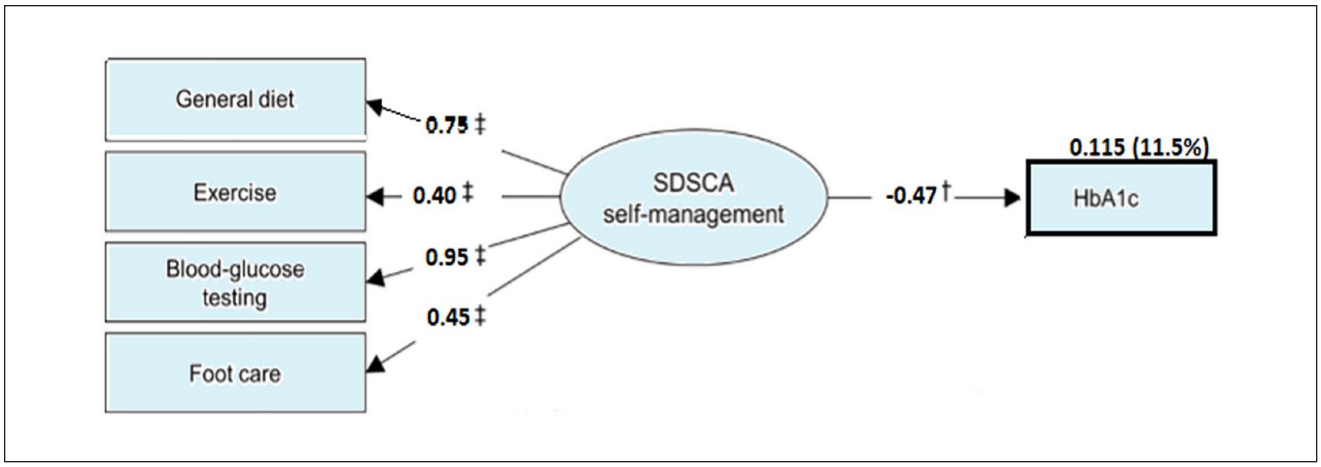

Figure 3. Structural equation model of diabetes self-management as measured by U-SDSCA for patients with type2 diabetes showing (R^2 = 0.115): 11.5% variation between self-management and HbA1c.

Confirmatory Factor Analysis

The confirmatory factor analysis (CFA) was carried out to determine the goodness of fit of the model defined by the 4 latent factors such as the diet (item 1-4), physical activity or exercise (item 5-6), blood glucose (item 7-8) and footcare (item 9-10). The structured modeling technique was used to develop the models. A CFA model is considered a good fit if Cumulative Fit Index (CFI), Tucker-Lewis Fit Index (TLI), Incremental Fit Index (IFI) values are greater than 0.90, Root Mean Square Error of Approximation (RMSEA) and Standardized Root Mean Square Residual (SRMR) is less than 0.08 [27].

The confirmatory analysis resulted in a good fit of the model 1 as shown in Figure 1. The model displays the latent variable correlations, standardized parameter estimates and squared multiple correlations. This may be observed from Figure 1 that item 3 and 4 (special diet) have low factor loadings of 0.03 and 0.18, respectively, thus making their contribution less significant to the model fit. This was also observed by Kamradt et al[18] during the confirmatory factor analysis of German SDSCA instrument evaluation.

Therefore, taking into consideration the poor performance of 2 items related to special diet, we decided to remove these items from the CFA Model 1, and carried out CFA analysis second time as shown in Figure 2 (CFA Model 2). In CFA model 2, the Chi-squared of the model is 30.895, sample size = 200 and *P*-value = .011. The model fit indices of this model are CFI = 0.98, TLI = 0.989, RMSEA = 0.045, SPMR = 0.048. The model has improved in terms of both the chi-squared value and the relevant model fit indices.

We may observe negative correlation between diabetes self-management and the variable HbA1c (r = –0.47; $P < .001$) for type 2 diabetes shown in Figure 3. The squared multiple correlations between self-management and HbA1c were 0.115 showing 11.5% variation of type 2 diabetes. Most relevant U-SDSCA activities or behaviors with regard to glycemic control were general diets, blood glucose testing, and exercise (physical activity). The model was adjusted for potential confounding effects for demographic variables but did not make any significant changes in the overall results, this finding is in agreement with the results highlighted by Kamradt et al.[18] In addition, "Diabetes Time" (duration) plays an important role in relation to HbA1c as longer the duration of diabetes, the higher the values of HbA1c. The Figure 4 shows strong correlation between the 2 variables Diabetes Time and HbA1c separated by gender (male = 1, female = 0).

Figure 5 also shows strong correlation between Age and HbA1c in males and females.

Table 2 provides the predictors of the self-management practices of participants. It may be observed in this table that women were more inclined to undertake appropriate diabetes self-management activities (β .302; $P = .000$). For blood glucose monitoring, participants with uncontrolled glucose levels (HbA1c > 7%) were unlikely to undertake appropriate diabetes care activities than those with controlled glucose levels (β = –.119; $P = .050$). The other independent variables related to patients' characteristics such as age and diabetes duration did not have much impact on the total self-management activities ($P > .05$).

