Impact of lifestyle intervention among prediabetic individuals

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Prediabetes is a stage before diabetes that refers to impaired fasting glucose or impaired glucose tolerance, or a combination of both. Sedentary work and unhealthy food patterns lead to prediabetes, and lifestyle modification is important. Hence the present study focuses on the impact of lifestyle intervention among prediabetic persons. One hundred and twenty-five people, excluding patients diagnosed with diabetes, from the Arthur Asirvatham Hospital in Madurai, Tamil Nadu, India were selected for the study. Demographic details were collected and anthropometric measurements like height, weight, body mass index and waist–hip ratio were made. The blood samples were analysed for fasting blood sugar, postprandial blood sugar, glycosylated haemoglobin, lipid profile and urine samples for urine microalbuminuria. Blood pressure was also measured. The participants were given a strict diet and exercise chart, after which they were followed up for six months. The collected data were analysed using appropriate statistical methods. Of the 125 prediabetes subjects enrolled, the mean age was 41.65 ± 7.56 years, with 71.2% male and 28.8% female. The mean height of the patients throughout the study was 159 ± 10.04 (cm). Overall there was a statistically significant reduction in weight (65.3 ± 13.24–64.4 ± 12.86 kg), body mass index (25.8 ± 4.42 to 25.5 ± 4.29 kg/m^2), fasting (111 ± 10.42 to 107 ± 8.5 mg/dl), postprandial blood sugar (159 ± 19.35 to 152 ± 18.8 mg/gl) and glycosylated haemoglobin (5.8 ± 0.18% to 5.7 ± 0.2%) between baseline and various follow-up visits ($P < 0.05$). Lifestyle intervention had a greater impact on lipid profile and no change in urine microalbuminuria in baseline and final visits. The study concludes that lifestyle intervention significantly impacts prediabetic subjects to avoid type-2 diabetes and its complications.

Keywords: Blood glucose, diet, exercise, lifestyle, prediabetes.

PREDIABETES is defined as the stage before diabetes with higher blood glucose concentration than normal, but lower than established thresholds for diabetes[1]. It is also known as 'impaired fasting glucose' or 'impaired glucose tolerance'[2]. If the fasting blood glucose level is between 100 and 125 mg/dl or the glycosylated haemoglobins is between 5.7% and 6.4% or 2 h blood glucose level is between 140 and 199 mg/dl in oral glucose tolerance, then it is diagnosed as prediabetes. It is reported that around 5–10% of people with prediabetes progress to diabetes every year. The number of diabetic persons worldwide in 1995 was around 135 million; this is predicted to increase to over 300 million in 2025. It is a warning signal for those who do not follow lifestyle modification. Prediabetes is associated with a high risk of developing diabetes and other complications[3]. However, it has been reported that prediabetes is positively impacted by diet and exercise[4].

Lifestyle intervention is defined as any intervention or changes in day-to-day activities like physical workouts and diet. Lifestyle modifications such as weight loss, an active lifestyle and a healthy diet can be suggested to prevent type-2 diabetes and cardiovascular disease in prediabetic individuals. Early diagnosis and lifestyle interventions for patients with prediabetes can prevent or delay the disease progression, improve health conditions and reduces diabetes complications[5]. An analysis conducted during 2005–06 through the National Health and Nutrition Examination Survey (NHANES) found that prediabetic individuals adopting a healthy lifestyle with weight control and diet modification showed better outcome[6].

Moreover, diabetes prevention programmes have shown that lifestyle intervention involving calorie restriction and exercises to promote weight loss significantly reduced the progression of prediabetes to type-2 diabetes by about 58% (ref. 7). Considering the tremendous growth of Madurai city, Tamil Nadu, India, in the present times with many lifestyle changes, the present study was carried out with a focus on lifestyle modification and its impact among prediabetic individuals. About 18.6% of the total population in Tamil Nadu was reported to have diabetes in 2006. This increased to 21.9% in 2016, with the prevalence of prediabetes being 19.0% (ref. 8). The last survey carried out in all pincode areas of Madurai city revealed disturbing results (*The Hindu*, 13 February 2013). The survey carried out by A. J. Asirvatham at Department of Diabetology, Government Rajaji Hospital, Madurai during 2011–12.

