Results & Discussion

RESULTS AND DISCUSSION

In this chapter the results are presented and discussed under the following heads

PHASE I: Metabolic alterations in T2DM subjects and the prevalence of microalbuminuria

PHASE II: Risk factor analysis and trends of dyslipidemia in T2DM subjects of an industrial population

PHASE III (a): Nutritional analysis of BGP

(b): Product development using BGP

(c): Sensory evaluation of the developed products

PHASE IV (a): Impact of BGP supplementation on the FBG, HbA1C and lipid profile of stable T2DM subjects

(b): Scaling up of BGP khakhra for consumers at large

PHASE I: METABOLIC ALTERATIONS IN T2DM SUBJECTS AND THE PREVALENCE OF MICROALBUMINURIA.

The epidemic nature of diabetes continues to affect ever increasing numbers of people around the world. India leads the global top ten in terms of the highest number of people with diabetes with a figure of 50.8 million for 2010 (IDF 2009). Diabetic nephropathy is the leading cause of end-stage renal disease (ESRD) worldwide. Nearly 30% of chronic renal failures in India are due to diabetic nephropathy (Agarwal & Dash, 2000). Microalbuminuria (MAU) is the earliest clinical evidence of nephropathy. Without specific interventions, 20–40% of type 2 diabetic patients with MAU progress to overt nephropathy (ADA 2004). MAU in diabetic patients is also a powerful risk factor for cardiovascular disease (Gerstein et al 2001). However, the implementation of routine screening for renal disease is still far below recommended goals.

The present study therefore, made an attempt to look at the albumin excretion levels among stable type 2 diabetic subjects and to study the metabolic alterations associated with MAU. For the study 102 stable diabetic subjects were enrolled from two pathology laboratories of Vadodara. Information regarding their socio economic status, educational status, anthropometric measurements and medical history were recorded. Biochemical indicators included fasting blood glucose (FBG), lipid parameters and renal function tests. MAU was diagnosed if the albumin excretion was between 30 and 299 µg/mg of Creatinine (Cr).

SOCIO-ECONOMIC STATUS OF THE T2DM SUBJECTS

Table 4.1 gives the socio-economic data related to the T2DM subjects. A total of 102 subjects were enrolled for this phase of which 53 were males and 49 were females. The mean age was 58y and 56y for male and female diabetics respectively. Majority of the subjects (98%) in the present study were Hindus and they belonged to the middle income group. Around 60% of the subjects had received elementary schooling and 20.6% of the subjects reported to be graduates. About 59% of the male diabetics were either in service or running a business and 41.5% had retired. Majority of the female diabetics were housewives. The distribution of diabetic subjects living in nuclear and joint families was almost equal (49% vs 47.1%).

OBESITY MEASURES AND DIABETES MELLITUS

Nowadays a number of obesity measures are available to assess abdominal and general obesity. We made an attempt to assess the prevalence using various indicators which is given in Table 4.2. Majority of the subjects were overweight or obese as indicated by their BMI. Female diabetic subjects had significantly higher Waist Stature Ratio (WSR) and % Body Fat as compared to the male diabetics. Waist Weight Ratio (WWR) means were found to be similar among the male and female diabetics. The prevalence of overweight was 13.7% and that of obesity was 65.6% among the diabetics using the Asia Pacific criteria (Figure 4.1).

Waist circumference values were found to be higher than the normal cut offs

TABLE 4.1

SOCIO-ECONOMIC STATUS OF THE T2DM SUBJECTS (N, %)

	Male N=53	Female N=49	Total N=102
Age (y) (Mean ± SD)	58 ± 9	56 ± 8	57 ± 8
Occupation			
Service	19 (35.8)	7 (14.3)	26 (25.5)
Business	12 (22.6)	3 (6.1)	15 (14.7)
Housewife	0 (0)	39 (79.6)	-
Retired	22 (41.5)	0 (0)	22 (21.6)
Religion			
Hindu	52 (98.1)	48 (97.95)	100 (98.0)
Muslim	0 (0)	1 (2.04)	1 (0.98)
Christian	1 (1.9)	0 (0)	1 (0.98)
Education			
Illiterate	0 (0)	2 (4.1)	2 (1.96)
Elementary	26 (49.1)	35 (71.4)	61 (59.8)
High School	4 (7.5)	5 (10.2)	9 (8.8)
Diploma	4 (7.5)	1 (2.04)	5 (4.9)
Graduate	17 (32.1)	4 (8.2)	21 (20.6)
Post Graduate	2 (3.8)	2 (4.1)	4 (3.9)
Family Type			
Nuclear	29 (54.7)	21 (42.9)	50 (49.0)
Extended Nuclear	2 (3.8)	2 (4.1)	4 (3.9)
Joint	22 (41.5)	26 (53.1)	48 (47.1)
PCI			
<1000	2 (3.8)	5 (10.2)	7 (6.9)
1000- <5000	34 (64.2)	31 (63.3)	65 (63.7)
5000- <10000	11 (20.8)	4 (8.2)	15 (14.7)
10000- <15000	1 (1.9)	2 (4.1)	3 (2.9)
≥15000	3 (5.7)	1 (2.04)	4 (3.9)
NA	2 (3.8)	6 (12.2)	8 (7.8)

PCI: Per Capita Income; NA: Not available

TABLE 4.2

OBESITY MEASURES IN T2DM SUBJECTS (Mean ± SD)

	Male N=53	Female N= 49	Total N= 102
Height(m)	1.64 ± 0.05	1.51 ± 0.05 ***	1.58 ± 0.08
Weight(Kg)	67 ± 10	66 ± 12	67 ± 11
WC(cm)	93 ± 8	93 ± 12	93 ± 10
Hip(cm)	95 ± 7	105 ± 11 ***	99 ± 10
WHR	0.98 ± 0.04	0.89 ± 0.08 ***	0.94 ± 0.08
BMI	24.87 ± 3.33	29.02 ± 4.44 ***	26.87 ± 4.41
WSR	0.566 ± 0.052	0.618 ± 0.072 ***	0.591 ± 0.067
WWR	1.40 ± 0.12	1.43 ± 0.16	1.41 ± 0.14
% Body Fat	27 ± 5	44 ± 5 ***	35 ± 10

WC = Waist Circumference

WHR = Waist Hip Ratio

BMI = Body Mass Index

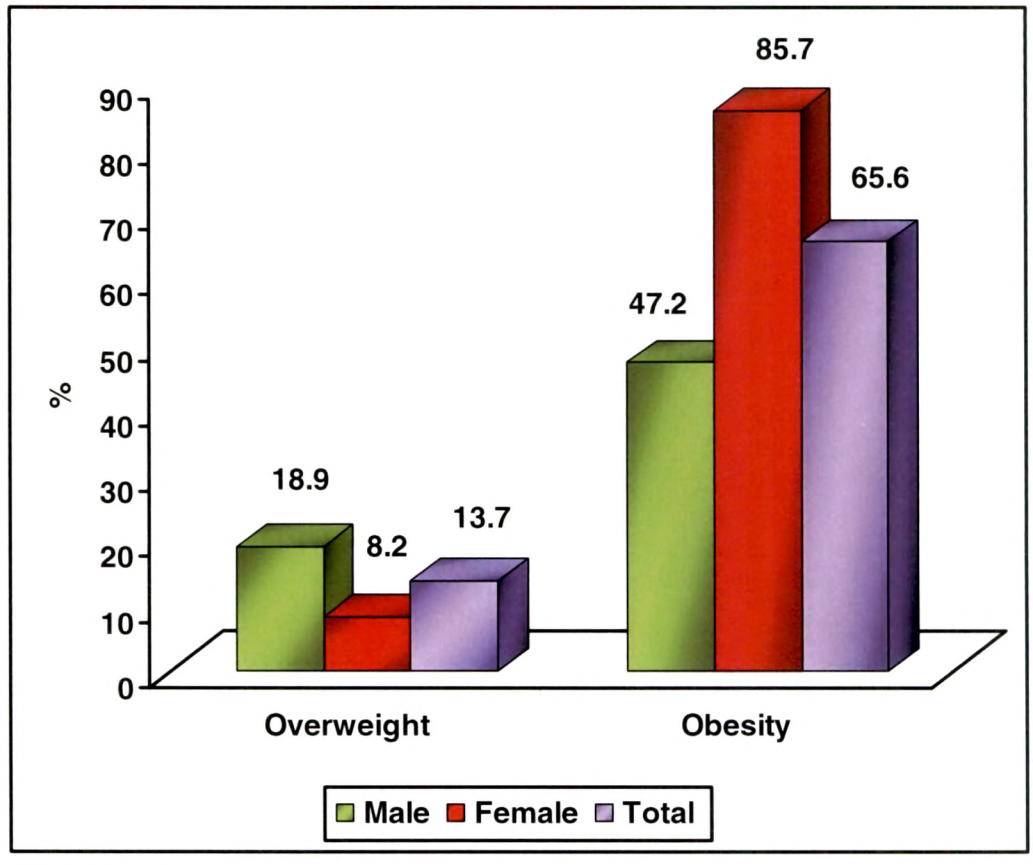
WSR= Waist Stature Ratio

WWR= Waist Weight Ratio

Significantly different from males at *** $p<0.001$

FIGURE 4.1

PREVALENCE OF OVERWEIGHT AND OBESITY IN T2DM SUBJECTS BASED ON ASIA PACIFIC CLASSIFICATION (%)



(≥ 90 cm for males & ≥ 80 cm for females) in both the genders (64.2% males and 91.8% females) indicating the presence of abdominal obesity (Figure 4.2). Majority of the male and female diabetics had higher than normal values for WHR, WSR, WWR and % Body fat as can be seen from Table 4.3. Obesity prevalence calculated from WHR, WSR, WWR and % Body fat was 85.3%, 100%, 54.9% and 83.3% respectively. Except for WWR all the obesity measures indicated that more than 75% of the T2DM subjects had abdominal obesity. Thus the prevalence of obesity as determined by various obesity measures was high in this study population.

BACKGROUND INFORMATION

The background information related to risk factors in the subjects is given in Table 4.4. Few subjects reported habitual consumption of alcohol, tobacco and smoking and it was found to be less than 10%.

MEDICAL HISTORY

Information on the medical history (Table 4.5) showed that hypertension was common in the diabetic subjects. Hypertension is common among patients with type 2 diabetes and may precede the onset of diabetes. Nearly 50% of the diabetic subjects were hypertensive. Around 4.9% of the diabetic subjects had cardiac related problems. Thus overweight, obesity, hypertension and CHD were seen in the diabetic subjects.

FAMILY HISTORY

About 61.8%, 28.4% and 6.9% of the subjects had a history of diabetes, hypertension and CHD in their family respectively.

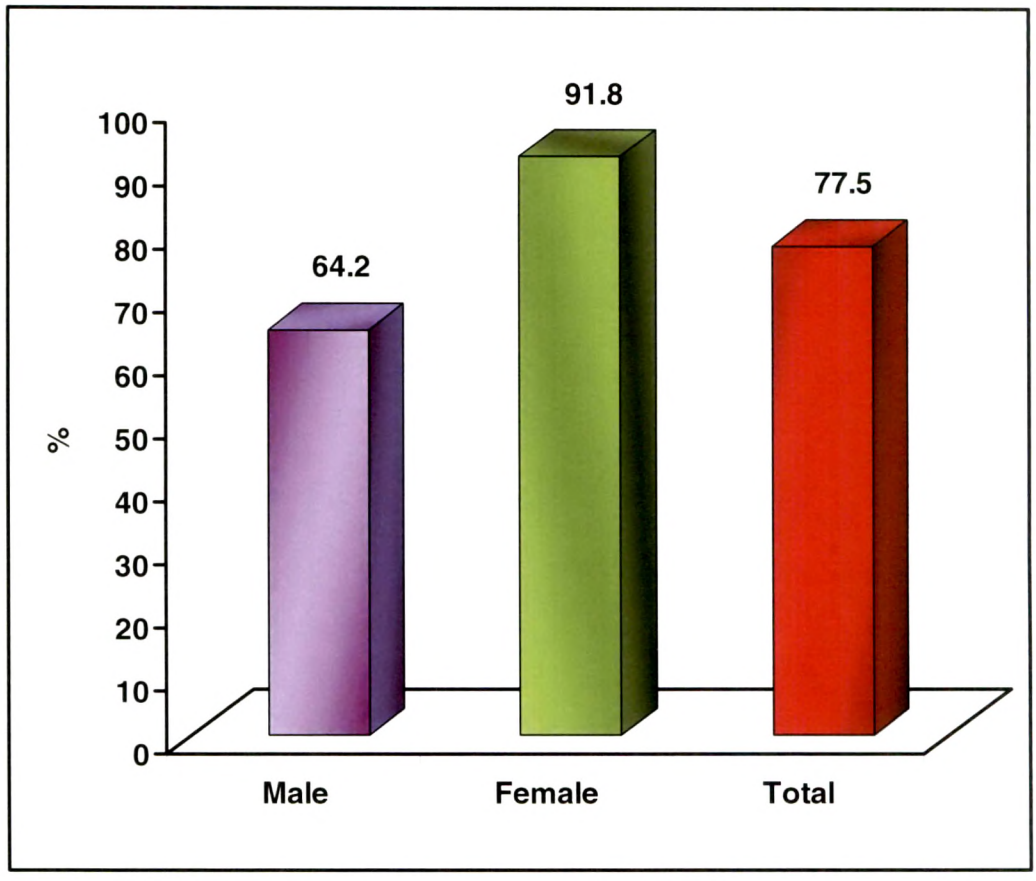
DIETARY INTAKE

Table 4.6 gives the mean nutrient intake of the subjects. Mean calorie intake was 1501 Kcal. There was a significant difference in the total calorie intake between the male and female diabetic subjects with the male subjects consuming 1588 Kcal as compared to 1407 Kcal by the female subjects. Both the genders met about 70% of the RDA for calorie intake. The mean carbohydrate intake ranged from 195 g for the female subjects to about 218 g

FIGURE 4.2

PERCENT PREVALENCE OF ABDOMINAL OBESITY

BASED ON IDF CRITERIA



WC: Males ≥ 90 cm
Females ≥ 80 cm

TABLE 4.3

OBESITY MEASURES IN T2DM SUBJECTS: PREVALENCE DATA

	Male N=53	Female N=49	Total N=102
BMI ≥ 23 Kg/m^2	35 (66)	46 (93.9)	81 (79.4)
WC (M: ≥ 90; F: ≥ 80)	34 (64.2)	45 (91.8)	79 (77.5)
WHR (M: ≥ 0.90; F: ≥ 0.85)	51 (96.2)	36 (73.5)	87 (85.3)
WSR ≥ 0.5	53 (100)	49 (100)	102 (100)
WWR (M: ≥ 1.36; F: ≥ 1.44)	34 (64.2)	22 (44.9)	56 (54.9)
% Body Fat (M: ≥ 25; F: ≥ 32)	36 (67.9)	49 (100)	85 (83.3)

Values in parenthesis indicate percentage

TABLE 4.4

BACKGROUND INFORMATION RELATED TO RISK FACTORS FOR T2DM SUBJECTS (N, %)

VARIABLE	Prevalence
Tobacco (M+F)	10 (9.8)
Smoking (M)	9 (8.8)
Alcohol (M)	5 (4.9)

Values in parenthesis indicate percentage

TABLE 4.5

MEDICAL HISTORY OF THE T2DM SUBJECTS (N, %)

	Male N=53	Female N=49	Total N=102
Hypertension	21 (39.6)	30 (61.2)	51 (50)
CHD	3 (5.7)	2 (4.1)	5 (4.9)

TABLE 4.6

MEAN NUTRIENT INTAKE OF THE T2DM SUBJECTS (Mean ± SD)

Nutrient	Males N=53	Females N=49	Total N=102
Calories (Kcal)	1588 ± 461 (68.5)	1407 ± 405 (74.1)	1501 ± 442
Carbohydrate (g)	217.6 ± 69	195.3 ± 60.0	206.9 ± 65.6
Protein (g)	46.1 ± 15.0 (76.8)	42.7 ± 15.4 (77.6)	44.4 ± 15.2
Fat (g)	58.3 ± 21.7 (291.5-388.7)	48.4 ± 17.0 (242-322.7)	53.5 ± 20.1
Iron (mg)	12.6 ± 5.4 (74.1)	10.9 ± 4.2 (51.9)	11.8 ± 4.9
Vitamin C (mg)	59.0 ± 58.6 (98.3)	40.9 ± 40.4 (68.2)	50.3 ± 51.3
β-carotene (µg)	1408 ± 2973 (29.3)	1020 ± 1610 (21.3)	1222 ± 2412
Total Dietary Fibre (g)	17.3 ± 9.9	15.8 ± 8.0	16.6 ± 9.0

Values in parenthesis indicate % RDA (2009) met by the subjects

for the male diabetics. Carbohydrates contributed 55% of the total calorie intake (Figure 4.3). The average protein intake was 44.4g which contributed to around 12% to the total calorie intake. The protein intake was comparable between the two genders and met around 77% of the RDA. Dietary fat contributed 32% towards the calorie intake. Fat intake among the diabetic subjects was high averaging around 53.5 g which was 242-389% of the RDA. Male diabetics had a significantly higher fat consumption as compared to the female diabetics. Iron intakes did not meet the RDA in both the genders averaging to a poor 11.8 mg but the male diabetics fared better (74% of the RDA) in comparison to female diabetics (52% of the RDA). Vitamin C intake in females met only 68.2% of the RDA whereas in males it met 98.3% of the RDA. Average β-carotene intake was 1222 µg. Male and female diabetics could meet only 29% and 21% of the RDA for β-carotene respectively. Thus, the diets of diabetic subjects provided a high quantum of fats and was poor in micronutrient, such as iron and beta-carotene content.