Discussion

The use of validated Urdu-version (U-SDSCA) found to be suitable for assessing self-management activities in patients with type 2 diabetes in the middle-aged population of rural areas of Pakistan. An interesting observation was the average inter-item correlation of medication

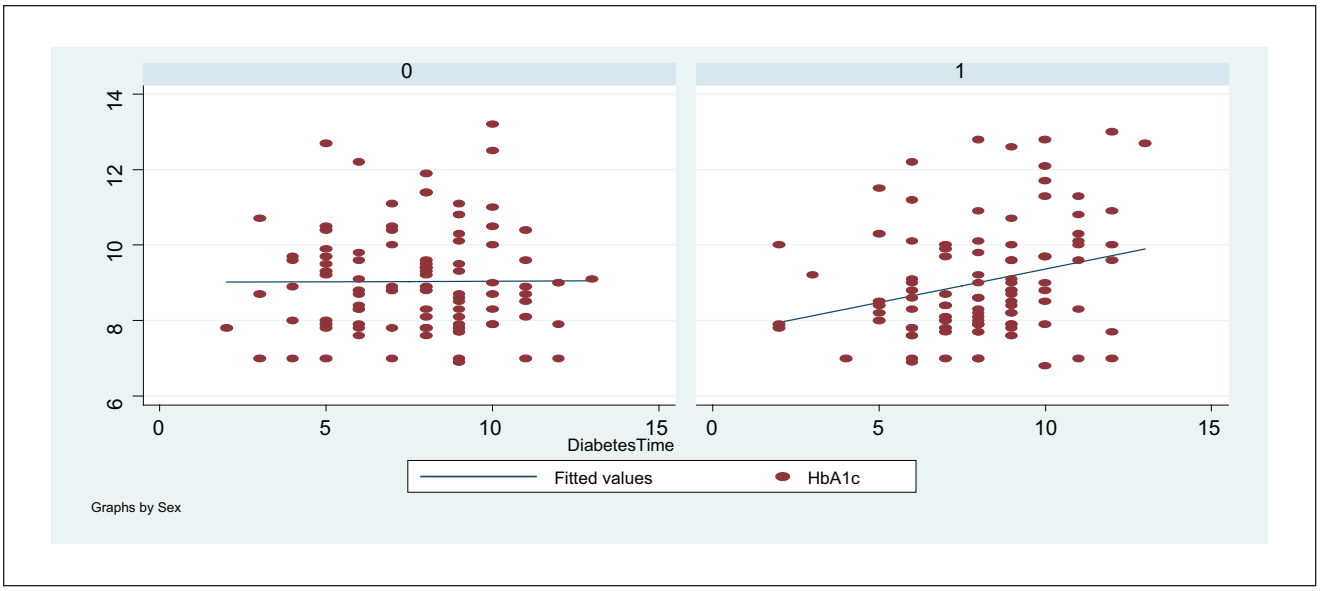

Figure 4. Correlation between the 2 variables diabetes time and HbA1c by gender (male = 1, female = 0).

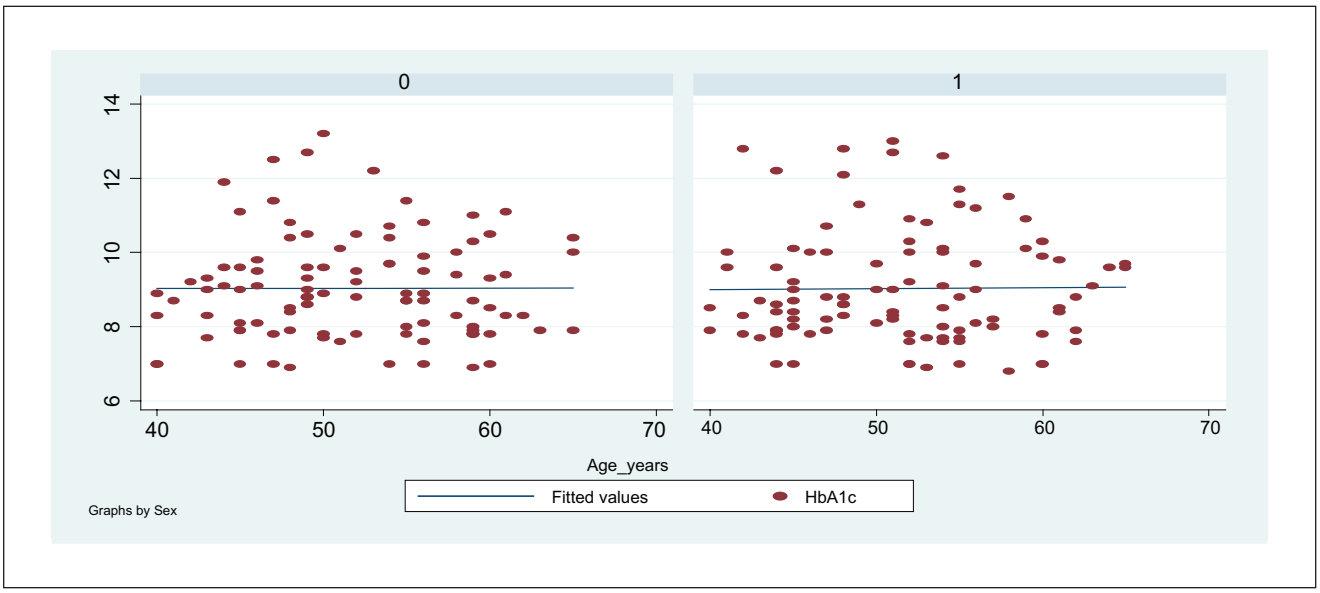

Figure 5. Correlation between the 2 variables age and HbA1c by gender (male = 1, female = 0).

