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RESEARCH ARTICLE

Effect of Lifestyle Promotion in the PRECEDE-PROCEED model among pre-diabetic adults based on PERSIAN cohort study: a randomized controlled trial study

Majed Meripour[1] · Hashem Mohamadian[1] · Morteza Abdullatif Khafaie[2]

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Abstract

Background Diabetes is a chronic disease caused by impaired glucose metabolism. This study aimed to design and evaluate the effect of a lifestyle promotion program based on the PRECEDE-PROCEED model among pre-diabetic individuals.

Methods This randomized controlled trial evaluated the effect of a lifestyle promotion program using the PRECEDE-PROCEED model among pre-diabetic individuals in Hoveizeh city in 2019. The study collected information on the disease status and risk factors associated with non-communicable conditions from the website of Hoveizeh Cohort Study Center. The primary outcome of the study was the percentage of glycated hemoglobin (HbA1c) with a three-month follow-up.

Results A total of 240 individuals participated in the study. There was no significant difference in anthropometric characteristics between the intervention and control groups ($P<0.05$). Initially, there was no significant difference in the mean HbA1c between the intervention and control groups ($P=0.97$). However, after three months of intervention, a statistically significant difference was observed ($P>0.001$). The results indicated an increase in the mean quality of life in the intervention group, but no significant difference was found between the two groups or before and after the intervention within each group ($P<0.05$).

Conclusion The findings suggest that the PRECEDE-PROCEED model provides a suitable framework for training pre-diabetic individuals and patients with type 2 diabetes mellitus (T2DM) to promote self-care behaviors.

Keywords Lifestyle · Glucose metabolism Disorders · Diabetes Mellitus, type 2 · Prediabetic state · Glycated hemoglobin A · Epidemiologic studies

Introduction

Diabetes is a prevalent chronic illness and a growing concern for global health, affecting approximately 463 million adults worldwide in 2019 [1]. Prediabetes, characterized by elevated blood sugar levels below the threshold of type 2 diabetes [2], poses a significant risk for the development of type 2 diabetes and cardiovascular diseases [3]. Lifestyle modifications, such as weight management and increased physical activity, have been shown to prevent 15–30% of prediabetic cases from progressing to type 2 diabetes within five years [4]. The burden of prediabetes is particularly high in low- and middle-income countries [5], where inadequate understanding of its prevalence and associated risk factors, including unhealthy diets, physical inactivity, and obesity, contributes to the global diabetes burden [6].

Addressing the knowledge gap surrounding prediabetes is crucial for public health planners and decision-makers [7]. Increasing awareness and developing targeted interventions are essential in preventing type 2 diabetes and implementing cost-effective programs [8]. Effective health promotion programs should consider cultural beliefs, language barriers, and health literacy levels to meet the specific needs of the target population [9]. Utilizing theoretical

✉ Morteza Abdullatif Khafaie
m.khafaie@live.com; khafaie-m@ajums.ac.ir

[1] Department of Health Education and Promotion, Faculty of Health, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran

[2] Department of Public Health, Faculty of Health, Ahvaz Jundishapur University of Medical Sciences, Golestan St, Ahvaz 15794_61357, Iran

frameworks enables the implementation of strategies that promote behavioral change and improve health outcomes [10]. The PRECEDE-PROCEED model, recognized for its success in designing health intervention programs [11–13], provides a comprehensive approach by assessing healthcare needs and facilitating program implementation, monitoring, and evaluation. The PRECEDE model focuses on developing a public health program, while the PROCEED component manages its implementation and evaluation, ensuring the systematic addressal of key factors related to the health issue at hand [11].

In the context of our study, we aimed to fill the gaps in knowledge regarding the prevalence and progression of risk factors associated with prediabetes in a specific population of pre-diabetic adults based on the PERSIAN Cohort Study. The PERSIAN Cohort Study is a large-scale, population-based study conducted in Iran that has collected comprehensive health data from a diverse population over several years.

Through our research, we conducted a randomized controlled trial to evaluate the impact of a tailored lifestyle promotion program, guided by the PRECEDE-PROCEED model and incorporating the photovoice method, on self-care behaviors, health outcomes, and the prevention of type 2 diabetes in this specific population. The photovoice method allowed us to actively engage participants, enabling them to document their experiences visually and contribute to the research process by expressing their thoughts and emotions in a more accessible way [14, 15].

In addition to addressing the cultural considerations, language barriers, and health literacy levels of the target population, we collaborated closely with community stakeholders, including healthcare providers, local organizations, and participants. This collaboration ensured the relevance, acceptability, and sustainability of our interventions.