BIOCHEMICAL PROFILE OF THE SUBJECTS

Glycemic Status

Glycemic control has been shown to prevent the development of secondary complications in diabetes especially nephropathy. The glycemic status of the subjects is given in Table 4.7. The glycemic status of the subjects was similar in both the genders with mean FBG and HbA1C values being 146 mg/dl and 8.7 g% respectively. Mean Insulin value was 4.08 µIU/ml which is lower than the normal range of 5-19 µIU/ml. The value of Insulin resistance (HOMA-IR) was 1.39 which was lower than the cut off value of 2.5. When the frequency distribution curve of the HbA1C values of the diabetic subjects was charted (Figure 4.4) it was found that 94.1% of the subjects had HbA1C values ≥ 7% indicating poor glycemic control among the subjects.

Lipemic Status

Table 4.8 gives the lipid profile of the diabetic subjects. The female diabetics had significantly higher TG, VLDL-C and HDL-C values as compared to male

FIGURE 4.3

DISTRIBUTION OF ENERGY COMING FROM MACRONUTRIENTS (%)

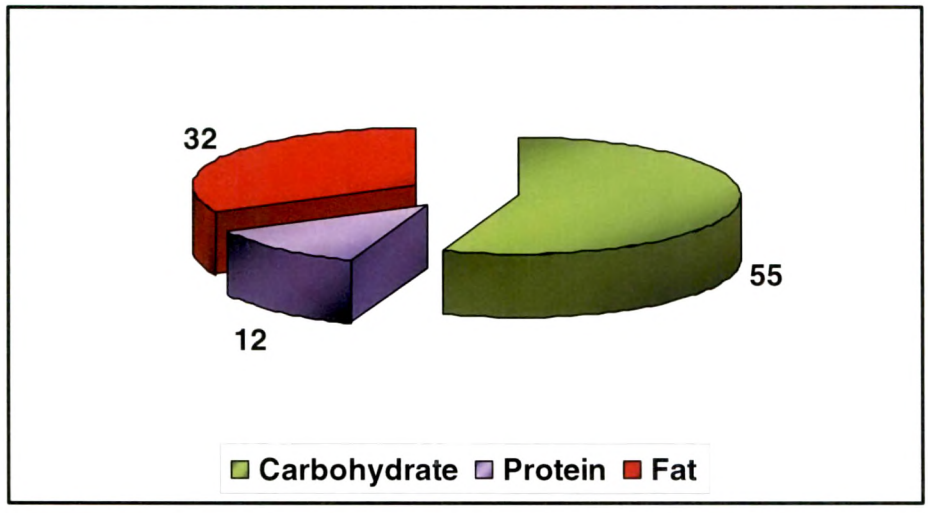


TABLE 4.7

GLYCEMIC STATUS OF THE T2DM SUBJECTS

	Male N=53	Female N=49	Total N=102
FBG (mg/dl)	142 ± 50	151 ± 49	146 ± 49
HbA1C (%)	8.5 ± 1.3	8.8 ± 1.5	8.7 ± 1.4
Insulin (µIU/ml)	4.49 ± 3.29	3.63 ± 3.13	4.08 ± 3.22
HOMA-IR	1.58 ± 1.36	1.18 ± 0.85	1.39 ± 1.15
HOMA-BF	33.07 ± 45.27	29.98 ± 53.35	31.59 ± 48.97

FIGURE: 4.4

FREQUENCY DISTRIBUTION OF HbA1C IN T2DM SUBJECTS

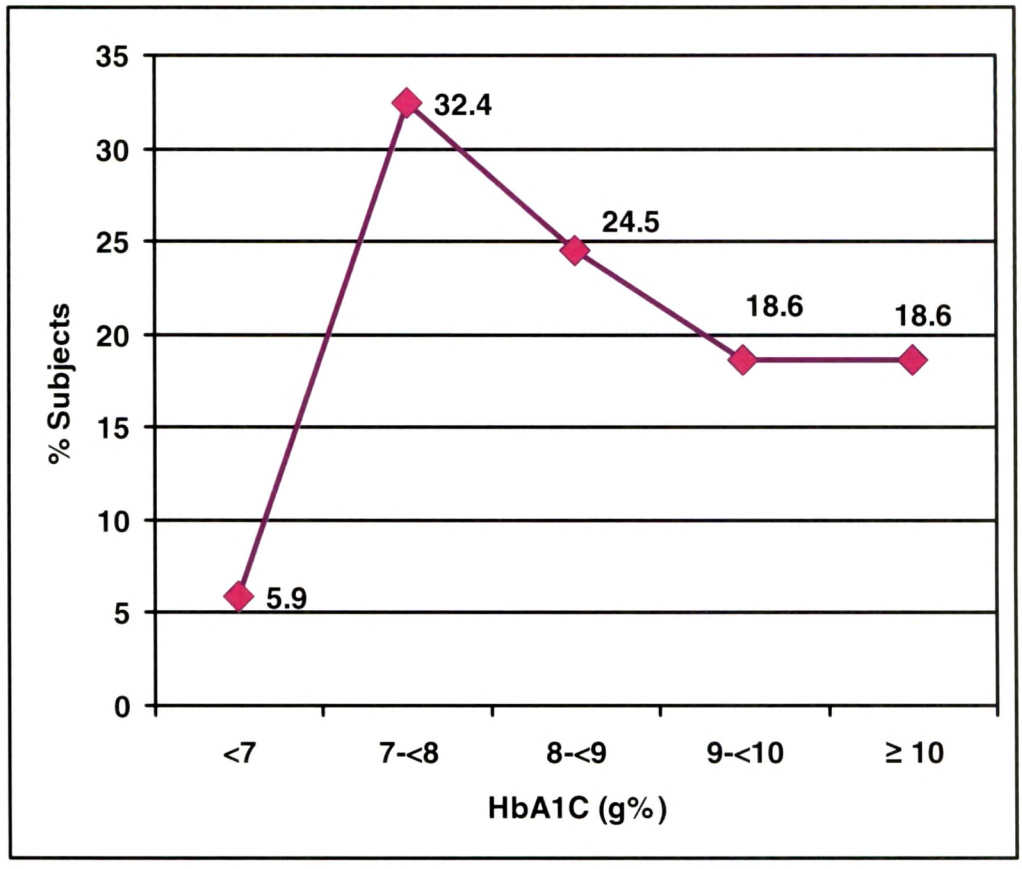


TABLE 4.8

LIPID PROFILE OF T2DM SUBJECTS (Mean ± SD, mg/dl)

Variable	Male N=53	Female N=49	Total N=102
TC	182 ± 49	197 ± 45	189 ± 48
TG	138 ± 55	164 ± 64 *	151 ± 61
HDL	41 ± 9	45 ± 10 *	43 ± 10
LDL	108 ± 38	117 ± 38	112 ± 38
VLDL	28 ± 11	33 ± 13 *	30 ± 12
Non HDL	141 ± 46	152 ± 43	146 ± 45
L/H	2.69 ± 0.85	2.68 ± 0.93	2.68 ± 0.88
TC/H	4.58 ± 1.31	4.51 ± 1.15	4.54 ± 1.23
TG/H	3.59 ± 1.96	3.86 ± 1.91	3.72 ± 1.93

Significantly different from males at * $p<0.05$

diabetics. In general it was observed that aberrations in the lipid profile were more profound among the female diabetic subjects as compared to the male diabetics.

Based on ATP III classification the prevalence of dyslipidemia was obtained using lipid parameters. This is given in Table 4.9. About 35% and 44% of the subjects had elevated levels of TC and TG respectively. An alarmingly high i.e. 62.7% of the subjects had LDL-C levels higher than 100 mg/dl. Low levels of HDL-C were seen in 60.8% of the diabetics. The percent prevalence of female diabetics having low HDL-C levels was higher than male diabetics (73.5% vs. 49.1%). The percent prevalence of high atherogenic lipoproteins (LDL-C ≥ 100 mg/dl, TG/H ≥ 3, Non HDL-C ≥ 130 mg/dl) was high in the diabetic subjects indicating the risk for cardiovascular disease. Further, around 88.9% of the hypertriglyceridemic subjects had Non HDL-C values ≥ 130 mg/dl.

The Atherogenic Index of Plasma (AIP), defined as log (TG/HDL-C), has been proposed as a marker of plasma atherogenicity because it is increased in people at higher risk for coronary heart disease and is inversely correlated with LDL particle size. When the AIP was calculated it was observed that around 93.1% of the subjects fell into the high risk category (Table 4.10).Thus a high prevalence of dyslipidemia was observed among the subjects and they were at increased risk of CHD as indicated by the AIP levels.

Kidney Function Indicators

We also studied the kidney function indicators among the diabetic subjects (Table 4.11). Serum creatinine levels were significantly lower in female diabetics as compared to male diabetics (0.69 mg/dl vs 0.92 mg/dl). Also female diabetics had higher mean urinary albumin values as compared to male diabetics (28 µg/mg Cr vs 21µg/mg Cr).

MAU was diagnosed if the albumin excretion was between 30 and 299 µg/mg of Creatinine (Cr). The overall prevalence of MAU in the present study was

TABLE 4.9

PREVALENCE OF DYSLIPIDEMIA IN T2DM SUBJECTS (%)

Variable	Male N=53	Female N=49	Total N=102
TC ≥ 200 (mg/dl)	16(30.2)	20(40.8)	36(35.3)
TG ≥ 150 (mg/dl)	20(37.7)	25(51.0)	45(44.1)
LDL ≥ 100 (mg/dl)	33(62.3)	31(63.3)	64(62.7)
HDL < 40 (mg/dl)	26(49.1)	36(73.5)	62(60.8)
TG/H ≥ 3	33 (62.3)	30 (61.2)	63 (61.8)
Non HDL ≥ 130 (mg/dl)	29 (54.7)	37 (75.5)	66 (64.7)

Values in parenthesis indicate percentage

TABLE 4.10

ATHEROGENIC INDEX OF PLASMA RISK LEVELS IN T2DM SUBJECTS (N, %)

AIP Risk Level	Male (53)	Female (49)	Total (102)
Low Risk (<0.11)	2 (3.8)	1 (2.0)	3 (2.9)
Intermediate Risk (0.11-0.21)	2 (3.8)	2 (4.1)	4 (3.9)
High Risk (>0.21)	49 (92.5)	46 (93.9)	95 (93.1)

TABLE 4.11

KIDNEY FUNCTION INDICATORS IN T2DM SUBJECTS

(Mean ± SD, mg/dl)

	Male N=53	Female N=49	Total N=102
Serum Cr	0.92 ± 0.23	0.69 ± 0.24 ***	0.81 ± 0.26
Serum Urea	25.40 ± 7.29	23.17 ± 5.13	24.33 ± 6.41
Urine Cr	100.83 ± 64.76	78.86 ± 99.52	90.28 ± 83.60
Urine Urea	482.32 ± 245.01	412.00 ± 248.19	448.54 ± 247.84
Urine Albumin (µg/mg Cr)	21 ± 14	28 ± 18 *	24 ± 17

Cr- Creatinine

Significantly different from males at * $p<0.05$, *** $p<0.001$

28.4%. Prevalence of MAU among males was 22.6% and among females it was 34.7% (Figure 4.5).

RISK FACTOR SCENARIO

As the glycemic and lipemic status of the diabetic subjects was found to be poor we looked into the risk factor prevalence among the subjects (Figure 4.6). A range of 9 risk factors (BMI ≥23, abdominal obesity, HbA1C ≥ 7 g%, TC ≥ 200 mg/dl, TG ≥ 150 mg/dl, LDL ≥ 100 mg/dl, HDL < 40 mg/dl, TG/H ≥ 3 and hypertension) has been depicted in the graph. The graph disturbingly indicates that all the diabetic subjects had risk factors. On an average the diabetic subjects had 5 risk factors indicating the presence of a multiple risk factor scenario. An alarming 86.2% of the subjects had > 3 risk factors.

BIOCHEMICAL PARAMETERS IN RELATION TO DETERMINANTS

The biochemical characteristics of the diabetic subjects were studied in relation to various obesity measures, HbA1C levels, presence or absence of the metabolic syndrome, urine microalbumin levels and AIP levels.

GLYCEMIC STATUS AND OBESITY MEASURES

The glycemic status of the diabetic subjects in relation to various obesity measures is given in Table 4.12.

Body Mass Index

The FBG, HbA1C, Insulin and HOMA-IR levels of the overweight/obese diabetic subjects were higher than the other group though not significant. When the data was segregated on the basis of gender it was observed that overweight/obese female diabetics had significantly lower HOMA-IR values (1.11 vs 1.81, $p<0.05$) as compared to their male counterparts.

Abdominal Obesity

Mean Insulin and HOMA-IR levels were found to be higher in the group with abdominal obesity. Male diabetic subjects who were abdominally obese had significantly higher Insulin and HOMA-IR values as compared to obese females (Insulin 5.60 µIU/ml vs 3.55 µIU/ml, $p<0.05$; HOMA-IR 2.0 vs 1.15,

