A Community-Based Diabetes Prevention and Management Education Program in a Rural Village in India

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OBJECTIVE — In this study we evaluated a 7-month community-based nonpharmacological lifestyle intervention to prevent/reduce the risk of developing diabetes and its complications in a resource-poor village in Tamilnadu, India.

RESEARCH DESIGN AND METHODS — A total of 703 village inhabitants, comprising adults and youth aged 10–92 years, were provided educational intervention using "trained trainers." Culturally and linguistically appropriate health education messages addressed diet, physical activity, and knowledge improvement. The prevalence of diabetes and the effectiveness of the intervention were assessed using select parameters.

RESULTS — The crude prevalences of diabetes and pre-diabetes among adults were 5.1 and 13.5%, respectively, while the prevalence of pre-diabetes in youth aged 10–17 years was 5.1%. Intervention reduced fasting blood glucose levels of pre-diabetic adults by 11%, pre-diabetic youth by 17%, and type 2 diabetic adults by 25%. Improvements in obesity parameters and dietary intake also occurred. A stepwise worsening of parameters progressing from the normoglycemic state to the impaired levels of pre-diabetes and diabetes was observed.

CONCLUSIONS — This study has charted the increasing prevalence of diabetes and pre-diabetes in rural India. Educational intervention was successful in reducing some of the obesity parameters and improving dietary patterns of individuals with pre-diabetes and diabetes.

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India has the dubious distinction of having the highest prevalence of diabetes worldwide (1–3). Further, the number of individuals with diabetes will reach 79.4 million by 2030 with earlier age manifestations (1,2,4). Approximately 70% of India's population lives in rural areas (2) in resource-poor settings where the increasing prevalence and chronic nature of type 2 diabetes become added burdens (5). Lack of awareness and poor access to quality care increase diabetes-related complications (5).

Lifestyle intervention is the most cost-effective strategy to prevent type 2 diabetes (5,6). However, there have been few well-designed studies in rural settings that have shown successful intervention in improving awareness and lifestyle. The purpose of this community-based program was to *1*) assess the prevalence of type 2 diabetes and pre-diabetes and 2) evaluate the effectiveness of a nonpharmacological lifestyle intervention aimed at reducing risk factors and improving disease self-management. The Diabetes Prevention and Management (DPM) program was designed to increase awareness at the grassroots level using the inclusive environment of a whole village with a population-based approach (7). Simple and practical lifestyle modifications were customized to educate the village inhabitants on type 2 diabetes risk factors and self-care.

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Abbreviations: DPM, Diabetes Prevention and Management; FBG, fasting blood glucose; IFG, impaired fasting glucose; NGL, normoglycemic level; WHR, waist-to-hip ratio.

RESEARCH DESIGN AND METHODS

The study used a collective population approach. The duration of the study was from October 2002 to April 2003. The village of Alamarathupatti, one of the field sites of Gandhigram Rural Institute, was selected. This village had a population of 950 residents aged ≥10 years and of mixed socioeconomic strata (Table 1).

An initial participatory rural analysis of the village enabled the involvement of the village leaders, peer educators, and residents in the planning and implementation phases of the project and served to highlight resources and requirements. Trained individuals performed data collection and educational intervention. Face-to-face interviews were considered the most appropriate method because 41% of respondents had less than a fifth grade education. The study was approved by the Institutional Review Board of Texas A & M University, and written informed consent was obtained from all participants.

Sample size

Although 850 residents participated in the baseline survey, 703 individuals (118 youth aged 10–17 years and 585 adults) completed the postintervention survey questionnaire, resulting in a response rate of 74%; the attrition rate due to migrations and refusals was 17%. Recruitment of respondents was completed through door-to-door visitations. There were two data collection points for the study, i.e., baseline and postintervention, and data were collected by trained personnel. No monetary compensation was provided, but health appraisal data were disseminated to the participants.

Measurements

Demographic characteristics included a personal/family history of diabetes, educational level, income, diet pattern, and smoking/alcohol intake. Because of a marked resistance among the village inhabitants toward venous blood drawing, capillary blood glucose values were used

