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Improvement in diet habits, independent of physical activity helps to reduce incident diabetes among prediabetic Asian Indian men

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ABSTRACT

Aims: To assess the beneficial effects of the components of lifestyle intervention in reducing incidence of diabetes in Asian Indian men with impaired glucose tolerance (IGT) in India.

Methods: This analysis was based on a 2 year prospective, randomized controlled primary prevention trial in a cohort of Asian Indian men with IGT ($n = 537$) (Clinical Trial No: NCT00819455). Intervention and control groups were given standard care advice at baseline. Additionally, the intervention group received frequent, mobile phone based text message reminders on healthy lifestyle principles. Dietary intake and physical activity habits were recorded by validated questionnaires. The lifestyle goals were: reductions in consumption of carbohydrates, oil, portion size and body mass index of at least 1 unit (1 kg/m^2) from baseline and maintenance of good physical activity. The association between diabetes and lifestyle goals achieved was assessed using multiple logistic regression analyses. Changes in insulin sensitivity (Matsuda's insulin sensitivity index) and oral disposition index during the follow-up were assessed.

Results: At the end of the study, 123 (23.8%) participants developed diabetes. The mean lifestyle score was higher in the intervention group compared with control (2.59 ± 1.13 vs. 2.28 ± 1.17; $P = 0.002$). Among the 5 lifestyle variables, significant improvements in the 3 dietary goal were seen with intervention. Concomitant improvement in insulin sensitivity and oral disposition index was noted. Higher lifestyle score was associated with lower risk of developing diabetes (odds ratio: 0.54 [95% CI: 0.44–0.70]; $P < 0.0001$).

Conclusions: Beneficial effects of intervention were associated with increased compliance to lifestyle goals. The plausible mechanism is through improvement in insulin sensitivity and beta cell preservation.

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Abbreviations: BMI, body mass index; DPP, Diabetes Prevention Programme; DPS, Finnish Diabetes Prevention Study; IDRF, India Diabetes Research Foundation; IGT, impaired glucose tolerance; IFG, impaired fasting glucose; NCD, non communicable diseases; OGTT, oral glucose tolerance test; WHO, World Health Organization.

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1. Introduction

The rising prevalence of common behavioural risk factors, namely poor diet, lack of physical activity, tobacco use and excessive alcohol consumption are associated with increased prevalence of diabetes, cardiovascular diseases, cancer and chronic pulmonary diseases. These diseases account for nearly 80% of deaths from non-communicable diseases (NCD), especially in developing countries [1]. Several randomized controlled trials in white populations [2,3] and in Asians [4–7] have successfully demonstrated that by controlling these lifestyle risk factors, it is possible to prevent or postpone development of type 2 diabetes in prediabetic participants. In western populations, the beneficial changes were largely associated with weight reduction [2,3], whereas in Asian populations the benefit of lifestyle intervention occurred independent of weight loss [4,6,7]. The components of lifestyle intervention that are responsible for the reduced incidence of diabetes have not been studied in detail in Asian Indians and this analysis has focused on this aspect.

2. Materials and methods

The present analysis is based on a primary prevention trial done in a cohort of Asian Indian men with impaired glucose tolerance (IGT) at baseline in south-east India between August 10, 2009, and November 30, 2012 [7]. The study design, methods, recruitment and characteristics of the study participants have been reported previously [7]. Briefly, all the participants had IGT at baseline on an initial testing with a 2 h post glucose capillary blood glucose followed by a confirmatory oral glucose tolerance test (OGTT) done within a week. During the second test, we collected venous blood samples at fasting, 30 min and 2 h after 75 g glucose ingestion. The eligible participants were randomly assigned to either the control group ($n = 266$) in which the participants received personalized standard advice and also printed educational information on healthy lifestyle practice only at baseline. The intervention group ($n = 271$) in addition, received frequent reminders on healthy lifestyle principles through automated, mobile-phone based text messages (SMS) for two years. Both the control and intervention groups received one-to-one, identical, lifestyle advice, the groups being distinguished solely by whether they received reinforcement of lifestyle advice by SMS. The study was approved by the Ethics Review Committee of the India Diabetes Research Foundation (IDRF) and all participants gave written informed consent before enrolling in the study (ClinicalTrial.Gov no: NCT00819455).