FIGURE 4.5

PREVALENCE OF MICROALBUMINURIA IN T2DM SUBJECTS

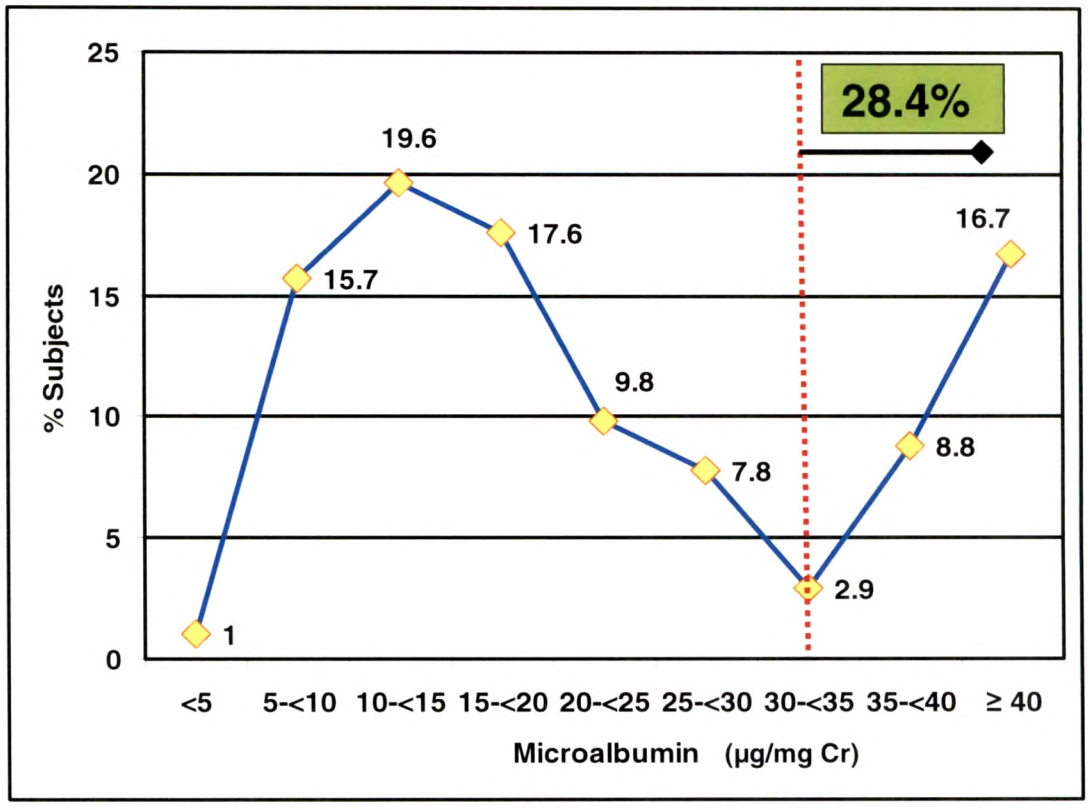


FIGURE 4.6

RISK FACTOR SCENARIO IN T2DM SUBJECTS

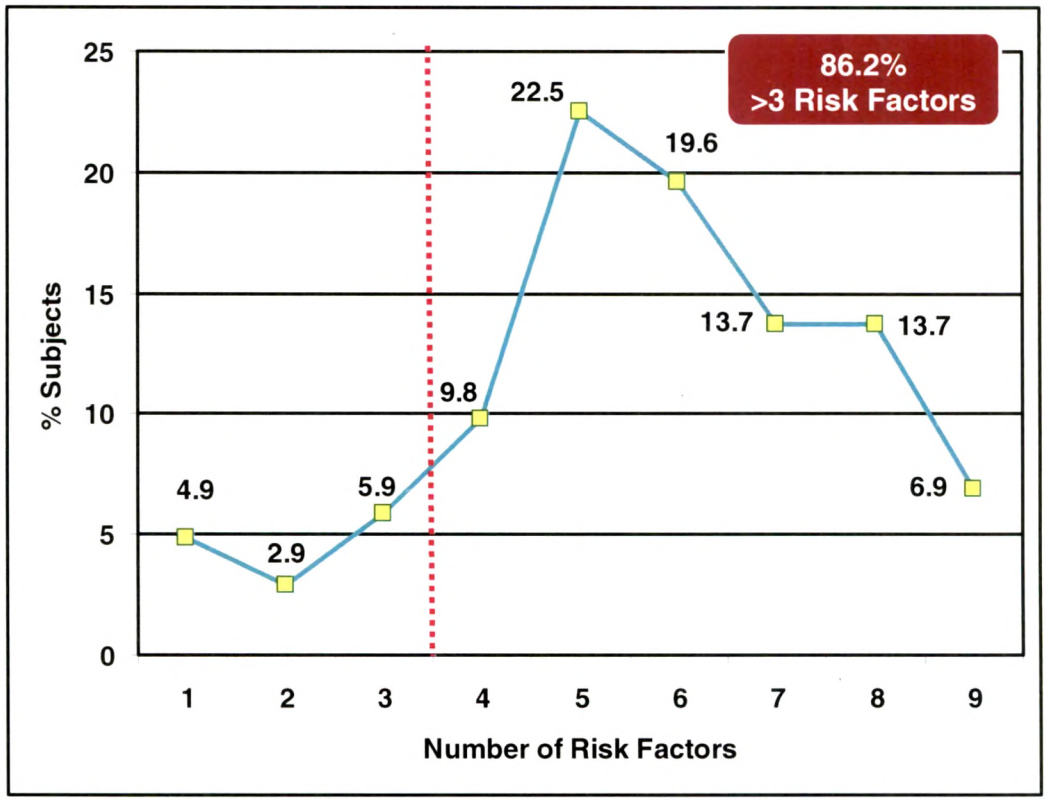


TABLE 4.12

GLYCEMIC STATUS OF THE DIABETIC SUBJECTS

IN RELATION TO OBESITY MEASURES (Mean ± SD)

Variable	FBG (mg/dl)	HbA1C (g %)	Insulin (μIU/ml)	HOMA-IR
BMI < 23 Kg/m^2	145 ± 58	8.6 ± 1.7	3.93 ± 3.83	1.34 ± 1.23
BMI ≥ 23 Kg/m^2	147 ± 47	8.7 ± 1.4	4.13 ± 3.05	1.41 ± 1.14
AO Absent	150 ± 58	8.7 ± 1.8	2.99 ± 2.96	1.02 ± 1.06
AO Present	145 ± 47	8.7 ± 1.3	4.42 ± 3.25	1.51 ± 1.16
Normal WHR	150 ± 48	8.6 ± 1.5	2.20 ± 1.18	0.70 ± 0.29
High WHR	146 ± 50	8.7 ± 1.4	4.35 ± 3.34	1.49 ± 1.20
Low WWR	141 ± 39	8.4 ± 1.2	3.68 ± 2.75	1.34 ± 1.18
High WWR	150 ± 57	8.8 ± 1.6	4.39 ± 3.55	1.43 ± 1.14
Normal % Body Fat	154 ± 59	8.9 ± 1.8	2.25 ± 2.39	0.82 ± 0.95
High % Body Fat	145 ± 48	8.6 ± 1.4	4.49 ± 3.26 *	1.52 ± 1.16 *
WSR <0.5	120 ± 54	7.7 ± 1.8	1.95 ± 2.80	0.58 ± 0.82
WSR ≥ 0.5	148 ± 49	8.7 ± 1.4	4.24 ± 3.21	1.45 ± 1.15

* Significantly different from normal % body fat at p<0.05

p<0.01) and also as compared to males with a normal WC (Insulin 5.60 µIU/ml vs 2.67 µIU/ml, p<0.01; HOMA-IR 2.0 vs 0.90, p<0.05).

Waist-Hip Ratio

Diabetic subjects in the high WHR group had higher, non significant mean HbA1C, Insulin and HOMA-IR levels in comparison to the normal WHR group. The gender based segregation of data did not reveal any significant differences.

Waist-Weight Ratio

No variations in glycemic and insulin status were seen in diabetic subjects with WWR as the obesity variable.

Percent Body Fat

Diabetic subjects with percent body fat higher than the normal cut offs had significantly higher mean Insulin (4.49 µIU/ml vs 2.25 µIU/ml, p<0.05) and HOMA-IR values (1.52 vs 0.82, p<0.05) when compared to diabetic subjects in the other group. When the data was segregated on the basis of gender it was observed that male diabetics with a high percent body fat had Insulin and HOMA-IR values significantly higher than females in the same group (Insulin 5.70 µIU/ml vs 3.63 µIU/ml, p<0.05; HOMA-IR 1.99 vs 1.18, p<0.01) and the males in the normal percent body fat group (Insulin 5.70 µIU/ml vs 2.25 µIU/ml, p<0.01; HOMA-IR 1.99 vs 0.82, p<0.01).

Waist-Stature Ratio

The mean Insulin and HOMA-IR levels increased with an increase in the WSR. However these increases were non significant.

LIPEMIC STATUS AND OBESITY MEASURES

The lipemic status of the diabetic subjects in relation to various obesity measures is given in Table 4.13. None of the obesity measures showed any significant differences in the lipid values monitored, thereby indicating that the clinical condition of diabetes mellitus brings about alterations in lipid metabolism. Further, the high prevalence of overweight, obesity and

TABLE 4.13

LIPEMIC STATUS OF THE DIABETIC SUBJECTS IN RELATION TO OBESITY MEASURES (Mean ± SD, mg/dl)

	TC	TG	HDL	LDL	VLDL	Non HDL	L/H	TC/H	TG/H
BMI < 23 Kg/m^2	201 ± 59	134 ± 65	46 ± 11	123 ± 45	27 ± 13	154 ± 59	2.82 ± 1.11	4.58 ± 1.72	3.08 ± 1.99
BMI ≥ 23 Kg/m^2	186 ± 44	155 ± 59	42 ± 9	109 ± 36	31 ± 12	144 ± 41	2.65 ± 0.82	4.54 ± 1.08	3.89 ± 1.89
AO Absent	199 ± 57	138 ± 66	45 ± 11	122 ± 43	28 ± 13	154 ± 57	2.85 ± 1.06	4.63 ± 1.62	3.30 ± 2.06
AO Present	186 ± 45	154 ± 59	42 ± 9	109 ± 36	31 ± 12	144 ± 41	2.64 ± 0.82	4.52 ± 1.10	3.85 ± 1.89
Low WWR	199 ± 46	150 ± 56	43 ± 9	120 ± 37	30 ± 11	155 ± 43	2.81 ± 0.85	4.64 ± 1.06	3.50 ± 1.39
High WWR	181 ± 48	152 ± 65	42 ± 11	106 ± 38	30 ± 13	139 ± 46	2.58 ± 0.90	4.47 ± 1.36	3.89 ± 2.27
Normal % Body Fat	204 ± 64	138 ± 67	45 ± 10	127 ± 47	28 ± 13	160 ± 62	2.92 ± 1.08	4.76 ± 1.75	3.36 ± 2.24
High % Body Fat	186 ± 44	153 ± 60	42 ± 10	109 ± 36	31 ± 12	144 ± 41	2.64 ± 0.84	4.50 ± 1.10	3.79 ± 1.87
WSR <0.5	194 ± 48	115 ± 38	50 ± 13	121 ± 47	23 ± 8	144 ± 53	2.66 ± 1.36	4.14 ± 1.51	2.40 ± 0.85
WSR 0.5-0.549	202 ± 59	148 ± 76	43 ± 10	121 ± 43	30 ± 15	159 ± 56	2.88 ± 0.96	4.86 ± 1.53	3.62 ± 2.22
WSR 0.550-0.599	198 ± 49	153 ± 52	44 ± 9	120 ± 41	31 ± 10	154 ± 46	2.76 ± 0.86	4.57 ± 1.03	3.58 ± 1.38
WSR 0.6-0.649	172 ± 42	143 ± 60	42 ± 11	98 ± 30	29 ± 12	130 ± 38	2.38 ± 0.72	4.21 ± 1.14	3.57 ± 1.87
WSR ≥ 0.650	179 ± 27	173 ± 63	39 ± 8	105 ± 27	35 ± 13	140 ± 28	2.78 ± 0.87	4.73 ± 1.17	4.77 ± 2.51

abdominal obesity coupled with diabetes mellitus could have modified the lipid profile unfavourably. However, some significant observations emerged when the data was compared between male and female diabetic subjects.

Body Mass Index

It was found that the overweight/obese female diabetics had a significantly aberrated lipid profile in terms of TC (198 mg/dl vs 170 mg/dl, $p<0.01$), LDL (118 mg/dl vs 97 mg/dl, $p<0.01$) and Non HDL-C (154 mg/dl vs 132 mg/dl, $p<0.05$) as compared to the male diabetics.

Abdominal Obesity

Male diabetic subjects who were abdominally obese had significantly lower HDL values as compared to male diabetics in the normal WC category (39 mg/dl vs 45 mg/dl, $p <0.05$). Similar observations were seen in female diabetic subjects (39 mg/dl vs 45 mg/dl, $p< 0.01$).

Waist-Weight Ratio

Female diabetics in the low WWR group had significantly higher TC, LDL and Non HDL values in comparison to male diabetics in the same group (TC 214 mg/dl vs 176 mg/dl, $p <0.01$; LDL 132 mg/dl vs 104 mg/dl, $p <0.01$; Non HDL 169 mg/dl vs 136 mg/dl, $p <0.01$) and female diabetics in the high WWR group (TC 214 mg/dl vs 176 mg/dl, $p <0.01$; LDL 132 mg/dl vs 98 mg/dl, $p <0.01$; Non HDL 169 mg/dl vs 132 mg/dl, $p <0.01$).

Percent Body Fat

Male diabetics of the high percent body fat group had significantly lower HDL (39 mg/dl vs 45 mg/dl, $p <0.05$) in relation to male diabetics of the normal percent body fat group. All the female diabetics in the study had percent body fat levels higher than the normal cut offs. Lipid profile disturbances were more profound among the female diabetics as compared to males with a high percent body fat with HDL as an exception which was significantly higher among the females (TC 197 mg/dl vs 171 mg/dl, $p <0.01$; LDL 117 mg/dl vs 99 mg/dl, $p <0.05$; Non HDL 152 mg/dl vs 132 mg/dl, $p <0.05$; HDL 49 mg/dl vs 35 mg/dl, $p<0.01$).

Waist-Stature Ratio

Overall the lipemic indices did not differ significantly between the various WSR categories.

MICROALBUMINURIA AND OBESITY MEASURES

Microalbumin levels in diabetic subjects in relation to various obesity measures is given in Table 4.14. None of the obesity indicators had an influence on microalbumin levels.

HbA1C LEVELS AND LIPID PROFILE

Table 4.15 gives the lipid profile in relation to the HbA1C levels. Based on glycemic control it was found that male diabetics who had poor glycemic control had significantly higher levels of TC, TG, VLDL-C, Non HDL-C and the atherogenic lipoproteins as compared to those diabetics who had HbA1C ≤ 8. Poor glycemic control was thus found to be associated with hyperlipidemia among the male diabetic subjects. Such a trend was not seen in female diabetic subjects. But it was observed that the female diabetics with HbA1C levels ≤ 8 had significantly higher TC, TG, LDL-C, VLDL-C and Non HDL-C values as compared to the male diabetics who had HbA1C ≤ 8. Thus female diabetic subjects had dyslipidemia irrespective of glycemic metabolic control.

The mean TG/H which represents small dense lipoprotein was >3.0 indicating high atherogenic risk among poorly controlled (HbA1C ≥ 8) diabetic subjects. **Percent subjects having TG/H ≥ 3 was 73.3% in poorly controlled diabetic subjects as compared to 45.2% in better controlled diabetic subjects.**

HbA1C LEVELS AND KIDNEY FUNCTION INDICATORS

When kidney function indicators were studied in relation to glycemic control (Table 4.16) it was noted that the female diabetics had lower serum and urine creatinine levels as compared to the male diabetics. In both the genders diabetic subjects who had poor glycemic control had significantly higher urine albumin levels as compared to the other group indicating the influence of metabolic control on albumin excretion.

TABLE 4.14

URINE MICROALBUMIN LEVELS IN THE DIABETIC SUBJECTS IN RELATION TO OBESITY MEASURES (Mean ± SD)

Variable	Microalbuminuria (µg/mg Cr)
BMI < 23 Kg/m^2	22 ± 14
BMI ≥ 23 Kg/m^2	25 ± 17
AO Absent	22 ± 14
AO Present	25 ± 17
Normal WHR	21 ± 13
High WHR	24 ± 17
Low WWR	24 ± 15
High WWR	24 ± 17
Normal % Body Fat	21 ± 12
High % Body Fat	25 ± 17
WSR <0.5	29 ± 20
WSR 0.5-0.549	20 ± 11
WSR 0.550-0.599	24 ± 16
WSR 0.6-0.649	25 ± 22
WSR ≥ 0.650	26 ± 11

TABLE 4.15

LIPID PROFILE OF THE DIABETIC SUBJECTS IN RELATION TO HbA1C LEVELS (Mean ± SD, mg/dl)

Parameter	Males	Females
HbA1C ≤ 8	**N= 23**	**N= 19**
TC	166 ± 41 *	200 ± 51 #
TG	104 ± 34 ***	150 ± 60 ##
HDL-C	41 ± 8	46 ± 12
LDL-C	98 ± 34	124 ± 44 #
VLDL-C	21 ± 7 ***	30 ± 12 ##
Non HDL	126 ± 38 *	154 ± 51 #
L/H	2.41 ± 0.66 *	2.86 ± 1.19
TC/H	4.15 ± 0.99 *	4.57 ± 1.46
TG/H	2.56 ± 0.81 ***	3.55 ± 2.10
HbA1C >8	**N= 30**	**N= 30**
TC	193 ± 52	195 ± 42
TG	163 ± 55	173 ± 66
HDL-C	41 ± 10	44 ± 9
LDL-C	115 ± 39	113 ± 34
VLDL-C	33 ± 11	35 ± 13
Non HDL	152 ± 49	151 ± 39
L/H	2.91 ± 0.92	2.57 ± 0.72
TC/H	4.91 ± 1.44	4.47 ± 0.92
TG/H	4.36 ± 2.22	4.07 ± 1.78

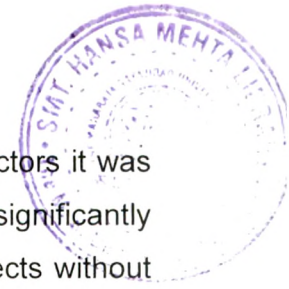
-Significantly different from males at $p<0.05$; ## -Significantly different from males at $p<0.01$; * -Significantly different from other group at $p<0.05$; *** - Significantly different from other group at $p<0.001$

TABLE 4.16

KIDNEY FUNCTION INDICATORS OF THE DIABETIC SUBJECTS IN RELATION TO HbA1C LEVELS (Mean ± SD, mg/dl)

Variable	Males	Females
HbA1C ≤ 8	**N= 23**	**N= 19**
Serum Cr	0.94 ± 0.23	0.65 ± 0.23 ###
Serum Urea	24.86 ± 6.76	22.55 ± 5.37
Urine Cr	100.09 ± 65.26	96.86 ± 147.11
Urine Urea	481.74 ± 289.70	360.81 ± 207.49
Urine Albumin	11.96 ± 4.08 ***	11.28 ± 4.32 **
Urine Albumin (µg/mg Cr)	15 ± 10 *	22 ± 14
HbA1C >8	**N= 30**	**N= 30**
Serum Cr	0.90 ± 0.23	0.71 ± 0.25 # #
Serum Urea	25.82 ± 7.77	23.56 ± 5.02
Urine Cr	101.40 ± 65.49	67.46 ± 51.13 #
Urine Urea	482.77 ± 209.69	444.43 ± 269.13
Urine Albumin	17.88 ± 6.01	16.29 ± 7.09
Urine Albumin (µg/mg Cr)	25 ± 16	32 ± 19

-Significantly different from males at p<0.05; ## -Significantly different from males at p<0.01; ### -Significantly different from males at p<0.001; * -Significantly different from other group at p<0.05; ** -Significantly different from other group at p<0.01; *** -Significantly different from other group at p<0.001



METABOLIC SYNDROME AND GLYCEMIC STATUS

Based on the presence or absence of metabolic syndrome risk factors it was found that diabetic subjects, with the metabolic syndrome had significantly higher FBG and HbA1C values as compared to the diabetic subjects without the metabolic syndrome (Table 4.17). In particular the female diabetic subjects with the metabolic syndrome had poor glycemic control (FBG 160 mg/dl vs 125 mg/dl, $p<0.05$; HbA1C 9.1 g% vs 7.9 g%, $p<0.05$) as compared to female diabetics who did not have the metabolic syndrome.