Table 1—*Demographic characteristics of the respondents*

Characteristic	Total sample*	Adults ≥18 years Male	Adults ≥18 years Female	Adults ≥18 years Total	Youth <18 years Male	Youth <18 years Female	Youth <18 years Total
n (%)	703	242 (41)	343 (59)	585 (83.2)	57 (48)	61 (52)	118 (16.8)
Age	35.8 ± 17.0	42.5 ± 15.2	38.8 ± 15	40.3 ± 15.1	13.5 ± 1.9	13.9 ± 2.2	13.68 ± 2.0
18–20 years	43 (7.4)	11 (4.5)	32 (9.3)	43 (7.4)	0 (0)	0 (0)	0 (0)
21–65 years	506 (86.5)	213 (88.0)	293 (85.4)	506 (86.5)	0 (0)	0 (0)	0 (0)
>65 years	36 (6.2)	18 (7.4)	18 (5.2)	36 (6.2)	0 (0)	0 (0)	0 (0)
Weight (kg)	46.7 ± 14.2	52.4 ± 14.9	46.9 ± 12.3	49.2 ± 13.7	32.1 ± 9.2	35.5 ± 9.1	34.0 ± 9.2
BMI (kg/m^2)	19.8 ± 4.0	20.5 ± 3.6	20.7 ± 4.0	—	15.1 ± 1.9	16.9 ± 3.1	16.01 ± 2.7
Underweight (BMI <18.5 kg/m^2)	304 (43.2)	82 (33.9)	121 (35.3)	203 (34.7)	54 (94.7)	47 (77.0)	101 (85.6)
BMI 18.5–22.9 kg/m^2	234 (33.3)	99 (40.9)	119 (34.7)	218 (37.3)	3 (5.3)	13 (21.3)	16 (13.6)
Overweight (BMI 23–24.9 kg/m^2)	68 (9.7)	29 (12.0)	39 (11.4)	68 (11.6)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Obese (BMI ≥25.0 kg/m^2)	97 (13.8)	32 (13.2)	64 (18.7)	96 (16.4)	0.0 (0.0)	1 (1.6)	118 (100.0)
Waist circumference (inches)	28.9 ± 4.4	31.1 ± 3.8	28.9 ± 4.1	29.8 ± 4.1	23.6 ± 2.5	25.3 ± 3.2	24.49 ± 2.9
Normal	—	203 (83.9)	230 (67.1)	433 (74.0)	NA	NA	NA
Abnormal (male >35 in.; female >31 in.)	—	39 (16.1)	113 (16.1)	152 (26.0)	NA	NA	NA
Hip circumference (inches)	33.7 ± 4.1	34.0 ± 2.9	35.1 ± 3.9	34.65 ± 3.5	27.7 ± 2.7	30.5 ± 3.4	29.14 ± 3.38
Thigh circumference (inches)	17.2 ± 2.3	17.5 ± 2.0	17.6 ± 2.3	17.58 ± 2.2	15.0 ± 1.9	15.6 ± 1.8	15.32 ± 1.85
WHR	0.86 ± 0.08	0.9 ± 0.1	0.8 ± 0.1	0.86 ± 0.08	0.9 ± 0.1	0.8 ± 0.1	0.84 ± 0.05
Normal	—	82 (33.9)	158 (46.1)	240 (41.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Abnormal (male >0.89; female >0.81)	—	160 (66.1)	185 (53.9)	345 (59.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Capillary glucose (mg/dl)							
In the fasting state†	92.2 ± 42.5	97.6 ± 39.7	92.2 ± 50.1	94.4 ± 46.1	82.2 ± 10.7	80.6 ± 8.6	81.3 ± 9.6
Prevalence of diabetes (%)	4.3	6.2	4.4	5.1	0.0	0.0	0.0
Prevalence of IFG (%)	12.1	19.0	9.6	13.5	7	3.3	5.1
Postprandial state‡	120.2 ± 49.0	128.7 ± 54.7	119.5 ± 50.9	123.3 ± 52.7	106.4 ± 17.2	103.6 ± 18.0	104.9 ± 17.6
Blood pressure (mm/Hg)							
Systolic blood pressure	119.3 ± 17.2	125.2 ± 16.9	119.5 ± 16.9	121.8 ± 17.1	103.7 ± 11.2	109.5 ± 10.7	106.7 ± 11.2
Prehypertension (%)	37.7	44.2	45.8	41.7	12.3	23.0	17.8
Hypertension (%)	15.5	24.8	39.9	18.6	0	0	0
Diastolic blood pressure	83.3 ± 15.1	89.0 ± 15.1	83.0 ± 14.8	85.5 ± 15.2	71.3 ± 8.1	74.0 ± 10.0	72.7 ± 9.2
Prehypertension (%)	28.9	29.3	26.5	27.7	33.3	36.1	34.7
Hypertension (%)	39.4	53.7	40.2	45.8	1.8	13.1	7.6
Education							
Illiterate	179 (25.5)	35 (14.5)	142 (41.4)	177 ± 30.3	1 (1.8)	1 (1.6)	2 ± 1.7
Up to primary education	108 (15.4)	42 (17.4)	53 (15.5)	95 ± 16.2	6 (10.5)	7 (11.5)	13 ± 11.0
High school	356 (50.6)	132 (54.5)	124 (36.2)	256 ± 43.8	48 (84.2)	52 (85.2)	100 ± 84.7
Some college/graduate	60 (8.5)	33 (54.5)	24 (7.0)	57 ± 9.7	2 (3.5)	1 (1.6)	3 ± 2.5

Income (Rs.)	1,438.6 ± 1,491	1,808.7 ± 1,543.8	970.2 ± 1,305.0	1,438.6 ± 1,491	—	—	—
<1,000	142 (24.3)	38 (15.7)	104 (30.3)	142 (24.3)	—	—	—
1,000–2,000	126 (21.5)	94 (38.8)	32 (9.3)	126 (21.5)	—	—	—
2,000–3,000	35 (6.0)	31 (12.8)	4 (1.2)	35 (6.0)	—	—	—
>3,000	38 (6.5)	32 (13.2)	6 (1.7)	38 (6.5)	—	—	—
Knowledge level	3.14 ± 2.4	3.0 ± 2.4	2.95 ± 2.4	2.99 ± 2.4	3.9 ± 2.4	3.9 ± 2.3	3.88 ± 2.3
Physical activity							
Sedentary	435 (61.9)	99 (40.9)	223 (65.0)	322 (55.0)	26 (45.0)	34 (55.0)	60 (50.8)
Moderate	91 (12.9)	68 (28.1)	21 (6.1)	89 (15.2)	17 (30.0)	18 (30.0)	35 (29.7)
Heavy	177 (25.2)	75 (31.0)	99 (28.9)	174 (29.7)	14 (25.1)	9 (15.2)	23 (19.5)
Smoking/tobacco	85 (12.1)	85 (35.1)	1 (0.3)	86 ± 12.1	0 (0)	0 (0)	0
Alcohol intake	52 (7.4)	51 (21.1)	1 (0.3)	52 ± 7.4	0 (0)	0 (0)	0
Carbohydrate (g)	298.24 (134.5)	334.70 (156.4)	287.77 (116.5)	307.2 ± 136.3	261.8 (121.4)	246.49 (111.4)	253.8 ± 116.2
Protein (g)	63.83 (29.1)	72.98 (35.0)	61.03 (25.1)	65.9 ± 30.2	55.54 (19.54)	51.02 (20.3)	53.2 ± 20.0
Fat (g)	15.90 (13.2)	18.71 (15.1)	13.97 (11.5)	15.9 ± 13.3	17.59 (13.4)	14.0 (11.7)	15.7 ± 12.6
Total calories	1,591.4 (667.8)	1,799.17 (784.9)	1,520.9 (574.9)	1,636.1 ± 683.1	1,427.7 (572.1)	1,316.1 (499.1)	1,370.0 ± 536.2
<1,000 cal	116 (16.5)	27 (11.2)	55 (16.0)	82 (14.0)	14 (24.6)	20 (32.8)	34 (28.8)
1,000–2,000 cal	444 (63.2)	146 (60.3)	227 (66.2)	373 (63.8)	34 (59.6)	37 (60.7)	71 (60.2)
2,000–3,000 cal	111 (15.8)	48 (19.8)	52 (15.2)	100 (17.1)	8 (14.0)	3 (4.9)	11 (9.3)
>3,000 cal	32 (4.6)	21 (8.7)	9 (2.6)	30 (5.1)	1 (1.8)	1 (1.6)	2 (1.7)
Fiber (g)	5.52 (2.9)	5.71 (3.07)	5.49 (2.83)	5.58 ± 2.93	4.97 (2.8)	5.50 (2.65)	5.24 ± 273