Measurement of self-care behaviors was an important aspect of our study. By assessing and measuring self-care behaviors, such as adherence to medication, monitoring blood sugar levels, following a healthy diet, and engaging in regular physical activity, we aimed to evaluate the effectiveness of our intervention in promoting positive health behaviors among pre-diabetic individuals.

By leveraging the strengths of the PRECEDE-PROCEED model and the photovoice method, our study aimed to develop a comprehensive and effective intervention program that can be adapted and implemented in similar settings. We sought to contribute to the evidence base for preventive interventions in prediabetes, with the goal of reducing the burden of type 2 diabetes and improving the overall health and well-being of individuals at risk.

Ultimately, our research aimed to fill the knowledge gaps regarding prediabetes, provide valuable insights into the experiences and perspectives of the target population, and develop evidence-based interventions that can make a meaningful impact on the prevention and management of type 2 diabetes.

Methods

Trial Design

This study employed a simple randomized controlled trial as part of the research design and evaluation of the effect of a lifestyle promotion program based on the PRECEDE-PROCEED model among pre-diabetics in Hoveizeh city. The study received the ethics code (IR.AJUMS.REC.1397.689) from the Ethics Committee of Ahvaz Jondishapur University of Medical Sciences and the IRCT20171226038083N1 clinical trial code (https://www.irct.ir). Informed written consent was obtained from all participants in accordance with the ethical principles outlined in the Helsinki Declaration. The participants were enrolled in a photo-voice course.

Participants

The pre-diabetic population in Hoveizeh city was identified and selected based on the status of the disease and risk factors associated with non-communicable conditions. This information was extracted from the website of the Hoveizeh Cohort Study Center (cohort.ajums.ac.ir), which is part of the larger PERSIAN cohort study in Iran. The target population consisted of individuals aged 35–70 years residing in urban and rural areas of Hoveizeh city.

Inclusion criteria

The inclusion criteria for this study were as follows: individuals aged 30–75 years who were diagnosed with prediabetes and were willing to participate in the research.

Exclusion criteria

Participants were excluded from the study if they had changed their place of residence outside of Hoveizeh city or if they were unwilling to continue participating. Additionally, individuals with acute or chronic associated diseases such as mental illness, mental retardation, chronic infectious diseases (e.g., tuberculosis), or debilitating motor diseases were also excluded.

Interventions

The control group received standard care according to national guidelines, while the intervention group received a lifestyle modification program based on the PRECEDE-PROCEED model. The intervention included counseling on dietary changes, exercise regimens to achieve and maintain the ideal body weight, and stress management techniques. Environmental experts and health workers participated in workshops to ensure effective delivery of the interventions. Trained personnel provided face-to-face counseling sessions and sent weekly short message service (SMS) reminders to the intervention group participants. The intervention duration was three months, during which participants attended health centers and selected households for the training sessions. The educational content was based on the International Diabetes Federation (IDF) guidelines available online through the World Diabetes Education Center.

Focus Group Discussions

Focus group discussions were conducted with individuals who were pre-diabetic, aiming to gather a diverse range of opinions and perspectives related to the study's topic. For detailed information, please refer to reference [16]. These discussions served two main purposes: first, to collect local terminology used to describe diabetes and its effects, and second, to explore the meanings behind survey findings that could not be statistically explained. Participants received training in using photography as a means to visually depict the impact of personal, social, and community environments on diabetes. They were asked to take 30 photographs in response to the following questions: "What does diabetes mean to you?", "How does diabetes affect you and your family?", and "What obstacles and challenges do you believe individuals with diabetes face?"

Subsequent focus group discussions involved participants selecting five photos from their initial set and sharing stories associated with each photo. Content analysis was then performed to identify common themes among the photographs. The constant comparison technique, in conjunction with Grounded Theory, was utilized to categorize the photos based on the narratives they conveyed. To ensure reliability in the analysis, two research assistants were involved, and internal reviews were conducted.

The presented pictures proved instrumental in determining potential variables, with each participant being assigned a photo index score reflecting the expression of specific concepts. This approach facilitated a deeper understanding of the participants' perspectives and added valuable insights to the study.

Outcomes

The study utilized a questionnaire consisting of several parts to collect data on various outcomes of interest. The questionnaire was designed to assess demographic-economic characteristics, lifestyle factors, quality of life, and factors related to healthy lifestyle and self-care behaviors for diabetes prevention.