METABOLIC SYNDROME AND LIPID PROFILE

Lipid profile in the presence and absence of the metabolic syndrome is given in Table 4.18. The presence of the metabolic syndrome led to significantly higher TG, VLDL-C and atherogenic lipoprotein levels and significantly lower HDL-C levels among the male and female diabetic subjects. Female subjects with the metabolic syndrome had significantly higher TC (200 mg/dl vs 175 mg/dl, $p<0.05$) and LDL (119 mg/dl vs 98 mg/dl, $p<0.05$) values as compared to male diabetics in the group but had lower HDL values (42 mg/dl vs 54 mg/dl, $p<0.001$) than female subjects without the metabolic syndrome.

METABOLIC SYNDROME AND KIDNEY FUNCTION INDICATORS

Table 4.19 gives the kidney function indicators segregated based on the presence or absence of the metabolic syndrome. Urine albumin (15.80 mg/dl vs 9.88 mg/dl, $p<0.01$) and serum creatinine (0.73 mg/dl vs 0.57mg/dl, $p<0.05$) levels were noted to be significantly higher in the female diabetic group with the metabolic syndrome as compared to female diabetics without the metabolic syndrome.

A higher percentage of subjects with the metabolic syndrome (32.3%) were found to be microalbuminuric as compared to those without the metabolic syndrome (21.6%). The diabetic individuals with the metabolic syndrome were 1.49 ($0.74< RR <3.03$) times at higher risk of developing MAU than those diabetic subjects without the metabolic syndrome (Table 4.20).

TABLE 4.17

GLYCEMIC STATUS OF THE DIABETIC SUBJECTS IN RELATION TO METABOLIC SYNDROME (Mean ± SD)

Variable	MS present N=65	MS absent N=37	't' Value
FBG (mg/dl)	156 ± 52	128 ± 38	2.84**
HbA1C (g %)	9.0 ± 1.4	8.1 ± 1.4	3.16**

** Significantly different at $p<0.01$

TABLE 4.18

LIPID PROFILE OF THE DIABETIC SUBJECTS

IN RELATION TO METABOLIC SYNDROME (Mean ± SD, mg/dl)

Variable	MS present N=65	MS absent N=37	't' Value
TC	189 ± 47	189 ± 49	0.08
TG	174 ± 62	113 ± 35	5.47***
HDL	39 ± 8	49 ± 9	5.79***
LDL	110 ± 36	117 ± 42	0.86
VLDL	35 ± 12	23 ± 7	5.47***
Non HDL	150 ± 44	139 ± 46	1.18
L/H	2.83 ± 0.85	2.43 ± 0.89	2.26*
TC/H	4.91 ± 1.20	3.90 ± 0.99	4.35***
TG/H	4.58 ± 1.96	2.35 ± 0.73	6.63***

* Significantly different from other group at $p<0.05$

*** Significantly different from other group at $p<0.001$

TABLE 4.19

KIDNEY FUNCTION INDICATORS OF THE DIABETIC SUBJECTS IN RELATION TO METABOLIC SYNDROME (Mean ± SD, mg/dl)

Parameter	MS present N=65	MS absent N=37	't' Value
Serum Cr	0.80 ± 0.26	0.82 ± 0.26	0.37
Serum Urea	23.78 ± 6.01	25.29 ± 7.05	1.14
Urine Cr	94.60 ± 91.87	82.68 ± 67.14	0.69
Urine Urea	463.99 ± 263.25	421.40 ± 218.96	0.83
Urine Albumin	16.02 ± 6.29	12.80 ± 5.78	2.55*
Urine Albumin (µg/mg Cr)	26 ± 18	21 ± 12	1.32

* Significantly different from other group at $p<0.05$

TABLE 4.20

RELATIVE RISK OF DEVELOPING MICROALBUMINURIA IN DIABETICS WITH METABOLIC SYNDROME

Metabolic Syndrome	Microalbuminuria		Relative risk (95% CI)
	Present	Absent	
Present	21	44	1.49 (0.74<RR<3.03)
Absent	8	29	

URINE MICROALBUMIN LEVELS AND GLYCEMIC STATUS

Table 4.21 displays the glycemic status of the diabetic subjects in relation to the urine microalbumin levels. With urine albumin levels ≥ 30 µg/mg Cr the diabetic subjects displayed poor glycemic control with significantly higher FBG and HbA1C values.

URINE MICROALBUMIN LEVELS AND LIPID PROFILE

The lipid profile values did not differ significantly when the data was looked in relation to urine microalbumin levels (Table 4.22). Gender based segregation of data revealed that the female subjects had lower HDL values (41 mg/dl vs 47 mg/dl, $p<0.05$) with higher urine microalbumin levels making them vulnerable to cardiovascular risk along with renal problems.

URINE MICROALBUMIN LEVELS AND KIDNEY FUNCTION INDICATORS

Serum creatinine and urine creatinine values were found to be significantly lower in the microalbuminuric group as compared to the normoalbuminuric subjects (Table 4.23).

Urinary microalbumin levels were looked in relation to the duration of diabetes, BMI, abdominal obesity and hypertension (Table 4.24). It was observed that hypertensive diabetics had significantly higher urinary microalbumin levels compared to the normotensives ($p< 0.01$).

When albumin excretion was cross tabulated with glycemic status and hypertension (Table 4.25) it was observed that irrespective of the presence or absence of hypertension, glycemic control (FBG $p<0.05$, HbA1C $p<0.01$) seemed to be influencing the levels of albumin in the urine. **Thus tight glycemic control and monitoring it on a regular basis should be the primary goal for any diabetic.**

ATHEROGENIC INDEX OF PLASMA

Anthropometric, glycemic, lipemic indices and urine microalbumin levels in relation to AIP levels of risk are given in Table 4.26. Diabetic subjects in the high risk AIP category had higher mean values for the various obesity

TABLE 4.21

GLYCEMIC STATUS OF DIABETIC SUBJECTS

IN RELATION TO URINE MICROALBUMIN LEVELS (Mean ± SD)

Variable	Urine Albumin < 30 µg/mg Cr N=73	Urine Albumin ≥ 30 µg/mg Cr N=29
FBG (mg/dl)	140 ± 49	163 ± 46 *
HbA1C (g %)	8.5 ± 1.4	9.1 ± 1.4 *

* Significantly different from other group at $p<0.05$

TABLE 4.22

LIPID PROFILE OF DIABETIC SUBJECTS

IN RELATION TO URINE MICROALBUMIN LEVELS (Mean ± SD, mg/dl)

	Urine Albumin < 30 µg/mg Cr N=73	Urine Albumin ≥ 30 µg/mg Cr N=29
TC	192 ± 50	183 ± 43
TG	149 ± 61	156 ± 61
HDL	43 ± 10	41 ± 9
LDL	114 ± 39	108 ± 35
VLDL	30 ± 12	31 ± 12
Non HDL	148 ± 46	141 ± 42
L/H	2.67 ± 0.87	2.71 ± 0.91
TC/H	4.54 ± 1.26	4.56 ± 1.17
TG/H	3.61 ± 1.91	4.00 ± 2.00

TABLE 4.23

KIDNEY FUNCTION INDICATORS OF DIABETIC SUBJECTS IN RELATION TO URINE MICROALBUMIN LEVELS (Mean ± SD, mg/dl)

	Urine Albumin < 30 µg/mg Cr N=73	Urine Albumin ≥ 30 µg/mg Cr N=29
Serum Cr	0.86 ± 0.24	0.67 ± 0.26 ***
Serum Urea	25.10 ± 6.39	22.39 ± 6.16
Urine Cr	109.94 ± 91.45	40.78 ± 12.56 ***
Urine Urea	460.95 ± 283.77	417.32 ± 114.47
Urine Albumin	13.61 ± 5.99	17.96 ± 5.97 **
Urine Albumin (µg/mg Cr)	15 ± 7	46 ± 14 ***

** Significantly different from other group at $p<0.01$

*** Significantly different from other group at $p<0.001$

TABLE 4.24

URINE MICROALBUMIN IN RELATION TO DURATION OF DIABETES, BODY MASS INDEX, ABDOMINAL OBESITY AND HYPERTENSION (MEAN ± SD)

Parameter	Urine Albumin (µg/mg Cr)
Duration of diabetes (years)	
< 5 (35)	22 ± 13
5-10 (37)	25 ± 16
> 10 (30)	25 ± 21
Body Mass Index (Kg/m^2)	
≥ 23 (81)	25 ± 17
< 23 (21)	22 ± 14
Abdominal obesity	
Present (79)	25 ± 17
Absent (23)	22 ± 14
Hypertension	
Hypertensives (51)	29 ± 19 **
Normotensives (51)	20 ± 11

Significantly different from normotensives at ** $p < 0.01$

Values in parenthesis indicate numbers

TABLE 4.25

ALBUMIN EXCRETION CROSS TABULATED WITH GLYCEMIC STATUS AND HYPERTENSION (Mean ± SD)

	Microalbuminurics	**Normoalbuminurics**
FBG (mg/dl)		
Hypertensives	160 ± 44	150 ± 53*
Normotensives	167 ± 52	147 ± 45
HbA1C (g %)		
Hypertensives	9.1 ± 1.2	8.1 ± 1.1**
Normotensives	9.3 ± 2	8.7 ± 1.6

Significantly different from microalbuminurics at * $p<0.05$, ** $p< 0.01$

TABLE 4.26

ANTHROPOMETRIC, GLYCEMIC, LIPEMIC INDICES AND MICROALBUMINURIA IN RELATION TO AIP RISK LEVELS (Mean ± SD)

	Low Risk <0.21	High Risk ≥ 0.21
	N=7	N=95
WC (cm)	88 ± 10	93 ± 10
BMI (Kg/m^2)	24 ± 4	27 ± 4
WHR	0.93 ± 0.07	0.94 ± 0.08
% Body Fat	32 ± 11	35 ± 10
WSR	0.553 ± 0.062	0.594 ± 0.067
WWR	1.46 ± 0.09	1.41 ± 0.14
FBG (mg/dl)	127 ± 38	148 ± 50
HbA1C (g %)	7.9 ± 1.1	8.7 ± 1.5
Insulin (µlU/ml)	3.13 ± 2.40	4.15 ± 3.28
HOMA-IR	1.16 ± 1.05	1.41 ± 1.16
HOMA-BF	14.57 ± 7.42	32.88 ± 50.55
TC (mg/dl)	165 ± 37	191 ± 48
TG (mg/dl)	75 ± 20	157 ± 59 ***
LDL (mg/dl)	96 ± 36	113 ± 38
HDL (mg/dl)	54 ± 10	42 ± 9 ***
VLDL (mg/dl)	15 ± 4	31 ± 12 ***
Non HDL (mg/dl)	111 ± 36	149 ± 45 *
L/H	1.81 ± 0.75	2.75 ± 0.86 **
TC/H	3.09 ± 0.76	4.65 ± 1.19 ***
TG/H	1.37 ± 0.27	3.91 ± 1.89 ***
Urine Albumin (µg/mg Cr)	25 ± 16	24 ± 17

* Significantly different from other group at p<0.05

** Significantly different from other group at p<0.01

*** Significantly different from other group at p<0.001

measures, glycemic status and insulin status as compared to the low risk group. The differences however were non significant. When the lipid indicators were compared between the two groups it was observed that the high risk AIP group had significantly higher levels of TG, VLDL, Non HDL and the atherogenic lipoproteins and significantly lower HDL levels. Urine microalbumin levels were not significantly different between the two groups. Thus, the AIP high risk group reflected poor glycemic and lipemic control.

The prevalence of risk factors was found to be similar in both microalbuminuric and normoalbuminuric subjects as given in Table 4.27.

CORRELATION ANALYSIS WITH MICROALBUMIN

Among the various variables studied (anthropometric, glycemic and lipemic levels), correlation analysis revealed that only FBG and HbA1C showed a positive correlation with urine albumin levels thus reiterating the fact that glycemic control should be prioritized for preventing the progression of MAU (Table 4.28, Figure 4.7 and 4.8).

ODDS RATIO FOR MICROALBUMINURIA IN RELATION TO VARIOUS INDICATORS

Table 4.29 shows the relation of various risk factors (n=19) to the presence of MAU. The predictor variables for MAU were abdominal obesity, % body fat, glycemic status, presence of hypertension and AIP levels. Based on CI ranges however, only two significant predictor variables emerged. They were HbA1C and hypertension. Thus these variables need to be monitored on a regular basis to arrest the progression of MAU.

LOGISTIC REGRESSION ANALYSIS

Table 4.30 gives the logistic regression analysis for presence of MAU with various indicators. The results of logistic regression reiterated the importance of glycemic control and blood pressure control. In addition to these two, family history for diabetes was also found to be significantly associated with MAU presence.