Data are frequency (percent) or mean ± SD unless otherwise noted. The numbers may not add up to 100% because of missing values. *Total column includes individuals with NGL, IFG, and diabetes. †$P < 0.05$. ‡Postprandial state = within 2 h after the meal. NA, standards for Asian Indian youth are not available; Rs., rupees.

to assess the prevalence of type 2 diabetes and pre-diabetes as used in a rural study by Chow et al. (8). Fasting blood glucose (FBG) testing was conducted using the Accu-check glucometer and individuals with impaired FBG were reconfirmed. Normoglycemic levels (NGLs), impaired fasting glucose (IFG), and diabetes levels were established according to the revised American Diabetes Association standards of care (9). Anthropometric data included height, weight, hip, waist, and thigh measurements. Height and weight were measured by standard procedures. Waist circumference was taken at the level of the last rib to the nearest 0.1 inch after a normal expiration. Hip circumference was taken at the maximum extension of the buttocks as viewed from the side. Thigh circumference was measured at the proximal right thigh directly below the gluteal fold (10). Blood pressure was measured by sphygmomanometry to the nearest millimeter of mercury in the left arm, with the individual seated after a 10-min rest, and validated with a repeated periodic measure on the same individual. A third reading was taken if the two readings were >4 mmHg apart when a mean value was determined. BMI and waist-to-hip ratio (WHR) were calculated, and reference guidelines for Asian Indians were used for all obesity measures (11,12).

Occupation levels for adults and scheduled physical activity at school for children were surrogate measures to calculate physical activity. A 24-h dietary recall was used to assess diet and macronutrient consumption (carbohydrate, protein, fat, fiber, and total kilocalories) using the National Institute of Nutrition guidelines for Indian foods (13). Knowledge of foods was assessed by a 10-item questionnaire with response options as true (1) or false (0). Results of principle components factor analyses with Varimax rotation indicated that all scale items loaded on a single factor and accounted for 63% of the variance, thus supporting the validity for the scale. A knowledge score was computed by summing the correct answers; greater scores indicated higher knowledge, and Cronbach's α was 0.85.

Educational intervention

Key features of the DPM intervention included culturally sensitive and linguistically appropriate (Tamil language) sessions on dietary modification (increasing fiber, reducing fat, and portion control), improving physical activity, and simple relaxing breathing techniques. Ten face-to-face encounters were provided to all respondents on a one-on-one basis with health messages tailored for sex, age, and socioeconomic differences. The topics included introduction to diabetes and its complications, diabetes prevention and modifiable risk factors, healthy body weight, central adiposity and waist circumference, elevated blood pressure levels, physical activity, fiber-rich wholesome foods, dietary behaviors, and stress relaxation. Reinforcement of the education intervention was supported by group events. The "core" group of individuals with impaired FBG values was given additional counseling as needed.

Weight loss goals were not universally emphasized because 77% of the individuals were normal/underweight. Dietary education focused on the intake of fiber and protein from local low-cost resources such as nutritionally rich drumstick leaves, millets, legumes/lentils, and whole grains. This was reinforced through cooking demonstrations, recipe competitions, and model meals. Further, avoidance of sweetened drinks and fried foods was emphasized. Physical activity was promoted and reinforced with demonstrations, competitive fun events, and dancercise events for the younger respondents. Stress relaxation instruction included the importance of meditation and breathing exercises (familiar to many of the respondents). Education and counseling for blood glucose management was provided by a certified diabetes educator on a one-on-one basis to the high-risk group. These included the importance of periodic blood glucose testing, weight control, portion-controlled diet, regulated physical activity, and medication management (where applicable). Low glycemic model meals demonstrated the supplementation of polished white rice with millets, sprouted legumes, and vegetables.

Trainers

The trainers were science graduates and were trained at Gandhigram Rural Institute for 6 months and in tandem with the intervention. The training curriculum included knowledge of type 2 diabetes, its risk factors, meal planning reinforced in the model kitchen, physical activity, and nonconfrontational interviewing and education techniques. Further, trainers underwent role-play and interactive problem-solving sessions and were housed in the village for the duration of the project.

Statistical analysis

Prevalences of diabetes and pre-diabetes were calculated from the baseline survey. Basic descriptive statistics were obtained for demographic and study variables. Student's t test and χ^2 analysis (for categorical variables) were used to evaluate pre- and postintervention changes. ANCOVA was used to examine significant postintervention differences between NGL, IFG, and type 2 diabetes with baseline scores used as covariates in the model. The acceptance level for statistical significance was lowered from 0.05 to 0.006 for the food variables and to 0.007 for the body measures, a Bonferroni correction for multiple comparisons; statistical significance for the knowledge score was set at 0.05. Hierarchical regression analysis was used to determine significant predictors of fasting blood glucose levels. Data analysis was performed using SPSS version 15.0.

RESULTS — The mean ± SD age of the respondents was 35.8 ± 17 years (Table 1). The majority of respondents were adults (83.2%), female (51.7%), and married (66%) and had an educational level of less than a high school diploma (66%). Approximately half (51%) were of low socioeconomic status (income in Rupees <3000 or $75.00/month), and 62% reported a sedentary lifestyle. Activity levels were lower among female respondents ($P = 0.001$) and type 2 diabetic individuals ($P = 0.08$). Of the youth, 51% met the Surgeon General's recommendation for physical activity with higher levels among male respondents ($P = 0.03$).

Prevalence of diabetes

The crude prevalences of diabetes and IFG were 4.3 and 12.1%, respectively. Age-specific prevalence of diabetes and IFG were 5.1 and 13.5% among adults and 0 and 5.1% IFG among youth. Sex-specific prevalence of diabetes and pre-diabetes among adults showed a significantly higher rate ($\chi^2 = 12.37$, $P = 0.002$) in men (6.2% diabetes and 19.0% pre-diabetes) than in women (4.4% diabetes and 9.6% pre-diabetes). Type 2 diabetes generally rose with age in both sexes ($P = 0.001$), reaching 43.3% among the 36- to 50-year age-group and 50.0% among the ≥50-year age-group.