Demographic-economic characteristics

The initial section of the questionnaire aimed to collect data on various demographic-economic characteristics that play a significant role in evaluating the study's outcome. Participants were asked to provide information on their age, gender, household size, literacy level (measured by years of education and the highest degree obtained), ethnicity, employment status, household income level, as well as anthropometric indices including height, weight, abdominal circumference, and hip circumference. Additionally, data on blood lipid factors such as fasting blood sugar (FBS), cholesterol, and triglycerides, along with physiological factors like blood pressure, were also gathered. For more detailed information on these factors, please refer to reference [17]. These comprehensive factors were considered essential in assessing the study's outcome effectively.

Lifestyle factors

The second part of the questionnaire focused on lifestyle questions and was further divided into three subscales:

a. Diet Status: This subscale consisted of 11 items assessing participants' dietary habits. Participants responded "yes" if they engaged in a specific dietary behavior or "no" if they did not. The subscale score was calculated based on these responses.
b. Physical Activity: This subscale comprised three items evaluating participants' physical activity levels. Similar to the diet status subscale, participants responded "yes" or "no," and a subscale score was calculated.
c. Stress: The stress subscale consisted of four items measuring participants' perceived stress levels. Responses were recorded as "yes" or "no," and a subscale score was calculated.

Quality of life

The survey's third section included the implementation of the World Health Organization Quality of Life (WHOQOL) standard questionnaire [17]. This validated and reliable questionnaire consisted of 22 questions and measured four

domains: physical health, psychological health, social relationships, and environment. The total score of quality of life was used as the study's criterion of action.

Healthy lifestyle and self-care behaviors for diabetes Prevention

The fourth questionnaire utilized was the PRECEDE model questionnaire about healthy lifestyle and self-care behaviors for diabetes prevention. This questionnaire consisted of different parts of questions related to the PRECEDE model:

a. Predisposing Factors: This section included questions related to knowledge (6 items), attitude (6 items), and self-efficacy (6 items) regarding healthy lifestyle and self-care behaviors for diabetes prevention.
b. Reinforcing Factors: This section consisted of three items related to the role of friends, family, health care staff, and mass media in supporting and reinforcing healthy behaviors.
c. Enabling Factors: This section included questions related to skills (9 items) and resources (9 items) that enable individuals to adopt and maintain healthy lifestyle and self-care behaviors.

The researchers evaluated these factors to determine individuals' readiness and willingness to adopt healthy lifestyle and self-care behaviors for diabetes prevention.

The questionnaire items were developed based on existing validated measures and expert input to ensure their reliability and validity. The data obtained from the questionnaire were analyzed to assess the impact of the lifestyle promotion program based on the PRECEDE-PROCEED model on the measured outcomes.

Sample size

A total of 121 participants were included in each group to detect at least a 25% change in the percentage of glycated hemoglobin before and after the intervention. The sample size calculation considered an alpha level of 0.5%, a power of 80%, and a predicted 20% loss.

Randomization

Participants were divided into intervention and control groups using a simple randomization method with a computer-generated blocked randomization list.

Statistical methods

An intention-to-treat analysis was conducted, which included all participants, including those with missing data. Missing participant data were handled using the latest method of previous observations. Paired t-tests were used to compare values before and after the intervention within each group. An independent t-test was performed to compare the mean differences between the groups. The statistical analysis was conducted using STATA software version 14, with a significance level set at $p < 0.05$.

To analyze the data for factor analysis, the Kaiser-Meyer-Olkin (KMO) sampling index test was performed. The KMO value ranges between 0 and 1, where a higher value closer to 1 indicates better suitability for factor analysis. KMO values below 0.5 indicate insignificant factor analysis (unacceptable), 0.5–0.7 indicate moderate factor analysis, 0.7–0.8 indicate balanced factor analysis, 0.8–0.9 indicate optimal factor analysis, and values greater than 0.9 indicate excellent factor analysis.

Additionally, the Bartlett sphericity test was used to determine whether the correlation matrix obtained from the data significantly differed from zero. This test helped justify the use of factor analysis by evaluating whether there was sufficient correlation among the variables to be integrated. Overall, these statistical methods were employed to analyze the data, assess the impact of the intervention, and evaluate the suitability of factor analysis for the study's variables.

Process evaluation

Throughout the program, participants were regularly assessed to evaluate the implementation of the intervention according to the program framework and to monitor any instances of program withdrawal. This process evaluation involved gathering information from participants regarding the quantity and quality of interventions received. Several metrics were used to track participants' engagement with the program. These included recording the number of visits made to receive program services, the frequency of blood glucose measurements conducted, and the quantity of SMS or emails received by participants. By collecting and analyzing these data points, the process evaluation aimed to assess the extent to which the program was delivered as intended and to identify any patterns of participation or attrition among the participants. This evaluation process provided valuable insights into the program's implementation and allowed for adjustments or improvements to be made as necessary.