TABLE 4.27

RISK FACTORS AND PERCENT PREVALENCE OF MICROALBUMINURIA AMONG DIABETIC SUBJECTS

Risk Factor	MAU Present N=29	MAU Absent N=73
BMI ≥ 23	23 (79.3)	58 (79.5)
AO Present	23 (79.3)	56 (76.7)
TC ≥ 200	9 (31)	27 (37)
TG ≥ 150	13 (44.8)	32 (43.8)
LDL ≥ 100	18 (62.1)	46 (63)
HDL < 40	19 (65.5)	43 (58.9)
Non HDL ≥ 130	19 (65.5)	47 (64.4)
MS Present	21 (72.4)	44 (60.3)
Hypertensive	20 (69)	31 (42.5)
AIP > 0.21	27 (93.1)	68 (93.2)

Values in parenthesis indicate percentage

TABLE 4.28

CORRELATION ANALYSIS OF URINE MICROALBUMIN WITH VARIABLES

Microalbumin vs...	r value
Waist circumference	0.0010
BMI	0.0478
WHR	0.0149
% Body Fat	0.1796
WSR	0.0983
WWR	0.1520
FBG	0.2586*
HbA1C	0.2855*
Total cholesterol	-0.0798
Triglycerides	0.0474

** Significantly at p<0.05

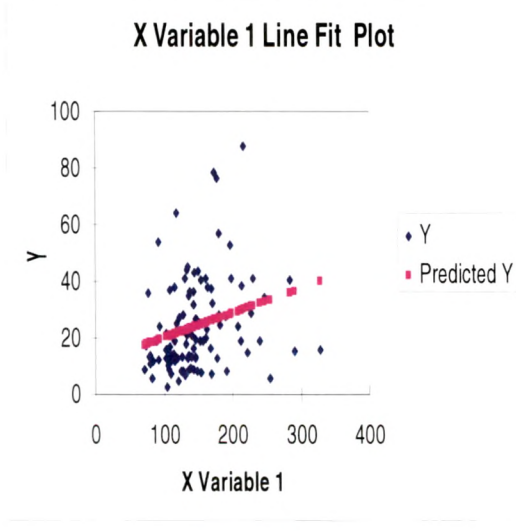


FIGURE 4.7
FBG: y=0.086x+11.37

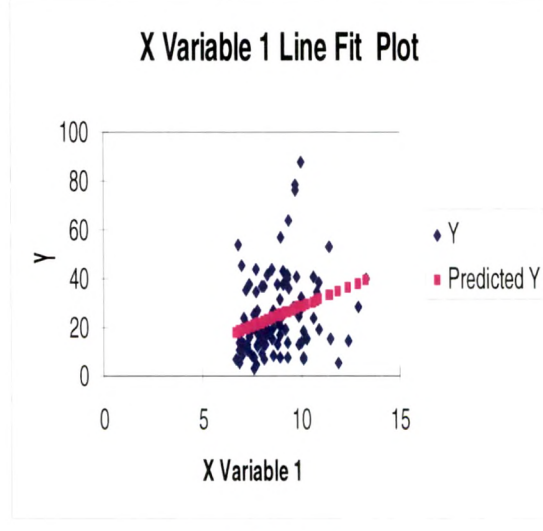


FIGURE 4.8
HbA1C: y=3.271x-4.290

Table 4.29

ODDS RATIO FOR THE PRESENCE OF MICROALBUMINURIA IN RELATION TO RISK FACTORS

Risk Factor	Odds Ratio	95 % CI Limits
BMI ≥23 Kg/m^2	0.99	0.31-3.29
WC (M: ≥ 90; F: ≥ 80)	1.16	0.37-3.80
WHR (M: ≥ 0.90; F: ≥ 0.85)	1.70	0.40-8.35
WSR ≥ 0.5	0.24	0.03-1.94
WWR (M: ≥ 1.36; F: ≥ 1.44)	0.84	0.32-2.16
% Body Fat (M: ≥ 25; F: ≥ 32)	1.24	0.37-4.43
FBG ≥ 140 mg/dl	2.57 *	0.97-6.96
HbA1C ≥ 8	3.16 *	1.06-9.89
TC ≥ 200 mg/dl	0.77	0.28-2.10
TG ≥ 150 mg/dl	1.04	0.40-2.70
HDL < 40 mg/dl	1.33	0.50-3.58
LDL ≥ 100 mg/dl	0.96	0.36-2.56
Non HDL ≥ 130 mg/dl	1.05	0.39-2.86
TG/H ≥ 3	1.94	0.70-5.51
Family History for diabetes	2.45	0.85-7.26
Diabetes duration ≥ 5 years	1.23	0.45-3.42
Presence of hypertension	3.01 *	1.11-8.33
Presence of metabolic syndrome	1.73	0.62-4.94
High risk AIP	0.99	0.16-7.92

* Significant at $p<0.05$

TABLE 4.30

LOGISTIC REGRESSION ANALYSIS FOR THE PRESENCE OF MICROALBUMINURIA IN RELATION TO INDICATORS

Variable	Odds Ratio	95 % CI Limits	p Value
FBG ≥ 140 mg/dl	3.78	1.12-12.79	0.0327
Family History for diabetes	4.00	1.16-13.81	0.0282
Presence of hypertension	8.97	2.20-36.56	0.0022

DISCUSSION

Type 2 diabetes mellitus is a common disease with substantial associated morbidity and mortality. Most adverse diabetes outcomes are a result of vascular complications, both at a macrovascular level (coronary artery disease, cerebrovascular disease, or peripheral vascular disease) and a microvascular level (retinopathy, nephropathy, or neuropathy). Multiple modifiable risk factors for late complications in patients with type 2 diabetes, including hyperglycemia, hypertension, and dyslipidemia, increase the risk of a poor outcome.

Hypertension

The epidemiological studies have indicated that hypertension and type 2 diabetes are commonly associated conditions, and their concordance is increased in populations. Hypertension affects up to 40% or more of diabetic patients (ADA 2003, Chobanian 2003 and Hu 2005). Dhobi et al in 2008 reported that 42% of patients newly diagnosed with type 2 diabetes mellitus were hypertensive. Patients with hypertension were found to be older, had higher body mass index and plasma triglyceride levels, and evidence of ventricular hypertrophy on electrocardiogram. Similar results have been reported by other studies where hypertensive cases were older, had higher BMI, serum TC, serum creatinine, higher prevalence of proteinuria, higher prevalence of associated cardiovascular disease and poorer metabolic control (Marin et al 2002). Hypertension and type 2 diabetes were found to increase stroke risk independently, and their combination increased the risk drastically (Hu et al 2005).

Dyslipidemia

The characteristic dyslipidemia associated with insulin resistance and type 2 diabetes is highly correlated with increased cardiovascular risk. Studies have documented that reduced HDL cholesterol levels are associated with an increased risk of coronary heart disease (Gordon 1989). Moreover, low HDL cholesterol levels are often accompanied by elevated triglyceride levels (Lamarche 1996), and the combination has been strongly associated with an

increased risk of CHD (Assmann & Schulte 1992, Jeppesen et al 1997, Manninen et al 1992).

A meta-analysis of 17 population based prospective studies found that for each 1-mmol/l increase in plasma triglyceride there is a 32% increase in coronary disease risk for men and a 76% increase in risk for women (Hokanson & Austin 1996). Adjustment for the effects of HDL cholesterol and other risk factors attenuated the risk to 14% in men and 37% in women, but these values remained statistically significant.

The measurement of non-HDL cholesterol can be used to assess the quantity of atherogenic apo B-containing lipoproteins (VLDL, IDL, and LDL). The NCEP guidelines recommend a non-HDL cholesterol goal of less than 3.4 mmol/liter (<130 mg/dl) in hypertriglyceridemic patients >2.3 mmol/liter (>200 mg/dl)] (NCEP 2001).

Another indicator used to assess the atherogenic risk is AIP levels. High prevalence of AIP risk levels along with elevated levels of TG and Non HDL-C places the diabetic subjects at an increased risk of CVD.

Waist Circumference

Regional body fat distribution has an important influence on metabolic and cardiovascular risk factors. Many prospective studies have shown that increased abdominal (visceral) fat accumulation is an independent risk factor for CAD, hypertension, stroke, and type 2 diabetes (DM2) (Larsson 1984, Lapidus 1984, Ducimetiere 1986).

Even normal weight individuals with increased amounts of abdominal adipose tissue can be metabolically obese, with insulin resistance and dyslipidemia (Fujimoto 1994, Ruderman 1998). The Hoorn study, a population-based cohort study of diabetes (Snijder et al 2003) reported that waist circumference was positively associated with the incidence of type 2 diabetes.

In a cross sectional survey in African origin populations from Nigeria, Jamaica and the U.S, waist circumference was found to be positively correlated with blood pressure and fasting blood glucose ($P< 0.05$). Increasing waist quartiles were significantly associated with higher risks of hypertension in the three populations. A highly elevated risk of type 2 diabetes (10-fold for Jamaican men and 23-fold for African-American women) was observed in the comparison of lowest to highest quartiles of waist circumference (Okosun et al 1998).

Metabolic Syndrome

Type 2 diabetes is associated with a cluster of interrelated plasma lipid and lipoprotein abnormalities, including reduced HDL cholesterol, a predominance of small dense LDL particles, and elevated triglycerides. These changes are also a feature of the metabolic syndrome, which underlies many cases of type 2 diabetes.

Pre-diabetic individuals often exhibit an atherogenic pattern of risk factors that includes higher levels of total cholesterol, LDL cholesterol, and triglycerides and lower levels of HDL cholesterol than individuals who do not develop diabetes (Haffner et al 1990 & 2000).

High prevalence of metabolic syndrome has been reported in Asia with early onset of metabolic syndrome and diabetes mellitus in Asian Indians (Ramachandran et al 2004, Misra & Vikram 2004). In a study on type 2 diabetics by Isomaa et al (2001) it was found that patients with the metabolic syndrome (WHO definition) had a higher prevalence of cardiovascular disease (52 vs 21%), micro or macroalbuminuria (23 vs 7%) and distal neuropathy than patients without the syndrome. In another study that followed a cohort of middle-aged adults for the development of new CVD, CHD, and T2DM over an 8-year period, at baseline, the prevalence of the metabolic syndrome was 26.8% in men and 16.6% in women. The metabolic syndrome increased the relative risk for CVD in men and for T2DM in both sexes (Wilson et al 2005).

In the Verona Diabetes Complications Study (Bonora et al 2004) the proportion of type 2 diabetic subjects with the metabolic syndrome was 92.3%. At the baseline, a higher percentage of subjects with the metabolic syndrome were coded positive for CVD. Among subjects free of CVD at the baseline, CVD events during the 4.5 years follow-up were significantly increased in patients with the Metabolic Syndrome as compared with those without it (19.9% vs. 3.9%, $P < 0.001$).

A threefold increase in the risk for coronary heart disease and stroke was found in type 2 diabetic subjects with the metabolic syndrome. Also, cardiovascular mortality was markedly increased in subjects with the metabolic syndrome (Isomaa et al 2001).

The aggregation of elements of the metabolic syndrome is associated with an increased risk of chronic macro and microvascular complications. The number of metabolic syndrome features has been associated with the prevalence of diabetes complications. Costa et al (2004) reported that more the metabolic syndrome features, higher is the proportion of diabetes complications.

It thus needs to be emphasized that Type 2 diabetes is a complex disease, and its management should not focus exclusively on hyperglycaemia but should also include strategies targeting the Metabolic Syndrome to reduce CVD risk.

Microalbuminuria

While macrovascular complications are associated with significant morbidity and mortality in diabetic subjects, microvascular complications also contribute significantly. About 30–45% of diabetic subjects suffer from microvascular complications, and type 2 diabetes has become the principal cause for blindness and end-stage renal disease in western countries (Rainor 2001). Kidney disease in diabetic patients is clinically characterized by increasing rates of urinary albumin excretion, starting from normoalbuminuria, which progresses to MAU, macroalbuminuria, and eventually to ESRD.

The earliest clinical evidence of nephropathy is the appearance of low but abnormal levels (≥30 mg/day or 20 µg/min) of albumin in the urine, referred to as MAU. MAU is a marker of increased cardiovascular morbidity and mortality. A worsening of albuminuria has been reported as associated with a rapid decline in renal function (ADA 2004, Gaede et al 2004).

Racial differences in the prevalence of diabetic renal disease have been reported. Asian subjects have significantly ($p < 0.01$) higher prevalence (52.6%) of diabetic end stage renal disease (ESRD) when compared with the Caucasians (36.2%) (Young et al 2003). South-Asian type 2 diabetic patients develop more nephropathy and have progressive renal failure in comparison with European diabetic patients (Chandie et al 2006). The prevalence of MAU in patients with type 2 diabetes was found to be higher in those of South Asian ethnic origin compared to white Europeans (Dixon et al 2006).

The prevalence of MAU in our study (28.4 %) was similar to that reported in other studies. The CURES 45 study found a prevalence of 26.9% (Unnikrishnan et al 2007). A study in Type 2 diabetics in Southern India found the prevalence of MAU to be 36.3% (Varghese et al 2001). The MicroAlbuminuria Prevalence (MAP) study found a high prevalence of MAU (39.8 %) in Asian hypertensive type 2 diabetic subjects (Wu et al 2005). **In the present study the prevalence of MAU in diabetic subjects with hypertension was found to be 39.2% which is similar to that obtained in the MAP study.**

According to the American Diabetes Association position statement (2009) recommendations for nephropathy screening and treatment, urine albumin excretion should be tested annually in all type 2 diabetic patients starting at diagnosis, as a high proportion of patients with type 2 diabetes are found to have MAU or overt nephropathy shortly after diagnosis of their diabetes. **Unfortunately, the implementation of routine screening for renal disease is still far below recommended goals.**

MAU in type 2 diabetes is often associated with the metabolic syndrome. Diabetic subjects with the metabolic syndrome were found to have a significantly higher (46.6%) frequency of microvascular-related complications (MAU, neuropathy, retinopathy and leg ulcers) than diabetic subjects without the syndrome (26.8%) (Abdul-Ghani et al 2006). **In our study 32.3% of the metabolic syndrome subjects had MAU as compared to 21.6% without the metabolic syndrome.**

Early screening for MAU is the key for early detection of the devastating complication. Optimal blood pressure, tight glycaemic control and pharmacological blockade of the renin–angiotensin system with ACE inhibitors or ARB have been shown to decrease albumin excretion rate and decrease progression from incipient to overt nephropathy.

The large pool of MAU suggests that there could be large increases in overt nephropathy with time, unless aggressive control of diabetes and hypertension is initiated. Given the high speed increase in the prevalence of diabetes in India our findings suggest the use of microalbumin to retard the development of renal and cardiovascular complications in type 2 diabetics. Therefore there is a need to propagate the importance of monitoring biochemical and biophysical parameters amongst diabetics.

In the present study we employed different types of statistical tests which signify towards the importance of 3 factors namely a) Glycemic control; b) Heredity and c) Hypertension in controlling or arresting MAU. We feel that as soon as the diabetic condition is detected interventions should be aggressive and one must try for consistent control of FBG/HbA1C and blood pressure to avert the micro and macro complications associated with diabetes mellitus.

SALIENT OBSERVATIONS OF THE STUDY:

1. A high prevalence of overweight (13.7%) and obesity (65.6%) among the T2DM subjects.

2. A high magnitude of abdominal obesity (77.5%) as indicated by waist circumference values.
3. Poor glycemic control (HbA1C ≥ 7) among the T2DM subjects (94.1%).
4. Nearly 50% prevalence of hypertension.
5. Lipid aberrations more profound among the female diabetics than male diabetics.
6. High prevalence of dyslipidemia among the subjects with 93.1% of the subjects in the high risk AIP category.
7. A 28.4% prevalence of MAU among the diabetic subjects.
8. Presence of multiple risk factor scenario with diabetic subjects having on an average 5 risk factors.
9. Determinants identified for MAU were glycemic control and blood pressure levels and the non modifiable factor, heredity.

OVERALL SUMMARY

Table 4.31 gives the summary of risk factors present in T2DM subjects. The present study enrolled diabetic subjects from pathological laboratories. These subjects rarely visited a physician for medical examination. The only thing they did regularly was to visit the laboratory for blood glucose testing. Our findings suggest that

a) A large number of diabetic subjects do not undergo routine medical examination that is recommended.
b) There is a need to sensitize and build capacities of these subjects at various pathological laboratories to appraise the importance of monitoring and managing the clinical condition.
c) Emphasis should be laid on tight glycemic control and blood pressure measurements to avert micro and macro complications associated with the condition.

TABLE 4.31

OVERALL SUMMARY OF RISK FACTORS IN T2DM SUBJECTS

Risk Factor	%	CI Limits (95%)
Ow + Ob	79.4	71.4 - 87.4
Hypertension	50	40.1 - 59.9
Abdominal Obesity	77.5	69.2 - 85.8
HbA1C ≥ 7	94.1	89.4 - 98.8
TC ≥ 200 (mg/dl)	35.3	25.8 - 44.8
TG ≥ 150 (mg/dl)	44.1	34.3 - 53.9
LDL ≥ 100 (mg/dl)	62.7	53.1 - 72.3
HDL < 40 (mg/dl)	60.8	51.1 - 70.5
TG/H ≥ 3	61.8	52.2 - 71.4
Non HDL ≥ 130 (mg/dl)	64.7	55.2 - 74.2
AIP > 0.21	93.1	88.1 - 98.1

PHASE II: RISK FACTOR ANALYSIS AND TRENDS OF DYSLIPIDEMIA IN T2DM SUBJECTS OF AN INDUSTRIAL POPULATION

Diabetes is the single most important metabolic disease and is, widely recognised as one of the leading causes of death and disability worldwide. Over time, diabetes can damage the heart, blood vessels, eyes, kidneys, and nerves. This huge disease burden puts an enormous load on the country's health care infrastructure. A healthy workforce is essential in the context of optimal productivity and enhanced competitiveness. It is now well established that most of the major non communicable diseases (NCDs) are linked through a 'cluster' of risk factors, and are responsible for the causation of disease. Risk factor data are especially important as predictors of future disease or injury. Knowledge about the distribution of these risk factors provides an opportunity to intervene. Industrial settings with their intramural resources and healthcare infrastructure are ideal for initiating preventive activities to increase the awareness and control of Diabetes. Unhealthy diet and physical inactivity are the leading causes of the major non communicable diseases. The important risk factors identified are high blood pressure, high serum cholesterol, inadequate intake of fruits and vegetables, excess weight, physical inactivity, smoking and tobacco use. Also, these factors are interrelated to each other in such a way that appearance of one factor paves the way for the other, thereby leading to the development of non communicable diseases.