Obesity measures

Mean BMI in the adult population was 20.59 ± 3.82 kg/m^2 and is in the normal range; 11.6% were overweight, and 16.4% were obese. There was a significant increase in the prevalence of IFG and type 2 diabetes with increasing BMI among adults ($F = 38.6$, $P = 0.001$); this difference was not observed in youth. Although waist circumference was low (74% in normal range), 59% had abnormal WHR (>0.81 for women and >0.89 for men). Both WHR ($P = 0.003$) and waist circumference ($P = 0.001$) were significantly higher among male than female respondents. Among the obesity parameters, a higher correlation was seen between waist circumference and hip circumference ($r = 0.86$ for men and $r = 0.76$ for women) than between hip circumference and thigh circumference ($r = 0.69$ for men and $r = 0.73$ for women) and waist circumference and thigh circumference ($r = 0.62$ for men and 0.60 for women). Thigh circumference was strongly associated with BMI in both sexes but had a moderate association with WHR and a weak association with FBG in men and no correlation in women.

The mean values of BMI, waist circumference, and WHR for youth were 16.0 ± 2.72 kg/m^2, 24.49 ± 2.98 inches, and 0.84 ± 0.03, respectively. Female youth had higher waist circumference ($P = 0.002$) and BMI ($P = 0.001$) but lower WHR ($P = 0.025$) compared with their male peers; the prevalence of IFG significantly correlated with central obesity (waist circumference and WHR) among youth. Waist circumference, hip circumference, and thigh circumference were not associated with WHR and FBG in either sex.

Dietary intake

Mean caloric intakes were 1,636.1 ± 683.1 and 1,370.5 ± 536.2 kcal in adults and youth, respectively; 14% of the study population reported consuming <1,000 kcal/day. It must be noted that even among individuals with intakes <1,000 kcal ($n = 82$), 8.1% had IFG and 6.3% had type 2 diabetes. Although male respondents had significantly higher intakes of total calories than female respondents ($P = 0.001$), no significant difference in calorie intake was noted by NGL, IFG, and type 2 diabetes groups ($P = 0.40$). The majority of adult respondents had high carbohydrate consumption (~80%) with 16% of calories coming from protein and ~4% from fat intake. Carbohydrate consumption came mainly from white polished rice with sporadic use of refined wheat. Adults with type 2 was noted diabetes had the lowest carbohydrate but highest fat intakes compared