Impact evaluation

The main focus of the study was to assess the impact of the intervention on the participants' readiness for change in three key areas: diet, physical activity, and stress control. The primary outcome measure used to evaluate this impact was the percentage of glycated hemoglobin (HbA1c).

To examine the effectiveness of the intervention, the study conducted pre-tests at the beginning of the program and post-tests three months after the completion of the training. These tests aimed to assess the participants' learning and evaluate the continuity of education. It should be noted that the post-test conducted three months after the intervention was deemed particularly significant based on the early output results.

The intervention targeted various factors that influence change, including predisposing, reinforcing, and enabling factors such as psychosocial and behavioral aspects, as well as patient attitudes towards the healthcare system. The expected outcome was an improvement in participants' readiness for change in the specified areas.

By analyzing the changes in HbA1c levels and assessing the participants' readiness for change, the impact evaluation aimed to determine the effectiveness of the intervention in promoting positive health outcomes and sustaining behavior change over time.

Reliability determination

In order to assess the reliability of the questionnaire used in the study, several methods were employed. Firstly, Cronbach's alpha index was calculated during a pilot study involving 30 participants from the study group who were not included in the final survey. The internal consistency of the questionnaire was evaluated using Cronbach's alpha, and no questions were removed due to a lack of internal consistency.

To determine the reliability of stability, a test-retest approach was implemented with a 2-week interval. The test-retest value was calculated, resulting in a correlation coefficient of $r = 0.812$ ($p = 0.0001$). This indicates a high level of reliability over time, suggesting that the questionnaire consistently measures the intended constructs.

In addition, the reliability of the dietary structure was assessed using the halving method. The questionnaire was divided into two halves, and the correlation between the two halves was examined. For the variables in this two-state questionnaire, incorrect answers were given a zero code, while correct answers were given a code of one. The reliability of the construct was then calculated using Spearman and Guttman correlation coefficients.

These reliability determination methods provide confidence in the consistency and stability of the questionnaire, ensuring that it is a reliable tool for measuring the intended variables in the study.

Results

A total of 240 individuals participated in the study, with 121 (50.41%) of them being female (Fig. 1). The comparative analysis between the intervention and control groups revealed slight differences in various parameters. The control group had slightly higher mean weight and height, while the intervention group had higher mean waist and hip circumference. The mean BMI was 27.60 in the intervention group and 28.09 in the control group (Tables 1 and 2).

Table 3 presents the results of FBS, triglycerides, total cholesterol, and blood pressure tests for both the intervention and control groups. The control group showed higher mean FBS, total cholesterol, and systolic blood pressure, whereas the intervention group had higher triglyceride levels and diastolic blood pressure. No significant difference was observed between the two groups regarding the distribution of paraclinical and clinical characteristics (Table 3).

blood pressure, while those under 40 years old had higher mean total cholesterol and triglyceride levels. Academic participants had higher mean total cholesterol, while non-academic participants had higher mean triglyceride, systolic blood pressure, and diastolic blood pressure levels. Among gender-based differences, men had higher mean total cholesterol, systolic and diastolic blood pressures, and triglycerides. Married participants had higher mean total cholesterol, while single and divorced participants had higher mean FBS, triglyceride levels, and systolic and diastolic blood pressures. Apart from diastolic hypertension and marital status, there were no statistically significant differences between paraclinical and clinical characteristics and demographic characteristics (Table 3).

Before the intervention, there was no significant difference in the mean HbA1c between the intervention and control groups ($P = 0.97$). However, three months after the intervention, a statistically significant difference was observed ($P < 0.001$). The paired t-test within the intervention group also showed a significant difference in HbA1c before and after the intervention. The change score index indicated a significant difference between the mean HbA1c of the intervention and control groups before and after the intervention ($P < 0.001$) (Table 3).

Regarding dietary scores, no significant difference was found between the intervention and control groups before the intervention ($P = 0.06$). However, a significant difference was observed between the two groups after the intervention