The primary outcome was incident diabetes. Diabetes was diagnosed on the basis of an annual OGTT or a semi-annual 2 h post glucose load test, according to the World Health Organization criteria [8]: plasma glucose of a value of 7.0 mmol/l or higher in the fasting state or 11.1 mmol/l or higher two hours after a 75-g oral glucose load. During interim visits, if the values were ≥11.1 mmol/l by 2 h post glucose load test, an OGTT was performed within a week to re-confirm the diagnosis of diabetes. The study showed for the first time that motivation through text messaging could help reduce the incidence of diabetes (intervention ($n = 50$ (18%) vs. standard care advice: $n = 73$ (27%); (HR: 0.64, 95% CI 0.45–0.92; $P = 0.015$)). Since the main objective of this post hoc analysis was to ascertain the benefits of compliance to the healthy lifestyle goals on incident diabetes and since both groups were advised on lifestyle changes at baseline we considered both groups as a single cohort for this analysis.

The prescribed healthy lifestyle recommendations were similar to those used in a previous trial in India [6]. Lifestyle advice was advocated by researchers experienced in epidemiological surveys and primary prevention strategies. We individualized the dietary recommendations to balance food intake and physical activity and to maintain appropriate bodyweight. The advice included: (a) avoidance of simple sugars and refined carbohydrates; (b) Reduce total fat intake (<20 g per day); (c) Restrict use of saturated fat; (d) Include more fibre-rich food—e.g., whole grains, legumes, vegetables, and fruits. Physical activity recommendations included: To enhance aerobic exercise like walking (3–4 km in 30 min at least 5 days a week or equivalent), cycling (6–7 km in 30 min), and jogging in participants with sedentary lifestyle. If occupation involves strenuous work, no specific advice was given.

All participants were reviewed at 6 monthly intervals for measurements of anthropometry and biochemical variables and for assessment of diet and physical activity habits. Matsuda's insulin sensitivity index was calculated by the following formula: (10^4/square root of (fasting glucose * insulin) * (mean OGTT glucose * mean OGTT insulin)), with mean glucose and insulin calculated from values at fasting, 30 and 120 min of the OGTT test [9] and beta cell function was calculated using and disposition index (total AUC insulin/glucose * Matsuda's insulin sensitivity index) [10].

2.1. *Lifestyle measurements*

The habitual nutrient intakes of the participants were recorded by a trained dietician by interview using the 24 h dietary recall method [6,7] at baseline and at the 6 monthly reviews. The total energy intake (kcal) and components of individual food constituents (carbohydrates, proteins and fat (in grams)) consumed by the participants were calculated with an in-house dietary analysis programme (visual basic programming tool) using the National Institute of Nutrition guidelines for India [11]. Information about adherence to recommendations for dietary intake was recorded at the 6-monthly reviews.

Physical activity was quantified on a score of 7–70. The activity questionnaire was based on that used previously in south-Asian Indians in a UK epidemiological survey [12], which we used in our previous study of diabetes prevention in India, but was slightly modified for the Indian environment [6,7]. The healthy lifestyle goals comprised of: (a) decreased consumption of carbohydrates; (b) decreased portion size; (c) decreased consumption of oil; (d) decrease in BMI of at least 1 unit (1 kg/m^2) from baseline; and (e) maintenance of good physical activity. Success in achieving healthy lifestyle goals were assessed on the basis of the food records and physical activity questionnaire. The success in each lifestyle change is determined based on achieving lifestyle recommendations given to the participants during the study period. At the end of the follow-up (at 24 months or when the participants progressed to diabetes), the number of goals scored were calculated according to their success in achieving the lifestyle principles (lifestyle score between 0 and 5) prescribed.

2.2. Statistical analysis

Scores were given for each goal achieved at the end of the study (with "0" indicating goal not achieved and "1" indicating the goal achieved), and a success score was computed as its sum. The intergroup differences in the changes in lifestyle goals were compared using the χ^2 test. Univariate logistic regression analysis was employed to study the association of individual component of lifestyle score with diabetes. The lifestyle score was divided into medians in order to find out the changes in beta cell compensation (oral disposition index) and insulin sensitivity (Matsuda's insulin sensitivity index) during the study period. Changes from baseline to follow-up were compared between groups by the *t* test when variables were normally distributed and by Wilcoxon's test for skewed variables. The possible association between diabetes and lifestyle score was calculated using multiple logistic regression analyses after adjusting for group, age, baseline BMI and baseline and change in disposition index. Since both the groups received standard lifestyle advice at baseline, the intervention and control groups were combined for this analysis. The analyses were performed using the statistical package SPSS (IBM SPSS Statistics for Windows, Version 19.0. Armonk, NY: IBM Corp).