Table 2—*Changes in risk factors after DPM intervention*

	Before			After			*t* value (*P* value)		
Variable	Total	IFG	Diabetes	Total	IFG	Diabetes	Total	IFG	Diabetes
Adults aged ≥18 years									
n	703	79	30	703	79	30	703	79	30
BMI (kg/m^2)	20.6 ± 3.9	23.3 ± 4.3	23.3 ± 3.4	20.8 ± 3.9	23.7 ± 4.4	23.5 ± 4.2	−2.87 (0.004)	−2.27 (0.026)	−0.486 (0.630)
Waist circumference (inches)	29.8 ± 4.1	33.1 ± 4.2	33.4 ± 4.3	28.0 ± 4.3	31.2 ± 4.8	31.5 ± 4.7	14.66 (0.001)	5.05 (0.001)	2.15 (0.039)
Hip circumference (inches)	34.6 ± 3.5	36.8 ± 3.6	37.3 ± 3.7	33.3 ± 3.5	35.7 ± 3.7	36.1 ± 5.1	13.68 (0.001)	4.53 (0.001)	1.94 (0.062)
WHR	0.86 ± 0.08	0.90 ± 0.08	0.90 ± 0.10	0.83 ± 0.08	0.87 ± 0.09	0.87 ± 0.10	6.32 (0.001)	3.04 (0.003)	1.06 (0.297)
Thigh circumference (inches)	17.5 ± 2.1	18.5 ± 2.0	18.3 ± 2.1	16.6 ± 2.2	17.8 ± 2.6	17.5 ± 2.3	13.47 (0.001)	3.45 (0.001)	2.39 (0.023)
Systolic blood pressure (mmHg)	121.8 ± 17.1	129.2 ± 15.8	132.9 ± 18.5	120.1 ± 18.5	123.5 ± 15.5	129.7 ± 22	1.98 (0.048)	3.49 (0.001)	0.72 (0.477)
Diastolic blood pressure (mmHg)	85.4 ± 15.2	93.2 ± 14.9	92.5 ± 18.2	79.5 ± 14.0	82.2 ± 13.7	87.0 ± 15.8	8.40 (0.001)	5.58 (0.001)	1.54 (0.134)
FBG (mg/dl)	94.4 ± 46.1	108.4 ± 7.4	240.7 ± 128	91.2 ± 30.8	96.5 ± 15.7	180.5 ± 81.9	2.01 (0.045)	7.08 (0.001)	2.27 (0.031)
Calories from carbohydrates (%)	74.7 ± 6.3	73.4 ± 6.5	75.77 ± 5.4	74.6 ± 6.2	73.4 ± 6.7	76.74 ± 4.1	−0.424 (0.671)	0.018 (0.986)	−0.96 (0.343)
Calories from protein (%)	16.0 ± 2.4	16.4 ± 2.9	16.58 ± 2.7	15.7 ± 2.0	15.6 ± 2.1	16.68 ± 1.4	−3.04 (0.002)	2.10 (0.039)	−0.18 (0.858)
Calories from fat (%)	4.0 ± 2.9	4.6 ± 2.6	7.63 ± 5.12	4.3 ± 2.9	4.9 ± 3.1	6.57 ± 4.36	−1.49 (0.136)	−0.78 (0.436)	1.15 (0.258)
Carbohydrates (g)	307.1 ± 136.2	285.3 ± 106.5	251.8 ± 96.1	310.5 ± 112.0	341.3 ± 115.1	260.3 ± 78	−0.487 (0.626)	−3.41 (0.001)	−0.376 (0.710)
Protein (g)	65.9 ± 30.1	63.5 ± 25.7	53.8 ± 18.7	65.2 ± 23.9	72.1 ± 22.8	56.6 ± 17.0	−2.81 (0.005)	−2.33 (0.022)	−0.588 (0.561)
Fat (g)	15.9 ± 13.3	18.1 ± 14.7	24.4 ± 18.3	18.0 ± 14.0	21.1 ± 12.9	23.1 ± 16.8	0.468 (0.640)	−1.40 (0.164)	0.374 (0.711)
Total caloric intake (cal)	1,636.1 ± 683.1	1,558.5 ± 576.8	1,442.4 ± 498.6	1,665.6 ± 574.1	1,844.0 ± 538.3	1,475.1 ± 441.9	−0.846 (0.398)	−3.37 (0.001)	−0.272 (0.787)
Dietary fiber intake (g)	5.5 ± 2.9	5.4 ± 3.1	5.50 ± 2.2	6.2 ± 3.5	6.6 ± 3.3	7.74 ± 4.43	−3.50 (0.001)	−2.61 (0.011)	−2.61 (0.014)
Knowledge score	2.9 ± 2.3	3.3 ± 2.5	3.63 ± 2.4	3.9 ± 2.4	4.7 ± 2.4	4.57 ± 2.3	−8.03 (0.001)	−4.50 (0.007)	−1.78 (0.085)
Youth aged 10–17 years									
n	112	6	0	112	6	0	112	6	0
BMI (kg/m^2)	16.0 ± 2.7	16.0 ± 1.7	—	16.5 ± 2.4	17.7 ± 2.2	—	3.86 (0.001)	−3.37 (0.020)	—
Waist circumference (inches)	24.4 ± 2.9	24.5 ± 3.6	—	22.7 ± 2.5	23.0 ± 3.3	—	6.84 (0.001)	1.46 (0.203)	—
Hip circumference (inches)	29.1 ± 3.3	29.5 ± 4.2	—	28.1 ± 3.1	28.84.2	—	5.22 (0.001)	1.00 (0.363)	—
WHR	0.8 ± 0.0	18.3 ± 0.08	—	0.8 ± 0.0	0.80 ± 0.06	—	3.90 (0.001)	1.163 (0.297)	—
Thigh circumference (inches)	15.3 ± 1.8	16.5 ± 2.1	—	14.5 ± 1.8	14.7 ± 2.4	—	4.59 (0.001)	2.61 (0.048)	—
Systolic blood pressure (mmHg)	106.6 ± 11.2	106.8 ± 12.8	—	103.9 ± 10.8	101.0 ± 8.9	—	1.95 (0.001)	0.85 (0.435)	—
Diastolic blood pressure (mmHg)	72.71 ± 9.2	76.7 ± 9.8	—	69.5 ± 8.6	71.7 ± 7.5	—	2.90 (0.004)	0.76 (0.482)	—
FBG (mg/dl)	81.3 ± 9.6	104.5 ± 7.94	—	82.2 ± 10.5	86.0 ± 10.9	—	−0.817 (0.416)	3.67 (0.014)	—
Calories from carbohydrates (%)	73.1 ± 7.8	104.5 ± 7.9	—	74.1 ± 7.7	74.2 ± 6.4	—	−1.00 (0.317)	−0.689 (0.522)	—
Calories from protein (%)	15.8 ± 3.1	72.0 ± 8.9	—	14.9 ± 2.0	13.8 ± 1.7	—	2.59 (0.011)	1.371 (0.229)	—
Calories from fat (%)	4.8 ± 3.5	15.4 ± 2.7	—	4.8 ± 3.9	5.3 ± 2.6	—	0.040 (0.968)	0.162 (0.878)	—
Carbohydrates (g)	253.8 ± 116.1	5.6 ± 4.3	—	263.0 ± 106.8	304.3 ± 113.4	—	−0.699 (0.486)	−0.053 (0.960)	—
Protein (g)	15.7 ± 12.6	300.0 ± 148.2	—	17.0 ± 14.4	56.7 ± 23.2	—	−0.813 (0.418)	0.328 (0.757)	—
Fat (g)	53.2 ± 20.0	18.8 ± 13.6	—	53.3 ± 22.9	19.8 ± 10.1	—	−0.056 (0.955)	−0.197 (0.852)	—
Total caloric intake (cal)	1,370.0 ± 536.2	1,617.9 ± 622.1	—	1,419.5 ± 547.6	1,621.8 ± 543.9	—	−0.766 (0.445)	−0.10 (0.992)	—
Dietary fiber intake (g)	5.2 ± 2.7	7.3 ± 3.3	—	5.7 ± 3.9	6.3 ± 5.1	—	−1.04 (0.300)	0.355 (0.737)	—
Knowledge score	3.8 ± 2.3	5.0 ± 1.8	—	4.5 ± 1.9	6.2 ± 1.8	—	−2.51 (0.013)	−1.12 (0.315)	—

Data are means ± SD. Total column includes individuals with NGL, IFG, and diabetes.

with NGL and IFG groups (P = 0.001). Female respondents had lower intake of calories and macronutrients than male respondents (P = 0.001). Nutrient consumption was similar for boys and girls in the youth group.

Hypertension

Prevalences of systolic and diastolic hypertension and prehypertension were significantly higher (P = 0.001) among male than female respondents, increasing with age (P = 0.001). There was a linear (significant) increase in systolic and diastolic blood pressure with the increase in respondents' blood glucose levels. Approximately one-fifth (17.4%) of the adult population had high blood pressure (≥140/90 mm/Hg; 23.6% men and 13.1% women). Among youth, 15.3% had systolic and diastolic prehypertension or hypertension values, which did not vary by sex.

Intervention

Intervention successfully reduced several risk factors among adults, youth, and high-risk groups for IFG and type 2 diabetes (Table 2). Intervention reduced FBG levels by 3% in the adults, 11% in adults with IFG, 17% in youth with IFG, and 25% in adults with type 2 diabetes. A significant reduction in all obesity parameters was also noted among adults and adults with IFG (significance ranging from 0.026 to 0.001). Diabetes management reduced waist circumference (P = 0.039) and thigh circumference (P = 0.023) in type 2 diabetic adults. In youth, intervention lowered waist circumference, hip circumference, thigh circumference, and WHR (P = 0.001) although BMI increased. Among youth with IFG there was a reduction in FBG approaching significance (P = 0.014).