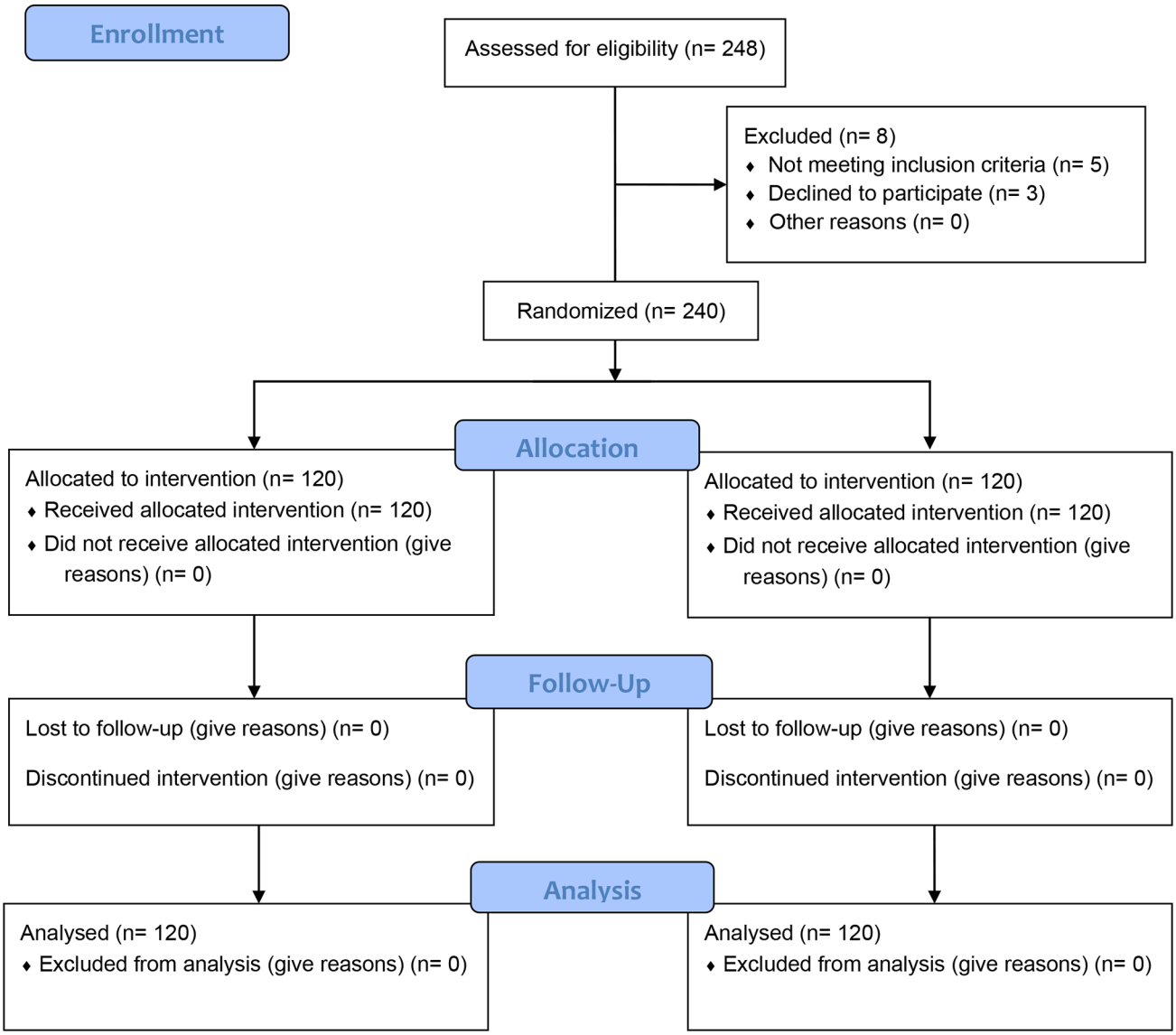

Fig. 1 CONSORT 2010 Flow Diagram

($P < 0.001$). The change score index also showed a significant difference between the two groups before and after the intervention ($P < 0.001$). Stress management training had a considerable impact on the difference between the intervention and control groups ($P = 0.04$) (Table 3).

The mean scores of predisposing factors showed no significant difference between the intervention and control groups before the intervention ($P = 0.3$). However, after the intervention, a statistically significant difference was observed between the two groups ($P < 0.001$) (Table 3).

The mean knowledge score did not significantly differ between the intervention and control groups before the intervention ($P = 0.12$). However, a significant difference was found between the two groups after the intervention ($P < 0.001$). Additionally, there was a substantial difference in the mean knowledge score before and after the intervention within the intervention group ($P > 0.001$) (Table 3). Similarly, the mean attitude score did not significantly differ between the intervention and control groups before the intervention ($P = 0.19$). However, after the intervention, a significant difference was observed between the two groups ($P < 0.001$). There was also a substantial difference in the mean attitude score before and after the intervention within the intervention group ($P < 0.001$) (Table 3).