The present study was thus planned with an objective to evaluate the diabetes risk profile. In the present study a total of 54 diabetics were identified from an industry of Vadodara. Information pertaining to various risk factors like heredity and lifestyle factors was obtained. Anthropometric data (height, weight) and medical history were recorded. Fasting blood glucose and lipid profile values for the past four years (2005-2008) was obtained from medical records for 43 diabetic subjects. This data was used to arrive at the trends of dyslipidemia and blood pressure over a period of four years.

BACKGROUND INFORMATION OF THE SUBJECTS

All the diabetic subjects were in their productive years with the subjects in the age range of 39-57 years. Mean age was 50.1 ± 4.7 years. Family history for diabetes, hypertension and heart disease was found in 57.4%, 38.9% and 16.7 % of the subjects respectively (Table 4.32).

MEDICAL HISTORY

Information on the medical history showed that the complication of hypertension was common in the diabetic subjects. Around 35.2 % of the subjects had medical history of hypertension as a complication in addition to diabetes (Table 4.33).

RISK FACTOR ANALYSIS

Data on the prevalence of risk factors is given in Table 4.34. There is robust evidence of increased vascular risk even in the presence of pre-hypertension (or high-normal blood pressure) (Vasan et al 2001). This risk category has a high rate of progression to hypertension. Pre-hypertension (≥120/80 mmHg) and hypertension (≥140/90 mmHg) were prevalent in 37% and 53.7% subjects respectively. Hypertension remains undetected and uncontrolled even in organized sector industries with medical facilities. Hence, health education among employees can improve early detection and management. The high prevalence of pre-hypertension suggests that there is a large vulnerable population which can develop an overt adverse risk profile and CVD in the future.

Based on the Asia Pacific classification, 14.8% of the study population were overweight and 57.4% were obese. The habit of smoking, tobacco usage and alcohol consumption was present in 14.8%, 22.2% and 13% of the study population respectively. Contrary to recent community based studies, 70.4% of the subjects reported exercising > 3 hours a week. Since the leading risk factor for NCDs is high blood pressure globally, a diet high in fruits and vegetables is recommended to control hypertension. About 57.4 % of the subjects reported that their consumption of fruits was more than thrice a week and 77.8% of the subjects reported that their consumption of green leafy

TABLE 4.32

FAMILY HISTORY OF DIABETES, HYPERTENSION AND CHD IN THE INDUSTRIAL T2DM SUBJECTS

	N (%)
Diabetes	31 (57.4)
Hypertension	21 (38.9)
Heart Disease	9 (16.7)

TABLE 4.33

MEDICAL HISTORY OF THE INDUSTRIAL T2DM SUBJECTS

Medical History	N (%)
Diabetes	34 (63)
Diabetes + Hypertension	19 (35.2)
Diabetes + Heart Disease	0 (0)
Diabetes + Hypertension + Heart Disease	1 (1.9)

TABLE 4.34

PREVALENCE OF RISK FACTORS IN THE INDUSTRIAL T2DM SUBJECTS

Variable	**N (%)**
Prehypertension	20 (37.0)
Hypertension	29 (53.7)
Overweight	8 (14.8)
Obesity	31 (57.4)
Smoking	8 (14.8)
Tobacco use	12 (22.2)
Alcohol consumption	7 (13)
Exercise Pattern	
< 3 hours/week	16 (29.6)
> 3 hours/week	38 (70.4)
Fruit & Vegetable Consumption	
Fruits	
< 3 times/week	23 (42.6)
>3 times/week	31 (57.4)
Green Leafy vegetables	
< 3 times/week	12 (22.2)
>3 times/week	42 (77.8)

vegetables was more than thrice a week. This observation is contrary to other studies that have observed lower fruit and vegetable intake than recommended. Overreporting as a possibility cannot be ruled out. A recent paper reported lower intake of vegetables and fruits among south Asians as compared to other ethnic groups based on Interheart study data (Goyal and Yusuf 2006). It was also emphasized that vegetarianism in Indians does not necessarily mean adequate intake of fruits and vegetables. We need to improve awareness among Indians to increase fruit and vegetable intake. An attempt to quantify fruit and vegetable intake may substantiate the claims made by the diabetic subjects. Nevertheless the positive habit needs to be encouraged for maintaining health benefits.

GLYCEMIC AND LIPEMIC STATUS OF THE T2DM SUBJECTS

Mean and Standard Deviation (SD) of various biochemical parameters is given in Table 4.35. The prevalence of dyslipidemia was also looked into for these T2DM subjects (Table 4.36). About 25.9% of the subjects were hypercholesterolemic and 39.6% of the subjects were hypertriglyceridemic. It was disheartening to note that 53.7% of the subjects had low levels of HDL-C and 62.96% had high levels of LDL-C. AIP levels predict cardiovascular risk (Table 4.37). It was observed that 94.3% of the subjects had AIP levels in the high risk category. High levels of atherogenic lipoproteins can predispose the subjects to cardiovascular morbidity and mortality.

MEDICAL TESTS UNDERGONE BY THE SUBJECTS

Diabetics are recommended to undergo certain tests on a routine basis to help them monitor their glycemic status and for early detection of the development of secondary complications. Table 4.38 gives the percentage of subjects who had undergone these tests for diabetes in the past one year. Among the various tests, majority of the diabetic subjects (85.2%) used to get their serum lipids tested followed by eye examination primarily for glasses (72.2%) and routine kidney function tests (68.5%) excluding microalbuminuria. Less than 50% got their HbA1C monitored. Around 40% got ECG/Stress test done and only 20% underwent a foot examination. These observations call for monitoring HbA1C, microalbuminuria and foot examinations along with other

TABLE 4.35

GLYCEMIC AND LIPEMIC STATUS OF THE INDUSTRIAL T2DM SUBJECTS

Variable	Mean ± SD
TG (mg/dl)	165 ± 109
TC (mg/dl)	185 ± 32
HDL-C (mg/dl)	39 ± 8
LDL-C (mg/dl)	112 ± 30
VLDL-C (mg/dl)	33 ± 22
Non HDL-C (mg/dl)	145 ± 30
TG/H	4.55 ± 3.51
FBG (mg/dl)	162 ± 47

TABLE 4.36

PREVALENCE OF DYSLIPIDEMIA IN THE INDUSTRIAL T2DM SUBJECTS

Variable	(%)
TC ≥ 200 (mg/dl)	25.9
TG ≥ 150 (mg/dl)	39.6
LDL ≥ 100 (mg/dl)	62.96
HDL < 40 (mg/dl)	53.7
Non HDL ≥ 130 (mg/dl)	64.8
TG/H ≥ 3	54.7

TABLE 4.37

ATHEROGENIC INDEX OF PLASMA RISK LEVELS

IN THE INDUSTRIAL T2DM SUBJECTS

AIP Risk Level	(%)
Low Risk (<0.11)	3.8
Intermediate Risk (0.11-0.21)	1.9
High Risk (>0.21)	94.3

TABLE 4.38

PERCENT INDUSTRIAL T2DM SUBJECTS

UNDERGOING ROUTINE TESTS

Test	N (%)
HbA1C	26 (48.1)
Kidney Function Tests	37 (68.5)
Lipid Profile	46 (85.2)
Foot Examination	11 (20.4)
Eye Examination (for glasses)	39 (72.2)
ECG/Stress Test	21 (38.9)

parameters on an yearly basis.

RISK FACTOR SCENARIO

Owing to the poor glycemic and lipemic status of the diabetic subjects the risk factor prevalence among the subjects was looked into (Figure 4.9). A range of 15 risk factors (Family history for diabetes, BMI ≥23, FBG ≥ 140 mg/dl, TC ≥ 200 mg/dl, TG ≥ 150 mg/dl, LDL ≥ 100 mg/dl, HDL < 40 mg/dl, Non HDL ≥ 130 mg/dl, hypertension, current smoking, alcohol usage, tobacco usage, physical inactivity, low intake of fruits and low intake of GLV's) have been plotted on the graph. It was observed that all the diabetic subjects had risk factors. An astonishing 87.2% of the subjects had ≥ 5 risk factors. On an average the diabetic subjects had 5-8 risk factors indicating the presence of a multiple risk factor scenario.

TRACKING THE DIABETIC SUBJECTS OVER A PERIOD OF FOUR YEARS

Table 4.39 gives the mean FBG, lipid profile, SBP, DBP and BMI values of the diabetic subjects over a period of four years. As can be seen from the table the subjects consistently had elevated levels of FBG, TG, LDL, Non HDL, TG/H, SBP, DBP and BMI. In 2006, 2007 and 2008 the FBG levels were significantly higher as compared to the levels in 2005. There was high prevalence of dyslipidemia among the diabetic subjects over the four year duration (Table 4.40). It was observed that high LDL values were present in about 44-74% of the subjects over this four year duration. More than 40% of the subjects consistently had low levels of HDL and high TG levels. Around 90-100% of the subjects had high risk AIP values thus predisposing them to CVD in the future.

The cumulative incidence of hypercholesterolemia, hypertriglyceridemia and hypertension over the four years is given in Table 4.41. The cumulative incidence for hypercholesterolemia in 2006 was 23.3. In 2007 this figure dropped to 8.7 and no new cases were identified in 2008. For the entire four year duration the cumulative incidence for hypercholesterolemia was 30 per 100 persons. Similarly the cumulative incidence for hypertriglyceridemia was

FIGURE 4.9

MULTIPLE RISK FACTOR SCENARIO IN THE INDUSTRIAL T2DM SUBJECTS

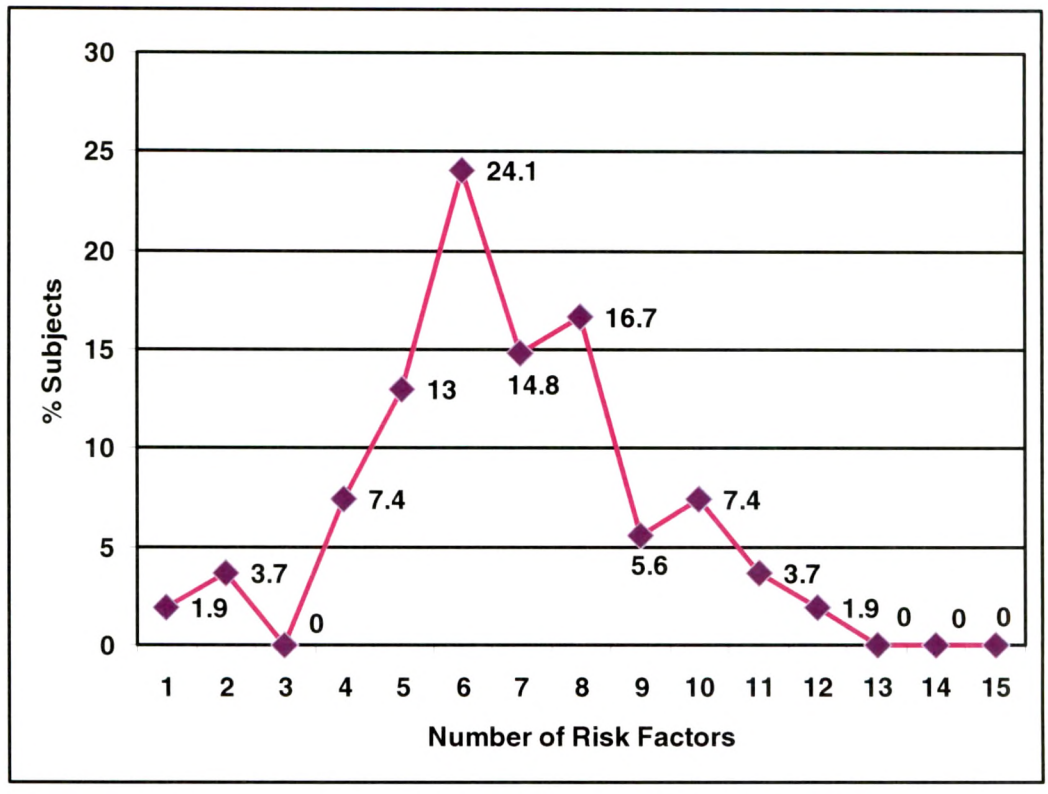


TABLE 4.39

LONGITUDINAL DATA ON BLOOD GLUCOSE AND LIPID PROFILE OF THE INDUSTRIAL DIABETIC SUBJECTS OVER A FOUR YEAR PERIOD (Mean ± SD)

Variable	2005	2006	2007	2008
FBG (mg/dl)	126 ± 29	143 ± 47 *	144 ± 44 †	158 ± 48 ‡
TC (mg/dl)	192 ± 30	195 ± 34	178 ± 36	183 ± 31
TG (mg/dl)	164 ± 90	173 ± 110	168 ± 93	169 ± 120
LDL-C (mg/dl)	118 ± 27	119 ± 30	106 ± 31	110 ± 29
HDL-C (mg/dl)	42 ± 8	41 ± 6	39 ± 7	40 ± 8
Non HDL-C (mg/dl)	151 ± 27	154 ± 31	139 ± 33	144 ± 28
TG/H	4.07 ± 2.28	4.28 ± 2.59	4.54 ± 2.90	4.65 ± 3.82
SBP (mm Hg)	126 ± 12	127 ± 18	128 ± 12	128 ± 19
DBP (mm Hg)	84 ± 6	87 ± 11	85 ± 7	87 ± 9
BMI (Kg/m^2)	25.74 ± 4.14	25.56 ± 4.39	25.43 ± 4.45	25.71 ± 4.39

* - Significantly different from levels in 2005 at $p< 0.01$

† - Significantly different from levels in 2005 at $p< 0.01$

‡ - Significantly different from levels in 2005 at $p< 0.001$

TABLE 4.40

DYSLIPIDEMIA IN THE INDUSTRIAL DIABETIC SUBJECTS OVER A FOUR YEAR PERIOD (%)

Variable	2005	2006	2007	2008	Range
TC ≥ 200 (mg/dl)	30.2	41.9	27.9	23.3	23.3-41.9
TG ≥ 150 (mg/dl)	40.5	47.6	47.6	40.5	40.5-47.6
LDL ≥ 100 (mg/dl)	72.1	74.4	44.2	60.5	44.2-74.4
HDL < 40 (mg/dl)	41.9	41.9	46.5	53.5	41.9-53.5
Non HDL ≥ 130 (mg/dl)	76.7	79.1	48.8	62.8	48.8-79.1
TG/H ≥ 3	64.3	61.9	61.9	52.4	52.4-64.3
AIP >0.21	90.5	100	92.9	92.9	90.5-100

TABLE 4.41

CUMULATIVE INCIDENCE OF HYPERCHOLESTEROLEMIA AND HYPERTRIGLYCERIDEMIA IN THE INDUSTRIAL DIABETIC SUBJECTS (PER 100 SUBJECTS)

Variable	2006	2007	2008	2005-2008
TC ≥ 200 (mg/dl)	23.3	8.7	-	30
TG ≥ 150 (mg/dl)	32	5.9	-	36
HTN (≥120/80 mm Hg)	100	-	-	100
HTN (≥140/90 mm Hg)	34.5	26.3	21.4	62.1

32 in 2006 and 5.9 in 2007. Again in 2008 no new cases were identified. The cumulative incidence for hypertriglyceridemia for the period from 2005-2008 was 36 per 100 persons. The cumulative incidence of hypertension over the four year duration was also calculated. Using 120/80 as the cut-off the cumulative incidence was 100 for the year 2006 and therefore no new cases appeared in 2007 and 2008. The figure remained the same for the entire four year duration. In the year 2006 cumulative incidence using 140/90 as the cut-off was 34.5. This figure dropped to 26.3 and 21.4 in 2007 and 2008 respectively. For the period 2005-2008 the figure was 62.1.

The data on tracking of the diabetic subjects revealed that:

1. Dyslipidemia was persistent among the diabetic subjects
2. New cases of dyslipidemia were identified over the years
3. The persistently high risk AIP values indicate a high risk for CVD among the industrial diabetic population
4. Consistently elevated blood pressure, including the pre-hypertensive stage warrants lifestyle intervention strategies to control blood pressure.

DISCUSSION

The Burden of Non Communicable Diseases

In 2005, noncommunicable diseases (NCDs) accounted for 60% of all projected deaths worldwide (WHO 2005). About 80% of the deaths from NCDs occur in low and middle income countries. The five major NCDs are heart disease, stroke, cancer, chronic respiratory diseases and diabetes. Also, it is estimated that approximately 80% of heart disease, stroke, type 2 diabetes and 40% of cancers can be prevented through inexpensive and cost-effective interventions that address the primary risk factors. The burden of NCDs has an impact on the country's socioeconomic structure alongwith an impact on the quality of life of affected individuals and their families. It is estimated that India will lose around 237 billion international dollars from 2005 to 2015 as result of the burden of NCDs (WHO 2005).