Significant improvements were noted in dietary fiber and protein intakes among adults; protein and carbohydrate intakes increased among adults with IFG with improvements in fiber intake approaching significance (P = 0.011). Concomitantly, their diets showed an increased calorie intake (P = 0.001). Although no significant change in diet patterns was noted in youth except for a decrease in their protein intake (P = 0.011), there was an increase in the knowledge level approaching significance (P = 0.013). Systolic and diastolic blood pressure was also reduced in adults, adults with IFG, and youth. The greatest improvement was noted in the reduction of hip circumference, and the lowest change was noted in dietary nutrient consumption.

Differences in postintervention parameters by groups showed that adults with IFG and type 2 diabetes had significantly higher hip circumference and thigh circumference than their normoglycemic peers (Table 3). These respondents showed a higher knowledge of the disease (P = 0.006). Carbohydrate, protein, and total caloric intake were lowest among those with type 2 diabetes and highest among those with IFG. Differences (approaching significance) were also noted between the groups for BMI, waist circumference, WHR, diastolic blood pressure, and total fiber intake (P = 0.02–0.07). The parameters of BMI and knowledge among youth with IFG were higher than those for their normoglycemic counterparts.

Postintervention dietary patterns were similar to the baseline data by sex. Adult men and youth showed higher intake of total calories, carbohydrate, protein, fat, and fiber intake than female respondents. Additionally, they also had higher levels of FBG, blood pressure, and obesity (WHR and waist circumference). However, male respondents had higher WHR, and female respondents had higher thigh circumference, BMI, and hip circumference.

Predictors of FBG among adults indicated diastolic blood pressure as the most significant predictor (β = 0.20), followed by systolic blood pressure (β = 0.17) and dietary fiber intake (β = 0.15), in the regression model; BMI and thigh circumference approached significance (P = 0.07 and 0.08, respectively). In other words, respondents who had a lower fiber intake and higher blood pressure, BMI, and thigh circumference had higher blood glucose levels. These five variables explained 14% of the variance (F = 4.54, P = 0.001). Among high-risk individuals, FBG was predicted by fiber intake and diastolic blood pressure (R^2 = 0.23, F = 1.86, P = 0.03). Significant predictors in youth included general and abdominal obesity (waist circumference and BMI) as well as a higher carbohydrate/fat intake; 31% of the variance was accounted for by these variables (F = 2.41, P = 0.003).

CONCLUSIONS — This population study showed a higher prevalence of type 2 diabetes and IFG in an agrarian community (despite low BMI) than in earlier studies (2,14). Further, type 2 diabetes was observed at a younger age than in earlier reports (2,4,14), affirming World Health Organization predictions (1). Although a higher prevalence of type 2 diabetes among males and older individuals was expected (8), there is a concerning prevalence of IFG in youth (15).

More than 11% of the illiterate population with IFG or type 2 diabetes were in the low-income groups, confirming that glucose impairment is not only a "rich man's disease" but also affects the rural poor. The poorest villagers suffered from a lack of knowledge, resources, and access to health care. These factors allow the deterioration of their glycemic status while this metabolic disease is still silent. Declining agrarian employment among adults and less sports/physical activity in youth coupled with television-viewing and labor-saving devices may collectively contribute to increasing physical inactivity, although physical activity was not accurately measured in the present study. Lower income has steered this population toward the use of subsidized white polished rice as a major component (80%) of the diet in lieu of higher-priced legumes, vegetables, and millets. However, the increased fiber intake suggests that their health benefits had been accepted.

The lifestyle modifications were effective in reducing some of the risk factors for type 2 diabetes and improving self-management of the disease. With the escalating rate of type 2 diabetes disproportionately affecting Indians (2), education of vulnerable communities can become a cost-effective public health strategy. It has been shown that self-care among individuals with type 2 diabetes improved glycemic control and reduced complications (16). Indians seem to have a genetic predisposition toward insulin resistance with a low BMI and high central adiposity: the Yudkin-Yajnik paradox (17–19). In this study we observed relatively low BMI and waist circumference but high WHR among adults (2,20–22). Approximately two-thirds of the respondents had abnormal WHR but did not classify under abnormal waist circumference or BMI levels even with Asian standards of classification, suggesting that rural Indians of thin stature may require lower waist circumference standards to measure central adiposity. Comparison of obesity between youth in this study and urban adolescents in New Delhi showed a lower waist circumference and BMI for rural youth but a higher WHR (12). In keeping with other successful lifestyle modification studies (16,23), our intervention proved that lifestyle modifications can

Table 3—*ANCOVA on study variables by normal, IFG, and diabetes for adolescent and adult groups*