Material and methods

Selection of participants

A total of 125 prediabetic participants (male = 89, female = 36) aged between 18 and 50 from Arthur Asirvatham Hospital in Madurai were selected for this cross-sectional

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study. The participants included only those who were not diagnosed with diabetes. Since the rise in the number of diabetic patients and their risk of developing other complications such as cardiovascular disease, nephropathy, retinopathy, etc. was evident, early diagnosis and treatment, along with appropriate lifestyle interventions, can be effective in controlling the increase in diabetic cases. The participants were informed about the details of the study. It was carried out between March 2020 and March 2021, with the participants' consent and clearance from the ethics committee. The demographic profile of the participants, such as age, sex, education, occupation and income, was collected.

Anthropometric measurements

Anthropometric measurements, including height, weight, waist circumference and hip circumference of the participants, were taken before and after the study. Height (cm) of the subjects was measured using a stadiometer. Their body weight (kg) was measured using a digital weighing scale. The weights were recorded to the nearest 0.5 kg. Waist and hip measurements (cm) were taken using a measurement tape.

Body mass index (BMI) or Quetelet's index and waist–hip ratio (WHR) were calculated using the standard formula.

$$\text{BMI} = \text{Weight (kg)}/\text{height (m}^2\text{)}.$$

$$\text{WHR} = \text{Waist measurement (cm)}/\text{hip measurement (cm)}.$$

Biochemical investigations

Blood and urine samples of the participants were collected during initial visits in the study period of six months. The blood samples were analysed for fasting and postprandial blood sugar, glycosylated haemoglobin and lipid profile. The urine samples were used to determine urine microalbuminuria. The tests for fasting and postprandial blood glucose estimation by hexokinase method and estimation of glycosylated haemoglobin by immunoturbidimetry method were conducted in the Hospital laboratory.

Lifestyle interventions

The main aim of dietary interventions is to include low-calorie, low-fat, low-carbohydrate and high-fibre-rich foods in the daily diet of people, viz. 55% carbohydrates, 25% protein and 20% fat[9]. Further, the consumption of sweets, fried items, cold beverages, fast food and junk food should be cut down. Limited intake of chicken and fish in a gravy form, consumption of egg white twice weekly, proper intake of mid-morning snacks, maintaining regular food timings, avoiding food at parties and functions can also reduce the risk of diabetes. These can be substituted by insisting on consuming more vegetables and low-calorie snacks like cucumber, buttermilk, popcorn, vegetable salad, etc.

A counselling session on lifestyle interventions in prediabetes was provided to the participants for a time period of six months on their monthly visit for follow-up. Further telephonic counselling was also provided at an interval of 15 days of regular follow-up. During the counselling sessions, the participants were encouraged to follow a strict prediabetic diet for six months consisting of low-calorie, low-carbohydrate, high-fibre, low-fat, normal proteins, vitamins and minerals. They also learnt about food exchange lists and foods with low glycaemic index. Each participant was given a printed prediabetic diet chart to follow on a regular basis. The participants were urged to engage in regular 30 min physical activity such as walking, swimming, jogging, running, dancing and playing at least five days a week, as recommended by the World Health Organization[10]. They were given an exercise chart and the need of physical activity was highlighted.

Measurement of blood pressure

Blood pressure of all the participants was measured using a sphygmomanometer during their initial to the final visits.

Calibrated tools

Calibrated stadiometer, weighing scale, centrifuge and sphygmomanometer were used for the study.

Analysis of data

For weight change, BMI, WHR, fasting and postprandial blood sugar levels, lipid profile, and glycosylated haemoglobin, the data collected from the participants were tabulated, analysed and interpreted using appropriate statistical methods. STATA version 14 (Texas, USA) was used for analysis. The normality of the data was checked using the Shapiro–Wilk test and if the data were non-normal, the corresponding non-parametric test was applied. The collected data were presented with a mean (SD) and frequency (%), and were analysed using repeated measures ANOVA and Friedman test for comparison between various follow-ups. Wilcoxon sign rank test was used to compare the baseline and final follow-up visit of BMI and glycosylated haemoglobin. P-values <0.05 were considered statistically significant.

Results

The final analysis revealed that none of the 125 participants had developed diabetes.