Projected increases in the global prevalence of Type 2 diabetes suggest that its treatment and prevention could become one of the major health challenges of the 21st century. With the rising burden of diabetes, the expenditure on healthcare facilities by every industry is likely to increase enormously. There is a lot of scope for and benefit in initiating low cost and comprehensive diabetes prevention programs at the workplace for employees and their dependents.

Workplace as a Setting for Health Interventions

The workplace has been recognized internationally as an appropriate setting for health promotion. Through workplace environments, it is possible to influence the health behaviours of large proportions of the population. Data on rates of economically active populations indicate that, globally, approximately 65% of the population aged over 15 years is part of the workforce (ILO 2007). The workplace is an advantageous setting because of the significant proportion of time spent at work by the large majority of the population, and also because it offers an opportunity to utilize peer pressure to encourage employees to make desirable alterations to their health habits.

Corporate health departments are frequently required to perform routine health examinations for occupational health and safety reasons. Meeting these obligations can provide opportunities to intervene in a positive way to reduce the burden of diabetes. Detection of previously unrecognized diabetes and pre-diabetes cases is possible by integrating a diabetes screening strategy into an existing occupational medical programme. There are cost and efficiency advantages in undertaking chronic disease interventions within the existing occupational health programmes.

The recent successes of intervention trials demonstrate that individuals at high risk can be identified and diabetes onset delayed, if not prevented (ADA 2004, Lindstro¨m et al 2003). Workplace health promotion programmes, targeting physical inactivity and unhealthy dietary habits, are effective in improving health related outcomes such as obesity, diabetes and cardiovascular disease risk factors. Enhancing employee productivity,

improving corporate image and moderating medical care costs are some of the advantages in initiating and investing in workplace health promotion programmes.

Risk Factor Prevalence in the Workplace

The present study found a high prevalence of risk factors among the industrial diabetic population. The risk factors included pre-hypertension (37%), hypertension (53.7%), overweight (14.8%), obesity (57.4%), smoking (14.8%), tobacco usage (22.2%), alcohol consumption (13%), physical inactivity (29.6%), low fruit intake (42.6%) and low vegetable intake (22.2%). Similar results have been obtained by other studies.

A cross-sectional study in an urban industrial population in south India which studied the prevalence and distribution of cardiovascular risk factors found the prevalence of current smoking, BMI ≥ 23 Kg/m^2 , central obesity, hypertension, TC ≥ 200 mg/dl to be 20.2%, 66.8%, 70.2%, 27.2% and 30.3% respectively. The prevalence of these risk factors increased during the most productive years (25-44 y) putting the employees at risk of cardiovascular morbidity and mortality at relatively younger age (Kaur et al 2007).

Earlier departmental studies have identified the profile of non communicable disease risk factors in an industrial setup (Mehan et al 2006 and 2007). Risk factors included low vegetable and fruit intake, hypertension, high BMI, abdominal obesity, physical inactivity, smoking, tobacco and alcohol usage.

Prabhakaran et al evaluated the cardiovascular risk factor prevalence among men in a large industry of northern India. They reported the prevalence of hypertension to be 30%. High serum TC/H ratio (≥ 4.5), current smoking, pre-hypertension and overweight (≥25 Kg/m^2) were present in 62%, 36%, 44% and 35% of the subjects respectively (Prabhakaran et al 2005).

Reddy et al (2006) conducted a baseline cross-sectional survey as part of a CVD surveillance program of industrial populations from 10 companies across India. The study subjects were employees and their family members. A high

prevalence of risk factors was observed in terms of overweight (51.3%), central obesity (30.9% men & 32.8% women), current tobacco use (40.2% men & 14.9% women), diabetes (10.1%) and hypertension (27.7%), pre-hypertension (56.3%), metabolic syndrome by modified NCEP ATP III criteria (26.6%).

The Praeford Study reported that 26% of diabetic employees achieved blood pressure targets, 54% achieved HbA1C target values and 31% achieved LDL target values. Only 8% of the 91 diabetic employees achieved all three recommended target values (Schneider et al 2007).

In a study of refinery and petrochemical employees in Louisiana it was found that the loss of productivity in terms of days of absence was greater for employees with selected health risk factors like smoking, high blood pressure, high cholesterol, and obesity (Tsai et al 2003).

In a study to document the association among obesity, cardiovascular risk factors, and work limitations in the U.S. workforce it was found that obesity affected 29.4% of workers. Obese workers had the highest prevalence of work limitations (6.9% vs. 3.0% among normal-weight workers), hypertension (35.3% vs. 8.8%), dyslipidemia (36.4% vs. 22.1%), type 2 diabetes (11.9% vs. 3.2%), and the metabolic syndrome (53.6% vs. 5.7%) (Hertz et al 2004).

Our study results indicated high prevalence of hypertension, overweight, obesity and dyslipidemia in an urban industrial population of Vadodara. The long-term follow-up in such settings will provide an opportunity to understand the influence of risk factors on diabetes outcomes. As a part of the study, longitudinal data on blood sugar, blood pressure and lipid profile was looked into. **Over the four year duration consistently elevated levels of BMI, SBP, DBP, FBG and lipid profile were reported. Adding to the existing problem was the identification of new cases of dyslipidemia over the years. This underlines the importance of identifying the employees at risk by regular surveillance and taking preventive measures.**

The high prevalence of risk factors present in the industrial population calls for action on the part of the management to take appropriate remedial measures. Health screening of the employees should be carried out on a regular basis in order to identify the 'at risk' individuals. Nutrition health awareness programs should be implemented in the industries to help reduce the future prevalence and incidence of chronic diseases. Dietary changes (changes in the amount and quality of fat, increased intake of fruits and vegetables), increasing physical activity and involvement of spouses of the employees (improvement in household cooking practices and overall motivation) should be the major focus areas of these health promotion programs.

Early diagnosis and regular monitoring is of prime importance for controlling the behavioural risk factor profile which can be modified by adopting a healthy lifestyle. Apart from the parameters monitored by the medical centre in the health check ups, anthropometric measurements like the waist circumference (an indicator of abdominal obesity), HbA1C, microalbuminuria (the earliest clinical evidence of nephropathy) and foot examination also need to be carried out. Upon identification of the 'at risk' individuals regular monitoring of this group also needs to be carried out.

Our results reinforce the need for initiating low-cost workplace intervention programs to identify and manage individuals with diabetes and who are at high risk for diabetes and its complications. The ultimate goal is to develop medical strategies to maximize good health in employees and to minimise both the frequency and duration of illness absences. The findings of our study are useful in setting priorities for medical programmes and directing health promotion efforts and other prevention strategies.

SALIENT OBSERVATIONS OF THE STUDY:

1. The industrial diabetic population had a variety of risk factors, the average being 5.
2. High prevalence of dyslipidemia was observed which was persistent over 4 years. Also, new cases of dyslipidemia were identified.

3. Consistently high blood pressure levels among the diabetics calls for regular monitoring and health promotion strategies.

OVERALL SUMMARY

There was a high prevalence of risk factors among the industrial T2DM population. Therefore regular screening and monitoring of the employees in order to identify the 'at risk' individuals needs to be done. Also worksite health promotion programs can be carried out to help put the brakes on the progression of risk factors in order to avert the devastating secondary complications.

PHASE III (a): NUTRITIONAL ANALYSIS OF BARLEY GRASS POWDER

Barley grass powder was analyzed for its nutritional value and the results of the analysis are given in Table 4.42. Moisture content was reported to be 10.81%. As can be seen from the table, barley grass powder is a rich source of many nutrients. It is high in protein, low in sodium and high in potassium. It also provides iron and calcium. Barley grass powder provides 160 mg of the antioxidant vitamin C.

PHASE III (b & c): PRODUCT DEVELOPMENT AND SENSORY EVALUATION USING BGP

In this phase of the study, four products were developed using standardized recipes namely- Thepla, Cutlet, Khakhra and Muthiya. Barley Grass Powder (BGP) was incorporated in each of these three recipes at 3 different levels i.e. 0.5g, 1.0g and 1.5g per piece of the product.

Sensory evaluation for the 4 products with different levels of BGP incorporation was done using Composite Rating test and Ranking test. Twelve semi trained panelists were asked to rate the samples on a scale of 0 to 10 for each attribute listed; using composite rating score. This was repeated for each of the four products. The attributes evaluated included colour, texture, size, shape, aroma, mouthfeel, aftertaste and overall acceptability.

Product wise results of the statistical analysis for all the recipes are given below.

THEPLA

Table 4.43 depicts the various attributes of theplas at different levels of BGP incorporation. The total scores did not vary significantly between the 3 samples and it ranged from 54.1 to 58.8. Thepla with 1.0g of BGP displayed higher scores for most of the attributes and mean total score as compared to

TABLE 4.42

NUTRIENT ANALYSIS OF BARLEY GRASS POWDER

Test	Result/100 g powder
Moisture (%)	10.81
Ash (%)	7.66
Fat	Traces
Protein (%)	34.6
Carbohydrate (%)	46.9
Energy (Kcal)	326
Calcium (mg)	462
Potassium (mg)	1895
Sodium (mg)	8.7
Iron (mg)	39.9
Vitamin C (mg)	160
Vitamin B2	Detected
Phytosterol	Weakly positive

TABLE 4.43

SCORES FOR VARIOUS ATTRIBUTES OF BARLEY GRASS POWDER INCORPORATED THEPLA (Mean ± SD)

Attributes	BGP = 0.5g	BGP = 1.0g	BGP = 1.5g	F value
	N=12	N=12	N=12	
Colour	7.8 ± 1.0	6.8 ± 1.1	6.6 ± 1.0	4.29*
Texture (Softness)	6.9 ± 1.0	7.7 ± 1.2	6.1 ± 0.9	6.81**
Size	7.3 ± 1.0	7.3 ± 1.1	7.2 ± 1.2	0.07
Shape	7.3 ± 1.1	7.1 ± 1.2	7.1 ± 1.3	0.18
Aroma	7.2 ± 1.2	7.3 ± 1.2	6.9 ± 1.2	0.38
Mouthfeel (Tenderness/Chewability)	7.2 ± 1.0	7.7 ± 1.2	6.9 ± 1.0	1.47
Aftertaste	7.3 ± 1.4	7.5 ± 1.4	6.7 ± 1.2	1.28
Overall acceptability	7.3 ± 1.4	7.5 ± 1.2	6.7 ± 0.9	1.58
Total score	58.3 ± 7.0	58.8 ± 8.2	54.1 ± 7.3	1.43

't' table for the attribute Colour

Level	't' value
0.5g v/s 1.0g	2.15 *
1.0g v/s 1.5g	0.58
0.5g v/s 1.5g	2.91 **

't' table for the attribute Texture

Level	't' value
0.5g v/s 1.0g	1.64
1.0g v/s 1.5g	3.60 **
0.5g v/s 1.5g	2.15 *

* Significantly different at $p < 0.05$

** Significantly different at $p < 0.01$

the other two samples. There was a significant difference in the texture element between the 3 samples. Theplas with the highest level of BGP incorporation were found to be the least soft. Among the three samples the 0.5g sample was found to have the best colour attribute.

CUTLET

Table 4.44 depicts the mean scores of various attributes at different levels of BGP incorporation in cutlets. The mean total scores ranged from 57.3 to 61.3. It was interesting to note that cutlets with 1.5g of BGP addition scored higher than the 1.0g sample in most of the attributes. The 0.5g sample had scores similar to the 1.5g sample. The element of texture was found to be the best in the 1.5g sample. Thus it can be said that acceptability was good even at the highest level of BGP incorporation and so BGP can be incorporated at all the 3 levels without any major differences in the sensory attributes.

KHAKHRA

Mean scores for various attributes of khakhra are given in Table 4.45. The mean scores for different attributes did not vary significantly between the 3 samples. However, the sample with 0.5g of BGP incorporation scored the highest in most of the attributes. The 1.5g sample got a significantly lower score for the aftertaste attribute as compared to the 0.5g sample. Total scores ranged from 56.6 to 60.7.

MUTHIYA

The mean scores for various sensory attributes of muthiya after BGP incorporation is depicted in Table 4.46. Muthiya with 1.5g BGP had considerably lower scores for most of the attributes like colour, texture, aftertaste and overall acceptability when compared to the samples with lower levels of BGP incorporation. None of these differences were significant and the mean total scores ranged from 52.3 to 59.

COMPARATIVE RANKING AND SCORES OF THE PRODUCTS

When the total scores obtained by the four products as a result of the Composite Rating Test (Table 4.47, Figure 4.10) were compared the following

TABLE 4.44

SCORES FOR VARIOUS ATTRIBUTES OF BARLEY GRASS POWDER INCORPORATED CUTLET (Mean ± SD)

Attributes	BGP = 0.5g	BGP = 1.0g	BGP = 1.5g	F value
	N=12	N=12	N=12	
Colour	7.3 ± 1.2	6.8 ± 1.3	7.2 ± 1.0	0.77
Texture (Softness)	7.5 ± 1.2	7.2 ± 1.3	7.8 ± 1.1	0.72
Size	8.0 ± 1.4	7.7 ± 1.7	7.9 ± 1.3	0.16
Shape	7.6 ± 1.4	7.1 ± 1.8	7.5 ± 1.2	0.39
Aroma	7.7 ± 1.2	7.3 ± 1.2	7.1 ± 1.3	0.69
Mouthfeel (Tenderness, Ease of swallowing)	7.9 ± 1.2	7.3 ± 1.6	7.9 ± 1.4	0.70
Aftertaste	7.5 ± 1.3	6.8 ± 1.5	6.8 ± 1.4	0.91
Overall acceptability	7.8 ± 1.5	7.2 ± 1.6	7.3 ± 1.0	0.55
Total score	61.3 ± 7.4	57.3 ± 9.5	59.5 ± 6.0	0.80

TABLE 4.45

SCORES FOR VARIOUS ATTRIBUTES OF BARLEY GRASS POWDER INCORPORATED KHAKHRA (Mean ± SD)

Attributes	BGP = 0.5g	BGP = 1.0g	BGP = 1.5g	F value
	N=12	N=12	N=12	
Colour	7.8 ± 1.2	6.6 ± 1.4	6.8 ± 1.7	2.27
Texture (Brittleness)	7.8 ± 1.1	7.4 ± 1.4	7.8 ± 1.4	0.26
Size	7.7 ± 1.1	7.6 ± 1.2	7.8 ± 1.3	0.14
Shape	7.8 ± 1.2	7.6 ± 1.2	7.6 ± 1.2	0.08
Aroma	7.3 ± 1.2	7.2 ± 1.5	6.8 ± 1.5	0.39
Mouthfeel (Crunchiness)	7.8 ± 1.0	7.4 ± 1.6	7.2 ± 1.7	0.48
Aftertaste	7.3 ± 0.8	6.8 ± 1.2	6.1 ± 1.2	3.44*
Overall acceptability	7.4 ± 0.8	6.7 ± 1.3	6.6 ± 1.2	1.96
Total score	60.7 ± 6.9	57.2 ± 9.6	56.6 ± 9.9	0.74

't' table for the attribute Texture

Level	't' value
0.5g v/s 1.0g	1.21
1.0g v/s 1.5g	1.33
0.5g v/s 1.5g	2.78 *

* Significantly different at $p < 0.05$

TABLE 4.46

SCORES FOR VARIOUS ATTRIBUTES OF BARLEY GRASS POWDER INCORPORATED MUTHIYA (Mean ± SD)

Attributes	BGP = 0.5g	BGP = 1.0g	BGP = 1.5g	F value
	N=12	N=12	N=12	
Colour	7.2 ± 0.7	6.4 ± 1.5	6.2 ± 0.9	2.66
Texture (Granular)	7.3 ± 0.8	6.6 ± 1.1	6.3 ± 1.4	2.60
Size	7.8 ± 1.0	7.5 ± 1.0	7.3 ± 1.3	0.63
Shape	7.8 ± 1.2	7.6 ± 1.2	7.5 ± 1.4	0.12
Aroma	7.5 ± 1.4	6.7 ± 1.4	6.5 ± 1.6	1.61
Mouthfeel (Tenderness, Ease of swallowing)	7.0 ± 1.1	6.4 ± 1.4	6.1 ± 1.5	1.38
Aftertaste	7.3 ± 1.8	6.8 ± 1.7	6.2 ± 1.7	1.16
Overall acceptability	7.3 ± 1.2	6.8 ± 1.3	6.3 ± 1.2	1.94
Total score	59.0 ± 7.8	54.8 ± 9.3	52.3 ± 9.2	1.81