Variables	NGL	IFG	Diabetes	*F* value	*P* value
Adults aged ≥18 years (*n* = 585)					
n	476	79	30	—	—
BMI (kg/m^2)	20.14 (3.57)	23.72 (4.38)	23.50 (4.28)	2.75	0.064
Waist circumference (inches)	27.29 (3.83)	31.22 (4.82)	31.57 (4.75)	3.34	0.036
Hip circumference (inches)	32.80 (3.08)	35.78 (3.73)	36.17 (5.14)	8.42	<0.001
WHR	0.83 (0.07)	0.87 (0.09)	0.88 (0.10)	2.65	0.07
Thigh circumference (inches)	16.35 (2.09)	17.77 (2.62)	17.50 (22.08)	6.04	0.003
Systolic blood pressure (mmHg)	119.03 (18.53)	123.47 (15.53)	129.70 (22.08)	1.57	0.208
Diastolic blood pressure (mmHg)	78.6 (13.81)	82.5 (13.65)	87.00 (15.79)	2.87	0.057
Knowledge score	3.74 (2.40)	4.70 (2.35)	4.57 (2.28)	5.22	0.006
% calories from carbohydrates	75.0 (25.98)	73.36 (6.72)	71.24 (7.01)	4.67	0.010
Carbohydrates (g)	308.58 (112.0)	341.34 (115.0)	260.53 (78.9)	6.13	0.002
% calories from protein	15.73 (2.05)	15.62 (2.07)	15.47 (1.71)	0.265	0.768
Protein (g)	64.70 (24.2)	72.10 (22.8)	56.55 (17.0)	5.27	0.005
% calories from fat	4.10 (2.90)	4.89 (3.06)	5.90 (3.58)	4.31	0.014
Fat (g)	17.20 (13.89)	21.14 (12.89)	23.07 (16.83)	3.53	0.030
Total calories (cal)	1,647.9 (581.5)	1,844.0 (538.3)	1,475.0 (441.9)	5.92	0.003
Total fiber (g)	6.06 (3.51)	6.59 (3.30)	7.74 (4.43)	3.81	0.023
Youth aged <18 years (*n* = 118)					
n	112	6	0	—	—
BMI (kg/m^2)	16.53 (2.45)	17.66 (2.16)	—	3.67	0.058
Waist circumference (inches)	22.7 (2.55)	23.00 (3.28)	—	0.061	0.806
Hip circumference (inches)	28.11 (3.14)	28.83 (4.16)	—	0.304	0.583
WHR	0.81 (0.06)	0.80 (0.06)	—	0.099	0.753
Thigh circumference (inches)	14.53 (1.83)	14.67 (2.33)	—	0.494	0.484
Systolic blood pressure (mmHg)	104.11 (10.94)	101.00 (8.94)	—	0.464	0.495
Diastolic blood pressure (mmHg)	69.46 (8.68)	71.67 (7.52)	—	0.220	0.640
Knowledge score	4.41 (1.93)	6.17 (1.83)	—	3.73	0.056
% calories from carbohydrates	74.13 (7.88)	74.22 (6.40)	—	0.007	0.933
Carbohydrates (g)	260.87 (106.62)	304.31 (113.37)	—	0.643	0.424
% calories from protein	14.98 (2.04)	13.79 (1.68)	—	1.99	0.160
Protein (g)	53.17 (23.04)	56.71 (23.15)	—	0.048	0.827
% calories from fat	4.83 (4.01)	5.32 (2.61)	—	0.057	0.812
Fat (g)	16.95 (14.67)	19.75 (10.10)	—	0.154	0.695
Total calories (cal)	1,408.74 (548.06)	1,621.83 (543.81)	—	0.566	0.454
Total fiber (g)	5.66 (3.95)	6.31 (5.11)	—	0.078	0.781

Data are means (SD). *n* = 703.

be successfully implemented in larger-based community settings in rural India. Future studies of population-based DPM programs in other sites should assess their cost-effectiveness and replicability.

This is the first study to measure thigh circumference among rural Indians, but lack of standards for the smaller-stature Asian Indians prevents a comparison with the Hoorn Study (24). Studies have shown an association between thigh measurements and FBG that is corroborated for adult men only (24), with a lower thigh circumference predicting increased risk for glucose intolerance (10). The emphasis of the DPM on walking may have contributed to decreased thigh circumference (owing to the low caloric intakes) and is a concern because of the association of these measures with incident diabetes (24).

DPM intervention emphasizing physical activity/stress relaxation/dietary changes successfully reduced systolic (4% drop) and diastolic blood pressure (11% drop) among pre-diabetic adults, thereby reducing their risk for heart disease (25). However, the presence of hypertensive levels of blood pressure with elevated blood glucose suggests the synergistic influence of comorbidities (26). Prior studies have also shown that lifestyle modification successfully reduced hypertension (6,16). We speculate that intervention successfully affected hypertension levels among adults with IFG but not among youth because of a wide window for impact, higher levels, and a larger sample size. The high rates (40%) of hypertension and prehypertension prevalent in an agricultural community call for aggressive attention owing to their causative links with cardiovascular disease, stroke, renal dysfunction, and mortality, conditions that are increasing in the Indian population (27,28).

An increase in the intake of carbohydrate was observed for adults, with a greater increase among adults with IFG. This increase may be due to a lack of controlled eating and should be emphasized in future studies. Model meals served as a valuable interactive tool and demonstrated that mixing of millets and legumes can stretch nutrient density (13). The major component of refined white rice, corroborated by earlier studies (13) with a low fiber intake, could be a factor in postprandial glucose overload (29). Although dietary education improved fiber intake, it was much lower than the recommended levels of >25 g/day.

The initial level of fat intake was very low (<5% of calories) and hence less likely to be affected by dietary intervention.

Use of fasting capillary blood values in this study, instead of serum values, may have had an impact on the prevalence figures, but findings are lower than those in the rural Andhra Pradesh study that also used the same method (8). Correlation of capillary and serum blood glucose values was high ($r = 0.81$, $P < 0.001$).

In summary, this population intervention program successfully reduced some of the obesity risk factors and improved FBG levels and fiber intake. The findings highlight the need to initiate preventive education in elementary schools as intervention helped to reduce IFG by 17%. Our results, if sustained in the future, suggest that the incidence of type 2 diabetes may be delayed or prevented and its course changed for improved outcomes among vulnerable population groups (30).