The mean score of enabling factors showed a statistically significant difference in pre-diabetic individuals within the intervention group before and after the intervention, whereas no such difference was observed in the control group ($P = 0.02$). Although the intervention group showed an increase in mean quality of life, there was no significant

Table 1 Basic characteristic of patients

Group Variables		Intervention (n = 120)	Control (n = 120)	P-value
Age, year (N (%))	≤45	36 (30)	38 (31.6)	0.78
	45–70	84 (70)	82 (68.3)	
Sex, male (N (%))	Male	22 (18.3)	18 (15)	0.48
	Female	98 (81.6)	102 (85)	
Number of household members (N (%))	≤4	61 (50.8)	58 (48.3)	0.70
	4 <	59 (49.1)	62 (51.6)	
Marital status (N (%))	Single	2 (1.6)	4 (3.3)	0.41
	Married	118 (98.3)	116 (96.6)	
profession (N (%))	Farmer	30 (25)	25 (20.8)	0.27
	Housewife	59 (49.1)	58 (48.3)	
	Employee	19 (15.8)	15 (12.5)	
	Other	12 (10)	22 (18.3)	
Education (N (%))	Illiterate	67 (55.8)	64 (53.3)	0.59
	Primary	26 (21)	25 (20.8)	
	Guidance	10 (8.3)	8 (6.6)	
	Diploma	6 (5)	8 (6.6)	
	Bachelor and higher	2 (1.6)	8 (6.6)	
Weight, Mean ± SD		75.94	77.44	0.33
Height, Mean ± SD		166.17	166.54	0.75
Waist, Mean ± SD		97.68	95.15	0.05
Hip circumference, Mean ± SD		103.84	101.33	0.08
BMI, Mean ± SD		27.60	28.09	0.42

Table 2 Frequency and percentage of cases in ten thousand participants of Hoveyzeh Cohort Study Center

Group Variables	Number (%)	Diagnostic criteria
Diabetes	1580 (15.8)	Self-declaration
High blood pressure	2110 (21.1)	
Ischemic heart disease	1190 (11.9)	
Heart attack	160 (1.6)	
Stroke	150 (1.5)	
Kidney failure	80 (0.8)	
History of gestational diabetes	340 (3.4)	
History of gestational hypertension	510 (5.1)	
Smoking	2220 (22.2)	
Drug use	210 (2.1)	
Alcohol consumption	190 (1.9)	
Diabetes	1640 (16.4)	FBS test 126 and above
Pre-diabetes	2094 (20.94)	FBS test between 100 and 125

difference observed between the two groups before and after the intervention or within each group (P = 0.8) (Table 3).

Figures 2 and 3 depict the amount of change in HbA1c and FBS, respectively. The absolute difference in HbA1c was statistically significant, indicating improvement. However, there was no significant improvement observed in FBS.

Discussion

Integrating diabetes prevention programs into the busy lifestyles of the community poses a significant challenge. People need to learn how to adapt to the demands of modern life and embrace empowerment related to a healthy lifestyle. Effective health promotion programs require a thorough assessment of community needs and specific groups, taking into account patients' perceptions.

The results of the present study align with previous research. Torres et al. [18] conducted a randomized clinical trial and found that the intervention group showed

Table 3 Comparison of scores of pre-diabetic individuals in the Intervention and control groups before and after the intervention

Group Variables		Intervention group (n = 120)	Control group (n = 120)	P-value
Fasting blood sugar, Mean ± SD		112.50 ± 6.57	113.77 ± 7.03	0.15
Triglyceride, Mean ± SD		183.23 ± 101.7	179.27 ± 129.18	0.79
Total cholesterol, Mean ± SD		191.56 ± 42.76	195.72 ± 38.59	0.43
Systolic blood pressure (SBP), Mean ± SD		113.92 ± 16.87	115.58 ± 13.63	0.40
Diastolic blood pressure (DBP), Mean ± SD		73.33 ± 9.64	73.17 ± 7.99	0.88
HbA1c, Mean ± SD	Before	5.92 ± 0.17	5.92 ± 0.19	< 0.001
	After	5.81 ± 0.15	5.92 ± 0.18	
Mean dietary scores, Mean ± SD	Before	22.64 ± 2.79	23.27 ± 2.37	< 0.001
	After	26.24 ± 2.14	23.55 ± 2.77	
Stress management training, Mean ± SD	Before	11.98 ± 4.23	11.11 ± 1.4	0.04
	After	12.34 ± 3.85	11.26 ± 4.14	
mean quality of life, Mean ± SD	Before	58.91 ± 11.57	57.56 ± 9.04	0.8
	After	59.19 ± 10.15	57.77 ± 8.47	
Predisposing factors, Mean ± SD	Before	31.26 ± 4.42	30.2 ± 5.15	< 0.001
	After	31.62 ± 3.99	30.31 ± 4.88	
Attitude score, Mean ± SD	Before	34.02 ± 4.61	38.12 ± 3.92	< 0.001
	After	33.27 ± 4.04	33.55 ± 4.05	
Knowledge, Mean ± SD	Before	15.97 ± 3.56	16.68 ± 3.55	< 0.001
	After	22.06 ± 3.83	16.7 ± 3.7	
Enabling factors, Mean ± SD	Before	34.81 ± 6.09	35.54 ± 6.45	0.02
	After	35.67 ± 5.65	35.84 ± 5.57	