adherence (0.48) and foot care (0.58). We found low factor loadings for item 3 and item 4 related to special diet which was in agreement with the previous findings by Kamradt et al.[18] A further CFA was conducted after removing the special diet items from the model, and the results showed improvements in the model's outcome including the model fit indices, which was also in agreement with the other studies.[18]

The findings in this study underline the multidimensional aspects of diabetes self-management activities. These results are in agreement with previous findings.[12,18] Of particular mention is the diet whose components are not highly correlated in the analysis. Therefore, the results of this study showed that type 2 diabetes patients did not link their eating habits with their disease, especially regarding high fat and oily rich food served in most of the families in Pakistan.

Table 2. The Self-Management Practices Model of Participants (n = 200).

Predictors	B	SE(B)	β	*P*-value
Age ≥ 60 years	–.250	.211	–.080	.251
Sex	.723	.163	.302	.000
Diabetes Time ≥ 8 years	–.121	.151	–.052	.422
HbA1c (Uncontrolled)	–.400	.201	–.119	.050

F = 8.26, *P*-value = 000, R Square = .211.
B = unstandardized co-efficient; SE (B) = standard error of B.
β = standardized co-efficient.

Toobert et al[12] suggested that specific eating habits may not be included in the overall analysis but should be analyzed independently. Therefore, in the present analysis, the items 3 and 4 related to special diet were removed from the analysis and it was observed that psychometric properties of the U-SDSCA were improved which made it a more reliable and valid tool to be used in the future for assessing the self-management activities of type 2 diabetes patients in the rural area of Pakistan.

The structural equation modeling development provided a powerful method to examine complex causal models. This modeling approach was preferred over the correlational-based approach currently used in the analysis to reduce the measurement errors. The other distinct advantage of this modeling approach was that when it was used as confirmatory factor analysis, it has yielded important information about the complex nature of type 2 diabetes and the health behaviors of diabetes patients. That is an important factor as it examined relationships between measured and latent variables directly and indirectly.[3,18]

This instrument developed for the middle-aged population will be of great help to identify the problems related to the self-management activities of diabetes patients. The strong associations between self-management activities identified by the Urdu version of SDSCA will help patients to improve their diabetes self-management activities. That might be useful to the patients to understand the importance of medication adherence, monitoring of glucose and adequate control of the diet, which would lead to better glycemic control and eventually reduce the complications related to diabetes.

Strengths and Limitations

The main strength of our study is the evaluation of the stability of the U-SDSCA; a test-retest analysis was carried out for over 1 week, and the results obtained were promising. The outcome of this test showed a statistically significant reliability score ($r = 0.918$, $P \leq .001$). The other strength of the study was that a larger sample was used (n = 200) to identify the agreement between the theoretical concept of self-management and the U-SDSCA measures and helped to obtain a good and reliable model which can be used for further research assessing the self-management of type 2 diabetes in the population of Pakistan.

The limitation of this study, as well as other studies measuring the self-management, is the lack of "gold standard" comparison.[25,26] The reason may be that the measurement of self-management of diabetes poses difficulties because of the various aspects that are inherent within this concept.[18] The other limitation of the study is the potential bias associated with self-reporting of diabetes self-management activities by the study participants.[27]

Conclusions

This study used the validated Urdu version of the SDSCA instrument for measuring the self-management activities in patients with type 2 diabetes in Pakistan and demonstrated that the instrument produced reliable and promising results and the use of this instrument may be extended to other Urdu speaking countries. The structural equation models of self-management showed a very good fit to the data. They provided excellent results which may be used for clinical assessments of patients with suboptimal diabetes outcomes or research on factors affecting the associations between self-management activities and glycemic control. The outcome of this study may be generalized to other populations as the data were collected and analyzed in this study represent multiple clinics, which take care of the majority of diabetes patients in that area in relation to their diabetes self-management activities.

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The authors are thankful to Dr. Deborah Toobert (Oregon Research Institute, USA) giving us permission to use the English version of The Summary of Diabetes Self-Care Activities (SDSCA) and translating it into the Urdu version. We are thankful to the director of Al-Rehman hospital, Abbottabad, Pakistan facilitating the interviews and data collection activities.

Authors' Contributions

RM made a substantial contribution to the design of this research work, collected and analyzed and interpreted the patient's data and performed the statistical analysis. HH and MH reviewed and revised it critically for important intellectual contents. NZ reviewed and approved the revised manuscript for publication.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Consent for Publication

The consent for publication was obtained from the participants in the study.

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