3. Results

At the end of the study, among the 537 participants recruited for the study, 517 (96%; standard care advice: $n = 256$; intervention: $n = 261$) responded for the final follow-up. They were included for the present analysis. Mean age and BMI were 46.0 ± 4.7 years and 25.8 ± 3.1 kg/m^2 respectively. The changes in dietary habits and regular physical activity at the end of the study are shown in Table 1. Higher percentage of persons in the intervention reported changes in dietary habits compared with the control group. Differences in levels of physical activity or change in BMI were similar among the study groups. Univariate logistic regression analysis showed that among the lifestyle goals, the protective effect was the highest for reduced BMI (OR: 0.15 [95%CI: 0.01–0.47]), followed by reduction in portion size (OR: 0.39 [95% CI: 0.25–0.60]), reduction in oil intake (OR: 0.46 [95% CI: 0.30–0.69]) and reduced consumption of carbohydrates (OR: 0.52 [95% CI: 0.34–0.78]). Improvement in the physical activity was not observed at the follow-up.

The proportion of participants with $\geq$2 lifestyle goals was higher in the intervention (216 (82.8%)) than in the standard care group (185 (72.2%); $P = 0.006$). Table 2 shows the impact of achieving higher lifestyle scores on the oral disposition index and Matsuda's insulin sensitivity index. The oral disposition index was similar at the baseline in those with and without improvement in lifestyle scores. On follow-up, among the participants with the score of $\geq$2 significant improvement occurred in the disposition index ($P < 0.0001$), whereas it showed significant deterioration in those who achieved <2 lifestyle goals. Similarly, insulin sensitivity also significantly improved ($P < 0.0001$) during follow-up in individuals who had higher lifestyle score.

Multivariable logistic regression analysis adjusted for baseline values of age, group, baseline BMI, baseline and change in disposition index showed that participants with increased lifestyle score were at reduced risk of developing diabetes (odds ratio: 0.54 [95%CI: 0.44–0.67]; $P < 0.0001$).

There was a strong inverse correlation between the success score and the incidence of diabetes as shown in Fig. 1. Among the 15 participants who did not achieve any of the lifestyle goals (control: 12; intervention: 3), 8 (53%) developed diabetes. None of the participants who achieved all the five goals (control: 5; intervention group: 13) developed diabetes.

4. Discussion

Good adherence to the lifestyle goals resulted in the beneficial outcome of lower incidence of T2DM in the intervention group in comparison with the control group. The outcome of lifestyle modification was more pronounced among participants who achieved higher lifestyle scores; on the other hand, the failure to make any changes resulted in an increased incidence of diabetes in either group. Compliance to the healthy dietary habits and regular physical activity improved insulin sensitivity and beta cell preservation as shown by enhanced disposition index in this cohort. Amongst the dietary goals, the

Table 1 – Number (%) of study participants showing improved diet habits and regular physical activity at the end of the study.

Variables *n* (%)	Control ($n = 256$)	Intervention ($n = 261$)	P value[b]	OR (95% CI) (all participants)
Decreased consumption of carbohydrates[a]	121 (47.3)	149 (57.1)	0.025	0.52 (0.34–0.78)
Decreased portion size[a]	107 (41.8)	137 (52.3)	0.015	0.39 (0.25–0.60)
Decreased consumption of oil intake[a]	124 (48.4)	162 (62.1)	0.002	0.46 (0.30–0.69)
Decreased BMI of at least 1 unit (kg/m^2)	34 (13.3)	27 (10.3)	0.301	0.15 (0.01–0.47)
Regular physical activity[c]	197 (76.9)	202 (77.4)	0.899	1.14 (0.70–1.89)

OR: odds ratio; CI: confidence intervals.

[a] Nutrient intakes were calculated from diet questionnaire.

[b] *P* values were determined by the chi-square test between the two groups.

[c] Exercise habits were assessed by self-reported physical activity questionnaire.

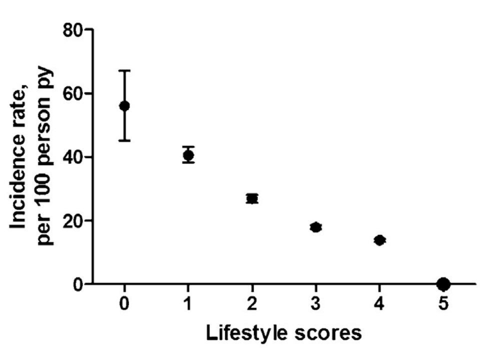
Table 2 – Impact of the improvement of disposition index and Matsuda's insulin sensitivity index when stratified based on median lifestyle score.