Baseline characteristics

Table 1 gives the baseline demographic characteristics of the selected participants and Table 2 shows the anthropometric

and biochemical characteristics. The mean age of the participants was observed to be 41.65 ± 7.56 years. Majority of the participants were male (71.2%, $n = 89$) and most of them (88.8%, $n = 111$) were married. There were 64 undergraduates and 24 postgraduates among them. They belonged to the upper class and were doing business or working in the private sector. The mean (SD) BMI was found to be 25.89 (± 4.42) kg/m^2. Based on the glycaemic indicators, 4.0% had impaired fasting glucose, 4% had impaired glucose tolerance and 92% had both. The mean glycosylated haemoglobin was 5.84% (±0.18), with range being 5.7–6.4%. Fasting blood sugar was 111.12 mg/dl (±10.42), with the range 100–125. The postprandial plasma glucose was 159.04 mg/dl (±19.35), with a range 93–190 mg/dl. The mean (SD) systolic blood pressure of the participants from their initial to final visit had decreased from 129 (±18.36) to 124 (±18.1) mm Hg. The diastolic blood pressure had also decreased from 80 (±9.94) to 74 (±893) mm Hg. Slight changes in reduction of blood pressure were observed, with $P < 0.0001$ in the Wilcoxon signed rank test.

Among the selected prediabetic participants, it was found that 28% were obese, 37% were overweight and none had a high lipid profile range.

Table 1. Baseline characteristics

Parameter	N (%) $N = 125$
Personal details	
Gender	
Male	89 (71.2)
Female	36 (28.8)
Age (yrs)	
Mean (SD)	41.65 (7.56)
Range	18–50
Marital status	
Married	111(88.8)
Unmarried	14 (11.2)
Socio-economic factors	
Education level	
Primary/SSLC	22 (17.6)
Higher secondary	11 (8.8)
UG	64 (51.2)
PG	24 (19.2)
Higher education	4 (3.2)
Occupation	
Agriculture	4 (3.2)
Business	32 (25.6)
Government officer	11 (8.8)
Homemaker	31 (24.8)
Labour	12 (9.6)
Private sector	28 (22.4)
Others	7 (5.6)
Monthly income	
Mean (SD)	20547.01 (8515.45)
Range	7500–48000
Socio-economic status	
Upper class	124 (99.2)
Upper–middle class	1 (0.80)
Anthropometric assessment	
Height (cm)	
Mean (SD)	159 (10.04)
Range	135–178
Weight (kg)	
Mean (SD)	65.31 (13.24)
Range	37–110
BMI	
Mean (SD)	25.84 (4.42)
Range	14.9–40.3
Waist (cm)	
Mean (SD)	67.94 (26.95)
Range	58–122
Hip (cm)	
Mean (SD)	69.53 (27.93)
Range	63–118
Waist–hip ratio (WHR)	
Mean (SD)	0.996 (0.16)
Range	0.50–1.84

Comparison of anthropometric measurements between different follow-up visits

Weight, WHR and BMI of the participants were compared between different visits (Table 3). The mean weight and

Table 2. Clinical assessment

Parameter	N (%) $N = 125$
Fasting blood sugar (FBS; mg/dl)	
Mean (SD)	111.12 (10.42)
Range	100–124
Post prandial plasma glucose (PPG; mg/dl)	
Mean (SD)	159.04 (19.35)
Range	93–190
HbA1C (%)	
Mean (SD)	5.8 (0.18)
Range	5.7–6.4
Microl (mg/l)	
Mean (SD)	8.35 (5.11)
Range	3–19
Lipid profile (mg/dl)	
Total cholesterol (TC)	
Mean (SD)	160.52 (31.59)
Range	100–290
LDL	
Mean (SD)	63.35 (19.43)
Range	49–98
HDL	
Mean (SD)	58.77 (9.24)
Range	32–55
Triglycerides (TGL)	
Mean (SD)	120.42 (25.98)
Range	45–150
GTT	
IFG	5 (4.0)
IFG + IGT	115 (92.0)
IGT	5 (4.0)
Systolic blood pressure (BP)	
Mean (SD)	129 (18.36)
Range	99–185
Diastolic blood pressure	
Mean (SD)	80 (9.94)
Range	60–105
Pulse rate	
Mean (SD)	77 (5.95)
Range	70–90