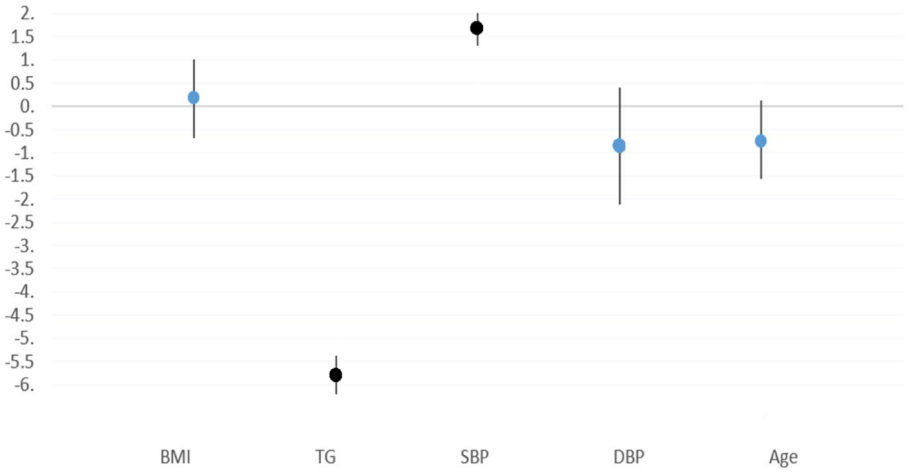

Fig. 2 Important determination of modification effects of HbA1C in PERSIAN Cohort prediabetic subgroup. Black circles indicate that associations are significant. Error bars indicate 95% CI.

significantly lower mean HbA1c levels at T3, T6, and T9 ($p < 0.05$). Norris et al. [19] conducted a meta-analysis of eight clinical trials and concluded that self-care learning interventions with 1–3 months of follow-up can lead to a reduction in HbA1c levels in adults with type 2 diabetes. Duke et al. [20], in their systematic review, reported that education programs for patients with type 2 diabetes resulted in reduced HbA1c levels.

In this study, the PRECEDE-PROCEED model provided a framework for understanding the factors influencing behavior, such as predisposing factors (knowledge, attitude, etc.), reinforcing factors (family, peers, etc.), and enabling factors (resources, skills, etc.), in the context of training diagnosis [21].

Similar to public education, health training aims to change people's knowledge, attitudes, and behaviors. The behavioral aspect of health education is crucial, and understanding the underlying reasons for specific behaviors is essential. Furthermore, cultivating a favorable inclination to engage in desired behaviors is as important as knowledge [22].

The results of our study demonstrated the positive effect of training interventions based on the PRECEDE-PROCEED model on predisposing factors, including knowledge,

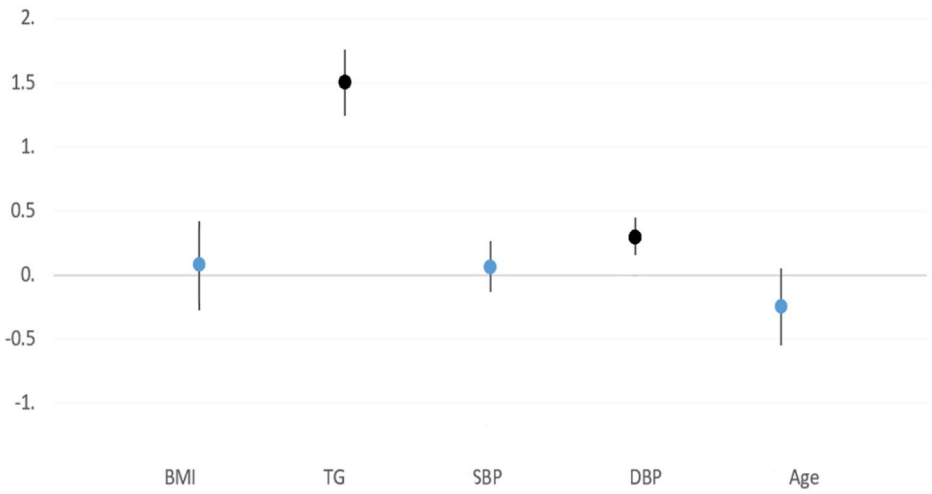

Fig. 3 Important determination of modification effects of FBS in PERSIAN Cohort prediabetic subgroup. Black circles indicate that associations are significant. Error bars indicate 95% CI.