	Lifestyle score		P value
	<2 (n = 116)	≥2 (n = 401)	
Disposition index[a]			
Baseline	156.7 (123.2–187.9)	150.6 (119.7–182.6)	0.373
Follow-up	117.6 (89.5–176.6)	160.6 (108.8–212.6)	<0.0001
Mean % change	−11.5	11.4	
P value[b]	<0.0001	<0.0001	
Matsuda's insulin sensitivity index[c]			
Baseline	2.2 ± 1.1	2.5 ± 1.3	0.053
Follow-up	2.4 ± 1.3	3.0 ± 1.5	<0.0001
Mean % change	17.1	37.6	
P value[d]	0.108	<0.0001	

Lifestyle score in median was used for analysis.
[a] Data expressed as median [inter quartile range] and P value computed by Mann–Whitney *U* test.
[b] P value computed by Wilcoxin test.
[c] Data expressed as mean ± SD and P value computed by Student's *t*-test.
[d] P value computed by paired sample *t*-test.

strongest association was observed with decrease in portion size (total energy intake) followed by decreased consumption of oil. Similar observations were also reported in the Finnish Diabetes Prevention Study (DPS) [3], in the Diabetes Prevention Programme (DPP) [2] and in the Nurses Health Study [13].

In the DPP [2] and the DPS [3] studies, the reduction in incidence of diabetes was mainly attributed to the benefits of weight reduction, which occurred due to the improvements in dietary habits and physical activity levels. In our study, a reduction in BMI had an independent protective effect, though the quantum of reduction was small and occurred only in small percentages in both groups. The benefit of lifestyle intervention appeared to be largely related to improvements in diet habits which led to biochemical and behavioural improvement. It is worth mentioning that the baseline BMI in western diabetes prevention studies (DPP: mean BMI: 34.0 kg/m^2; DPS-mean BMI: 31.3 kg/m^2) were much higher than that of the present study (mean BMI: 25.8 kg/m^2).



	Zero	One	Two	Three	Four	Five
Total at risk (n)	15	101	164	135	84	18
Converted to diabetes (n)	8	39	42	23	11	0

Fig. 1 – Diabetes incidence in relation to the goals achieved at the end of the study period is shown. Intervention and control groups were combined for the analysis. For diabetes cases the value at the time of diagnosis was considered as the final value.

We did not find an improvement in physical activity in this cohort, which might have been due to the fact that 64% of the cohort already had good levels of occupational activity. No further improvement in physical activity resulted at follow-up. Beneficial effect of improved physicial activity was seen in many other Diabetes Prevention Programmes [2–4] including a previous study by us [6].

This study has some limitations. We assessed change in diet by a single 24 h recall method which was not a ideal way to assess the dietary measurements [14]. Also, we did not have quantitative assessment of the amounts of saturated fat intake and micro-nutrient levels taken by the participants. But, in a community based epidemiological setting this is a most cost effective and feasible method to capture the diet information. In this study, we assessed physical activity by a self-reported questionnaire, a method that could have missed small changes in improvement.

The rapidly increasing prevalence of diabetes in Asian Indians has been largely attributed to urbanization, industrialization, nutritional transition and increasing levels of sedentary habits. In developing countries like India, the traditional diet pattern is being replaced by foods rich in high-fat, high-calorie westernized diet. South Asians have an inherent inability to metabolically adapt to the high calorie diet compared with the white populations and this may partly explain their increased prevalence of diabetes [15]. In addition to an increased propensity of insulin resistance, South Asians may also show an early decline in beta cell function, compared with other ethnic groups [16]. Our findings emphasize that moderate improvements in dietary habits are beneficial in preventing development of diabetes in Asian Indian prediabetic men.

Author contributions

J. Ram, S. Selvam, C. Snehalatha, D.G. Johnston and A. Ramachandran researched data, contributed to discussion, wrote manuscript, reviewed/edited manuscript; A. Nanditha and Mary Simon researched data, reviewed/edited manuscript;

Samith A. Shetty and I.F. Godsland contributed to discussion, reviewed/edited manuscript.

Conflicts of interest

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