Table 3. Comparison of parameters between different follow-up visits

Variables	Month 1 (baseline) Mean (SD)	Month 2 Mean (SD)	Month 3 Mean (SD)	Month 4 Mean (SD)	Month 5 Mean (SD)	Month 6 Mean (SD)	*P*-value
Weight (kg)	65.3 (13.24)	65.2 (13.23)	65.2 (13.23)	65.2 (12.96)	65.1 (12.09)	64.4 (12.86)	<0.0001 (S)[A]
BMI (kg/m^2)	25.8 (4.42)					25.5 (4.29)	<0.0001 (S)[A]
WHR	0.9 (0.16)	0.9 (0.16)	0.9 (0.167)	0.9 (0.167)	0.9 (0.167)	0.9 (0.167)	<0.0001 (S)[F]
FPS (mg/dl)	111 (10.42)	112 (9.36)	109 (9.7)	108 (8.9)	107 (7.9)	107 (8.5)	<0.0001 (S)[F]
PPG (mg/dl)	159 (19.35)	159 (20.1)	157 (19.73)	155 (19.53)	152 (17.6)	152 (18.8)	<0.0001 (S)[F]
HbA1C (%)	5.8 (0.18)	–	–	–	–	5.7(0.2)	<0.0001 (S)[W]
Microalbuminuria (mg/l)	8 (5.11)	–	–	–	–	8 (4.96)	<0.0001 (S)[W]
TC (mg/dl)	161 (31.59)	–	–	–	–	159 (30.5)	<0.0001 (S)[W]
LDL (mg/dl)	83 (19.43)	–	–	–	–	80 (19.14)	<0.0001 (S)[W]
HDL (mg/dl)	49 (9.2)	–	–	–	–	49 (9.1)	<0.0001 (S)[W]
TGL (mg/dl)	120 (25.98)	–	–	–	–	119 (24.62)	<0.0001 (S)[W]
BP (mmHg; systolic/diastolic)	129/80 (18.36/9.94)	–	–	–	–	124/74 (18.1/8.93	<0.0001 (S)[W]

A, ANOVA test; F, Friedman test; W, Wilcox signed rank test; $P < 0.05$ considered statistically significant.

WHR were found to be different during various visits. The difference was statistically significant with $P < 0.0001$. Comparison of mean weight from baseline to six months and mean BMI between different follow-ups showed slight variations in weight from 65.31 (±13.24) to 64.44 kg (±12.86). Through repeated ANOVA tests, it was found that BMI changed from 25.84 (±4.42) to 25.48 kg/m^2 (±4.29) with a statistically significant difference of $P < 0.0001$. Similarly, mean waist and hip circumferences were compared separately between different visits. It was shown that there was a statistical significance of $P < 0.0001$ and WHR changed from 0.996 (±0.16) to 0.992 (±0.167) cm, which was also shown using the Friedman test.

Comparison of biochemical investigations between different follow-up visits

Lifestyle intervention in the participants showed an improvement in fasting plasma glucose that decreased from 111.11 (±10.42) to 106.69 (±8.5) mg/dl after six months with a *P*-value < 0.0001. Similarly, the postprandial plasma glucose was observed to change from 159.04 (±19.35) to 152.52 (±18.8) mg/dl and glycosylated haemoglobin decreased from 5.84 (±0.18)% to 5.75 (±0.2)%. Notable reductions were seen in the lipid profile from baseline to the sixth month, and no effect was noticed in the urine microalbuminuria (8 mg/l) till the end of the study. From the baseline to the six months a significant decrease was also observed in glycated haemoglobin, fasting plasma glucose, postprandial plasma glucose, low-density cholesterol and triglyceride levels, though they were normal.

Comparison of nutrient intake and exercise with other variables

From the initial to the final visits, the mean nutrient intake was reduced from 1612.14 (±172.92) to 1524.704 (±243.83) calories in energy, 269.33 (±21.59) to 265.84 (±25.32) g in carbohydrate, 22.49 (±4.98) to 22.54 (±9.88) g in fat and 46.18 (±4.99) to 44.008 (±5.20) g in protein intake. However, fibre consumption was also reduced from 34.97 (±5.68) to 33.79 (±5.26) g. Most of the participants took up walking as their daily physical workout. It was found that they adhered to the diet and exercise schedule. Another remarkable finding of the study was that there was a reduction in total energy intake, as well as carbohydrates and, fat from baseline to six months, reflected in the improved weight reduction and glycaemic parameters.

Discussion

The most important aim of this lifestyle intervention study was to prevent the progression of the participants from prediabetic to type-2 diabetes mellitus. Our results indicated a significant reduction in the fasting plasma glucose 2 h postprandial plasma glucose, glycated haemoglobin A1C, waist circumference, blood pressure and cholesterol over the six months study period.

In the present study, the mean age of the participants was 41.65 years. The results of the present study are similar to other studies reported in the literature[8,11].