attitude, and self-efficacy. These findings are consistent with previous studies. Chiang et al. [23] and Moshki et al. [24], reported an increase in knowledge and attitude scores following interventions based on the PRECEDE-PROCEED model, which aligns with the findings of our study. Similarly, studies by Myung T. Kim et al. [25] and Barasheh [26] found that interventions using the PRECEDE-PROCEED model resulted in increased knowledge, attitude, and self-efficacy in the intervention group. These studies further support our findings regarding the positive impact of the PRECEDE-PROCEED model on knowledge, attitude, and self-efficacy.

The results of our study revealed a significant difference in enabling factors between the intervention and control groups after the intervention, as well as within the intervention group before and after the intervention. These findings are consistent with previous studies conducted by Taghdisi et al. [27], Nazari [28], Dehdari [29], and Hosseini [30]. These studies support the notion that enabling factors play a crucial role in facilitating behavioral changes. Additionally, lifestyle modifications and appropriate dietary choices have been shown to be effective in preventing the progression of prediabetes to diabetes, which aligns with the positive effect of the intervention on dietary changes observed in the study by Moshki et al. [24].

In a study by Chen et al. [31], which aimed to evaluate the effectiveness of a training empowerment program for individuals with prediabetes, significant improvements in self-efficacy were observed in the intervention group compared to the control group ($P<0.01$). However, this study did not find a positive effect of using the PRECEDE-PROCEED model on increasing knowledge [32]. While our study aligns with the findings regarding the positive impact on self-efficacy, it suggests that further research is needed to explore the relationship between the PRECEDE-PROCEED model and knowledge improvement in individuals with prediabetes.

Improving the quality of life is a long-term process. Although there was an increase in the mean quality of life score in the intervention group, no significant difference was found between the two groups or within each group before and after the intervention ($P>0.05$). These results are consistent with studies by Litaker [33] and Taghdisi [28]. However, other studies by Myung et al. [25], Shams et al. [34], and Babazadeh et al. [35] reported significant improvements in quality of life. The discrepancy in findings may be attributed to the shorter duration of the intervention assessment in our study.

The present study had certain limitations that should be acknowledged. First, the sample size was relatively small, which may limit the generalizability of the findings. Additionally, the follow-up period was relatively short, with only three months after the intervention, which might not capture long-term effects. These limitations should be taken into consideration when interpreting the results. The external validity and applicability of the trial findings should be considered. While the study was conducted in a specific setting and with a specific population, the results can provide insights into the effectiveness of training interventions for pre-diabetic individuals. However, caution should be exercised when generalizing the findings to other populations or settings. Further research with larger sample sizes and diverse populations is needed to enhance the generalizability of the findings. The interpretation of the results should be consistent with the findings of the study. The positive effects of the training intervention based on the PRECEDE-PROCEED model on predisposing factors, such as knowledge, attitude, and self-efficacy, are supported by the results. These findings align with previous studies that have demonstrated the efficacy of training programs in improving

self-care and quality of life in patients with type 2 diabetes. However, it is important to balance the benefits and harms of the intervention and consider other relevant evidence in order to provide a comprehensive interpretation.

Overall, while the study has provided valuable insights into the effectiveness of the training intervention, it is important to acknowledge the limitations, consider the generalizability of the findings, and interpret the results in a manner that takes into account the balance of benefits and harms, as well as the existing body of evidence. Future research should address these limitations and further explore the impact of training interventions on self-care behaviors in pre-diabetic individuals, using larger sample sizes and longer follow-up periods.

Conclusion

In conclusion, training interventions are highly effective in improving self-care and quality of life in patients with type 2 diabetes. The findings of this study suggest that the PRECEDE-PROCEED model provides a suitable framework for training pre-diabetic individuals and patients with type 2 diabetes, thereby promoting self-care behaviors. Based on these results, it is recommended to design comprehensive and well-planned training programs on self-care behaviors for patients and high-risk individuals, such as pre-diabetic individuals, in health houses and health centers. Increasing psychological support from the families and communities of diabetic and pre-diabetic patients can influence their perception of self-care, leading to improved quality of life and increased active years. Moreover, the use of new training models, appropriate infrastructures, and adequate facilities can further enhance the effectiveness of interventions for high-risk individuals such as pre-diabetics.

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Declarations

Competing Interests The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Consent to participate Informed consent was obtained from all individual participants included in the study.

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