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References

1. King H, Aubert RE, Herman WH: Global burden of diabetes, 1995–2025: prevalence, numerical estimates, and projections. *Diabetes Care* 21:1414–1431, 1998
2. Ramachandran A, Snehalatha C, Baskar AD, Mary S, Kumar CK, Selvam S, Catherine S, Vijay V: Temporal changes in prevalence of diabetes and impaired glucose tolerance associated with lifestyle transition occurring in the rural population in India. *Diabetologia* 47:860–865, 2004
3. Zimmet PK, Alberti KG, Shaw J: Global and societal implications of the diabetes epidemic *Nature* 414:782–787, 2001
4. Wild S, Roglic G, Green A, Sicree R, King H: Global prevalence of diabetes: estimates for the year 2000 and projections for 2030. *Diabetes Care* 27:1047–1053, 2004
5. The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus: the Diabetes Control and Complications Trial Research Group. *N Engl J Med* 329:977–986, 1993
6. Intensive blood-glucose control with sulphonylureas or insulin compared with conventional treatment and risk of complications in patients with type 2 diabetes (UKPDS 33).: UK Prospective Diabetes Study (UKPDS) Group. *Lancet* 352:837–853, 1998
7. Satterfield DW, Volansky M, Caspersen CJ, Engelgau MM, Bowman BA, Gregg EW, Geiss LS, Hosey GM, May J, Vinicor F: Community-based lifestyle interventions to prevent type 2 diabetes. *Diabetes Care* 26:2643–2652, 2003
8. Chow CK, Raju PK, Raju R, Reddy KS, Cardona M, Celermajer DS, Neal BC: The prevalence and management of diabetes in rural India. *Diabetes Care* 29: 1717–1718, 2006
9. American Diabetes Association: Standards of medical care for patients with diabetes mellitus. *Diabetes Care* 26:S33–S50, 2005
10. Kuk JL, Janiszewski PM, Ross R: Body mass index and hip and thigh circumferences are negatively associated with visceral adipose tissue after control for waist circumference. *Am J Clin Nutr* 85:1540–1544, 2007
11. Chamukuttan S, Viswanathan V, Ramachandran A: Cut-off values for normal anthropometric variables in Asian Indian adults. *Diabetes Care* 26:1380–1384, 2003
12. Misra A, Madhavan M, Vikram NK, Pandey RM, Dhingra V, Luthra K: Simple anthropometric measures identify fasting hyperinsulinemia and clustering of cardiovascular risk factors in Asian Indian adolescents. *Metabolism* 55:1569–1573, 2006
13. Gopalan C, Rama Sastri BV, Balasubramanian SC: *Nutritive Value of Indian Foods.* Hyderabad, India, National Institute of Nutrition, ICMR, 1989.
14. Sadikot SM, Nigam A, Das S, Bajaj S, Zargar AH, Prasannakumar KM, Sosale A, Munichoodappa C, Seshiah V, Singh SK, Jamal A, Sai K, Sadasivrao Y, Murthy SS, Hazra DK, Jain S, Mukherjee S, Bandyopadhay S, Sinha NK, Mishra R, Dora M, Jena B, Patra P, Goenka K, DiabetesIndia: The burden of diabetes and impaired glucose tolerance in India using the WHO 1999 criteria: prevalence of diabetes in India study (PODIS). *Diabetes Res Clin Pract* 66:301–307, 2004
15. Pinhas-Hamiel O, Dolan LM, Daniels SR, Standiford D, Khoury PR, Zeitler P: Increased incidence of non-insulin-dependent diabetes mellitus among adolescents. *J Pediatr* 128:608–615, 1996
16. Ramachandran A, Snehalatha C, Mary S, Mukesh B, Bhaskar AD, Vijay V, Indian Diabetes Prevention Programme (IDPP): The Indian Diabetes Prevention Programme shows that lifestyle modification and metformin prevent type 2 diabetes in Asian Indian subjects with impaired glucose tolerance (IDPP-1). *Diabetologia* 49: 289–297, 2006
17. Yajnik CS: Early life origins of insulin resistance and type 2 diabetes in India and other Asian countries. *J Nutr* 134: 205–210, 2004
18. Goodpaster BH, Krishnaswami S, Harris TB, Katsiaras A, Kritchevsky SB, Simonsick EM, Nevitt M, Holvoet P, Newman AB: Obesity, regional body fat distribution, and the metabolic syndrome in older men and women. *Arch Intern Med* 165: 777–783, 2005
19. Banerji MA, Faridi N, Atluri R, Chaiken RL, Lebovitz HE: Body composition, visceral fat, leptin, and insulin resistance in Asian Indian men. *J Clin Endocrinol Metab* 84:137–144, 1999
20. Neel JV, Weder AB, Julius S: Type II diabetes, essential hypertension, and obesity as "syndromes of impaired genetic homeostasis": the "thrifty genotype" hypothesis enters the 21st century. *Perspect Biol Med* 42:44–74, 1998
21. Mohan A, Sandeep S, Deepa R, Vimaleswaran KS, Farooq S, Mohan V: Visceral and central abdominal fat and anthropometry in relation to diabetes in Asian Indians. *Diabetes Care* 27:2948–2953, 2004
22. Misra A, Vikram NK: Insulin resistance syndrome (metabolic syndrome) and obesity in Asian Indians: evidence and implications. *Nutrition* 20:482–491, 2004
23. Fujimoto WY, Jablonski KA, Bray GA, Kriska A, Barrett-Connor E, Haffner S, Hanson R, Hill JO, Hubbard V, Stamm E, Pi-Sunyer FX, Diabetes Prevention Program Research Group: Body size and shape changes and the risk of diabetes in the diabetes prevention program. *Diabetes* 56:1680–1685, 2007
24. Snijder MB, Dekker JM, Visser M, Yudkin JS, Stehouwer CD, Bouter LM, Heine RJ, Nijpels G, Seidell JC: Larger thigh and hip circumferences are associated with better glucose tolerance: the Hoorn study. *Obes Res,* 11(1):104–111, 2003
25. Joshi P, Islam S, Pais P, Reddy S, Dorairaj P, Kazmi K, Pandey MR, Haque S, Mendis S, Rangarajan S, Yusuf S: Risk factors for early myocardial infarction in South Asians compared with individuals in other countries. *JAMA* 297:286–294, 2007
26. Wylie-Rossett J: Hypertension and diabetes: clinical synergy and challenges. *On Cutting Edge* 25:1–10, 2004
27. Chow CK, Naidu S, Raju K, Raju R, Joshi R, Sullivan D, Celermajer DS, Neal BC:. Significant lipid, adiposity and metabolic abnormalities amongst 4535 Indians from a developing region of rural Andhra Pradesh. Atherosclerosis 196:943–952, 2008
28. Singh RB, Bajaj S, Niaz MA, Rastogi SS, Moshiri M: Prevalence of type 2 diabetes mellitus and risk of hypertension and coronary artery disease in rural and urban population with low rates of obesity. *Int J Cardiol* 66:65–72, 1998
29. Englyst HN, Veenstra J, Hudson GJ: Measurement of rapidly available glucose (RAG) in plant foods: a potential in vitro predictor of the glycaemic response *Br J Nutr* 75:327–337, 1996
30. Newby PK, Peterson KE, Berkey CS, Leppert J, Willett WC, Colditz GA: Dietary patterns and changes in body mass index and waist circumference in adults. *Am J Clin Nutr* 77:1417–1425, 2003