The degree of weight loss was less than 1% [0.72] in the present study at the completion of six months which was achieved through a strict diabetic diet – low calorie and low fat – with regular exercise. This was similar to the weight reduction of 0.93% in a study by Alfawaz *et al.*[12], a modest reduction in BMI of 0.32 kg/m^2 at six months in a randomized controlled study conducted among Arab prediabetic individuals[13] and 0.86–1.6 kg/m^2 reduction in BMI in the Co-HELP study conducted by Ibrahim *et al.*[14]. This modest reduction was due to less consumption of high fibre-rich foods, like green leafy vegetables, whole greens, cereals and pulses. In the present study, prediabetic individuals were advised strict diet and exercise plan for six months. If the same continues for a longer period, more positive results can be gained. Many randomized controlled trials and intervention studies confirmed that individual planning

of diet with prediabetic individuals significantly reduced the risk of type-2 diabetes[15,16]. In the present study, mean weight reduction and BMI reduction are contrary to those of Kaur *et al.*[11], who reported a mean weight reduction of 3.9 kg and BMI of 1.6 kg/m^2. Also, the mean weight reduction was not significant compared to previous studies conducted in Western countries. This might be due to the lower baseline BMI (<30.0) in the present study that corresponds to moderate weight reduction[17,18]. The mean change in waist and hip circumferences was nil in the present study, similar to that reported by Kulkarni *et al.*[19].

With regard to HbA1c, the present study showed a 0.1% reduction compared to the study conducted by Kulkarni *et al.*[19], who noticed minor changes occurring after six months might be due to the short follow-up period and they mentioned that we could expect better improvement in HbA1c only in a long-term study. In the present study, the improvement in the mean fasting plasma glucose was about 4 mg/dl (3.21%) and plasma glucose postprandial 7 mg/dl (5.61%) from the initial to final visit. This might be because consuming a low-calorie, low-carbohydrate, low-fat diet which showed comparable results of (HbA1c – 0.2%, Fasting Plasma glucose – 4.1 mg/dl) in the study conducted among prediabetic in Saudi Arabia[11,13]. There was no change in urine microalbuminuria among the participants. Thus the study strongly reflects that there is no early nephropathy condition among the prediabetic subjects from the initial to final visit. There was no abnormal lipid profile in the study groups; however, there was some reduction in the serum total cholesterol, low density lipoproteins, triglycerides and no change in high density lipoprotein. This may be due to a low-fat diet, consumption of less oil in regular preparation of food, restriction of red meat and deep-fried food, similar to the results of a study by Campbell *et al.*[20] dealing with a plant-based lifestyle programme.

Studies have reported that participants in the 18–50 age group had the lowest baseline waist circumference, weight, BMI, fasting plasma glucose and 2 h postprandial blood glucose[21]. Recent meta-analysis studies also showed that a low-carbohydrate diet improves glycaemic profile events along with weight change in a short period[22]. It was also reported that when compared to weight reduction, lifestyle intervention was more effective in preventing diabetes[13]. There was a mean reduction in the intake of total calories, carbohydrates, fat and fibre. Along with regular exercise, a marked improvement in the glycaemic profile and lipid profile of the participants was observed in the present study, which is in agreement with a study done at health centres in New Zealand where diet advice and exercise counselling given for six months showed an improvement in glycaemic profile[23]. Nearly all the participants walked for at least 30 min daily as advised. The results observed were similar to those from a study conducted among Japanese patients with prediabetes, which reported that light-intensity physical exercise is essential for the management of prediabetes[24].

The reduction of 4% in systolic blood pressure found in our study group was similar to the study conducted by Ibrahim *et al.*[14], among adults with prediabetes in developing countries.

Adherence to strict dietary patterns and exercise needs to be emphasized in future studies by spending more time with the study subjects, identifying their difficulties and challenges and motivating them.

Conclusion

It has been noted that the lifestyle interventions followed in the present study will have an influence in the long run, as the six months study showed only slight variations from baseline to final visits.

The strength of the present study includes conducting diabetes awareness programmes once a month and monitoring blood glucose levels regularly with follow-ups for adhering to lifestyle modification through diet, regular exercise, meditation and avoiding junk and fast food. Various behavioural treatment protocols, motivation and education about healthy food choices had to be promoted for healthier eating habits and to increase physical activity. The main limitation of this study is the small sample size.

Conflict of interest: None.

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