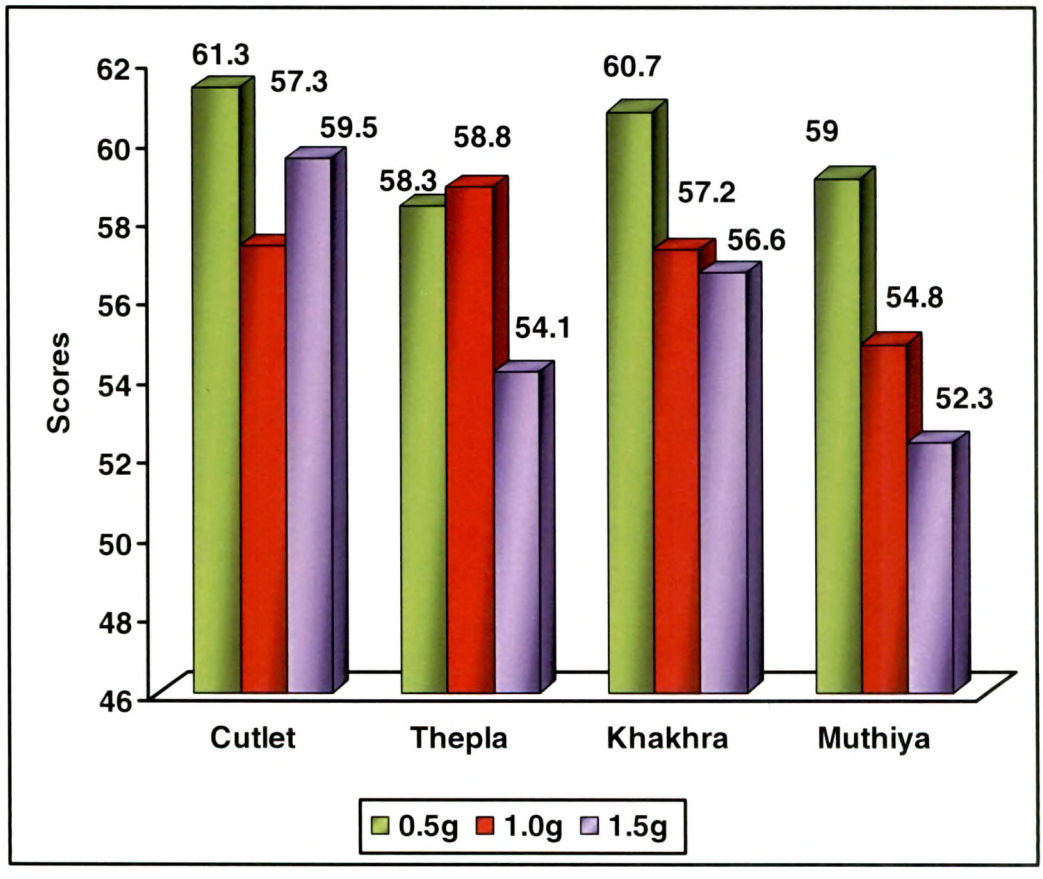
TABLE 4.47

MEAN TOTAL SCORES OF THE FOUR BARLEY GRASS POWDER INCORPORATED RECIPES (Mean ± SD)

	BGP = 0.5g	BGP = 1.0g	BGP = 1.5g	F value
	N=12	N=12	N=12	
Cutlet	61.3 ± 7.4	57.3 ± 9.5	59.5 ± 6.0	0.80
Thepla	58.3 ± 7.0	58.8 ± 8.2	54.1 ± 7.3	1.43
Khakhra	60.7 ± 6.9	57.2 ± 9.6	56.6 ± 9.9	0.74
Muthiya	59.0 ± 7.8	54.8 ± 9.3	52.3 ± 9.2	1.81

FIGURE 4.10

MEAN TOTAL SCORES OF THE FOUR RECIPES



trend was observed,

1. **At 0.5 g level the ranking was:**
   Cutlet > Khakhra > Muthiya > Thepla
2. **At 1.0 g level the ranking was:**
   Thepla > Cutlet > Khakhra > Muthiya
3. **At 1.5 g level the ranking was:**
   Cutlet > Khakhra > Thepla > Muthiya

When the semi trained panelists were asked to rank the products based on overall sensory acceptability the following observations emerged (Table 4.48)

1. More than half (58.3%) of the panelists ranked Cutlet as 1st. Thepla was also designated as 1st by 33.3% of the panelists.
2. 2nd ranks were received by Cutlet (25%), Thepla (41.7%) and Khakhra (25%).
3. Khakhra received the 3rd rank by majority of the panelists.
4. Muthiya received the 4th rank by majority (83.3%) of the panelists.

These observations substantiated the results of the Composite Rating test, where cutlets were rated the best followed sequentially by Thepla, Khakhra and Muthiya.

DISCUSSION

Cereal grass is the young green plant that grows to produce the cereal grain. Barley grass is a popular nutritional supplement. Barley has served as a food staple in most cultures. The use of barley for food and medicinal purposes dates to antiquity. Agronomists place this ancient cereal grass as being cultivated as early as 7000 BC. Barley grass contains a myriad of vitamins, minerals, antioxidants, antioxidant enzymes, phytochemicals and is rich in chlorophyll.

Barley grass supplements are promoted for multiple uses. Claims have been made that they help prevent and fight cancer, lower cholesterol, detoxify many

TABLE 4.48

RANKING OF THE VARIOUS BGP INCORPORATED FOOD RECIPES BY THE PANELISTS (%)

Rank	Cutlet	Thepla	Khakhra	Muthiya
	N=12	N=12	N=12	N=12
1	7 (58.3)	4 (33.3)		1 (8.3)
2	3 (25)	5 (41.7)	3 (25)	1 (8.3)
3	2 (16.7)	3 (25)	7 (58.3)	
4			2 (16.7)	10 (83.3)

Values in parenthesis indicate percentages.

pollutants, protect against solar and other forms of radiation, boost energy and immunity, enhance wound healing, help with digestion, fight tooth decay, promote healthy skin, reverse graying of hair and lower blood pressure, among other things. However substantiating research for many of the health benefits is currently lacking.

A few studies have reported the antioxidative and hypolipidemic properties of barley leaf extract (Yu et al in 2004, Yu et al 2002). Food products developed with BGP can be thought to have health benefits. In this study BGP was incorporated into four recipes to study the effects if any, on organoleptic qualities and acceptability. The incorporation of BGP into foods does not significantly alter the organoleptic qualities like aroma, mouthfeel, texture, taste and overall acceptability as suggested by results of the sensory evaluation of four recipes incorporated with BGP at different levels.

IMPLICATIONS AND USAGE

With a background of the purported health benefits of barley grass its use in daily lives at a household level needs to be looked into. Barley grass can be grown at a household level in kitchen gardens. Barley grass can be used in two forms-as barley grass juice and as fresh leaves. Barley grass can be pulverized with water to make juice. Fresh barley grass can be incorporated in traditional recipes like parantha, thepla etc. Barley grass powder is the most common commercial form of green barley grass but is not widely available. The powder can be sprinkled on foods such as cereal or salad, mixed into juice, dal etc. As seen in our study BGP can be used efficiently in some household recipes with good acceptability.

SALIENT OBSERVATIONS FROM THE STUDY

1. BGP can be effectively incorporated in some traditional Indian recipes.
2. As BGP is a source of number of nutrients and non nutrients, it can be used as a functional food for optimizing health.
3. There is a need to propagate the use of BGP as a functional food.

4. Of the various recipes developed, Khakhra can be scaled up and marketed as a functional food to improve the general health of the population.

OVERALL SUMMARY

It is feasible to incorporate barley grass powder in different traditional Indian recipes with overall acceptability. BGP food products should be commercialized for optimizing the health of the population.

PHASE IV (a): EFFECT OF BARLEY GRASS POWDER (*Hordeum Vulgare*) SUPPLEMENTATION IN THE MANAGEMENT OF DIABETES MELLITUS

Recent developments in understanding the pathophysiology of the diabetic disease process have opened up several new avenues to identify and develop novel therapies to combat the disease. Concurrently, phytochemicals identified from traditional medicinal plants are presenting an exciting opportunity for the development of new types of therapeutics. This has accelerated the global effort to harness and harvest those medicinal plants that bear substantial amount of potential phytochemicals showing multiple beneficial effects in combating diabetes and diabetes-related complications.

The present study was planned to assess the effect of barley grass powder on the metabolic control of type 2 diabetes mellitus. As discussed in the methods and materials chapter, for the study, fifty nine stable Type 2 diabetes mellitus (T2DM) subjects were enrolled from pathology laboratories of Vadodara city and then the subjects were divided into two groups, control group (N=23) and experimental group (N=36). The baseline data was collected on general information, anthropometry, medical history and 24 hour dietary recall along with fasting blood glucose, lipid profile and glycosylated haemoglobin. The control group received no supplementation whereas the experimental group was given four capsules of barley grass powder daily (1.2 g/day) for a period of 60 days. Neither diet, medication or physical activity pattern were altered throughout the study period.

ANTHROPOMETRIC PROFILE

The anthropometric profile of the diabetic subjects is given in Table 4.49. The anthropometric profile included height, weight, BMI and Waist Hip ratio. The subjects were in the age range of 55 to 62 years. Majority of the subjects were overweight or obese as indicated by their BMI. Waist circumference values were found to be higher than the normal cut offs (≥ 90 cm for males & ≥ 80 cm for females) for both the genders indicating the presence of abdominal obesity. Thus the anthropometric profile of the control and the experimental group revealed that the baseline characteristics were similar in both the

TABLE 4.49

ANTHROPOMETRIC PROFILE OF T2DM SUBJECTS IN THE CONTROL AND THE EXPERIMENTAL GROUP (Mean ± SD)

	CONTROL		EXPERIMENTAL	
	Male N=11	**Female N=12**	**Male N=20**	**Female N=16**
Age(y)	62 ± 6	55 ± 10	55 ± 9	59 ± 6
Height (m)	1.66 ± 0.06	1.5 ± 0.05	1.63 ± 0.05	1.5 ± 0.05
Weight (Kg)	66 ± 12	64 ± 12	65 ± 10	69 ± 11
BMI	24.0 ± 4.3	28.1 ± 3.8	25 ± 3	30 ± 5
WC (cm)	92 ± 11	90 ± 10	90 ± 9	90 ± 13
WHR	0.98 ± 0.04	0.89 ± 0.08	0.96 ± 0.06	0.84 ± 0.07

BMI : Body Mass Index

WC : Waist Circumference

WHR : Waist-Hip Ratio

groups.

BACKGROUND INFORMATION

The background information related to risk factors in the subjects is given in Table 4.50. Few subjects reported habitual consumption of tobacco and smoking and this finding was slightly higher in the experimental group than the control group.

ANTHROPOMETRY AND MEDICAL HISTORY

Information on the medical history (Table 4.51) showed that the complications of hypertension and obesity were common in diabetic subjects from both the groups. Nearly 50% of the diabetic subjects were hypertensive. The subjects were categorized as overweight and obese on the basis of the Asia Pacific Classification (BMI ≥ 23 overweight and BMI ≥ 25 obese). A high percentage of subjects were found to be overweight and obese in the control and experimental groups. The prevalence of overweight and obesity in control and experimental group was 69.56% and 83.33% respectively. Relatively very few diabetic subjects (N=4) had cardiac related problems. Thus overweight, obesity and hypertension were the most common associated complications seen in the diabetic subjects of the control and experimental groups.

DIETARY INTAKE

Dietary information as obtained from a 24 hour dietary recall (Table 4.52) revealed that there were no significant differences between the control and experimental groups in terms of mean intake and as % RDA. Diets in both the groups were high in fat content and low in micronutrient content.

IMPACT OF BARLEY GRASS POWDER (BGP) SUPPLEMENTATION ON THE CARBOHYDRATE METABOLISM OF T2DM SUBJECTS

IMPACT OF BGP SUPPLEMENTATION ON THE FBG AND HbA1C LEVELS OF T2DM SUBJECTS

FBG and HbA1C levels of the diabetic subjects before and after two months of BGP supplementation have been depicted in Table 4.53. As can be seen

TABLE 4.50

BACKGROUND INFORMATION RELATED TO RISK FACTORS FOR T2DM SUBJECTS IN THE CONTROL AND EXPERIMENTAL GROUPS (N, %)

	CONTROL N=23	EXPERIMENTAL N=36
Tobacco (M+F)	1 (4.3)	7 (19.4)
Smoking (M)	-	6 (16.7)

TABLE 4.51

MEDICAL HISTORY OF THE T2DM SUBJECTS (N, %)

	CONTROL N=23		EXPERIMENTAL N=36	
	Male N=11	Female N=12	Male N=20	Female N=16
Hypertension	5 (45.5)	5 (41.7)	10 (50)	9 (56.25)
CHD	1 (9.1)	-	2 (10)	1 (6.25)
Overweight	3 (27.3)	-	5 (25)	2 (12.5)
Obesity	3 (27.3)	10 (83.3)	9 (45)	14 (87.5)
Duration of DM [Range (years)]	2-30	<1-26	<1-22	1½ -25

TABLE 4.52

MEAN NUTRIENT INTAKE OF THE SUBJECTS (Mean ± SD)

Nutrient	Experimental N=36	Control N=23
Calories (Kcal)	1533 ± 464 (M: 73.5; F: 69.5)	1464 ± 344 (M: 64.8; F: 75.3)
Carbohydrate (g)	222.1 ± 74.4	198.2 ± 56.0
Protein (g)	44.0 ± 14.3 (M: 80.2; F: 70.5)	43.0± 10.1 (M: 71; F: 78.9)
Fat (g)	51.4 ± 20.8 (M: 303-404; F: 200-267)	53.0 ± 17.8 (M: 285-381; F: 246-329)
Iron (mg)	12.1 ± 4.1 (M: 74.1; F: 53.8)	11.8 ± 4.5 (M: 65.3; F: 59.5)
Vitamin C (mg)	52.2 ± 41.6 (M: 93.3; F: 79)	42.2 ± 66.3 (M: 91.8; F: 50.5)
β-carotene (µg)	1527 ± 2302 (M: 26.6; F: 38.3)	486 ± 503 (M: 12.6; F: 7.9)
Total Dietary Fibre (g)	16.3 ± 6.4	13.3 ± 7.1

Values in parenthesis indicate % RDA (2009) met by the subjects

M: Male

F: Female

TABLE 4.53

IMPACT OF BARLEY GRASS POWDER SUPPLEMENTATION ON THE FASTING BLOOD GLUCOSE AND HbA1C LEVELS OF T2DM SUBJECTS

(Mean ± SD, mg/dl)

	CONTROL N=23			EXPERIMENTAL N=36		
	Pre	**Post**	**'t' value**	**Pre**	**Post**	**'t' value**
FBG	154 ± 36	142 ± 49	1.67 (0.1087)	148 ± 56	132 ± 39	2.05* (0.0478)
HbA1C (%)	8.7 ± 1.2	8.6 ± 1.0	1.95 (0.0638)	8.46 ± 1.22	8.02 ± 0.87	3.6*** (0.0009)

* Significantly different from baseline value at $p<0.05$

*** Significantly different from baseline value at $p<0.001$

Values in parenthesis indicate p value

from the table, supplementation of BGP led to a significant fall in the FBG and HbA1C values in the experimental group. Such a change was not observed in the control group.

The response of FBG and HbA1C was also looked in relation to gender. The fall in HbA1C was significant in male diabetic subjects while in case of female diabetic subjects reductions were noticed which were not significant (Table 4.54). In control group no appreciable changes in HbA1C values were seen. BGP supplementation for a period of 60 days led to a significant fall of 10.8% in FBG values (Mean fall=15.91 mg/dl, CI (0.70-31.12)) and 5.2% in HbA1C values (Mean fall=0.45%, CI (0.21-0.70)) as shown in Figures 4.11 & 4.12. Insignificant reductions were seen in the control group.

Initial values are important determinants for the response in the supplementation studies. Therefore the blood glucose and its long term metabolic control were seen in relation to the initial blood glucose values (Table 4.55). BGP supplementation led to a significant reduction in the blood glucose and HbA1C values of subjects who had initial fasting blood glucose greater than 140 mg/dl. Such a trend was not seen in the control group. The percent reduction of FBG and HbA1C in the experimental group was 19.2% (Mean fall=37.1 mg/ dl, CI (8.2-66)) and 7.3% (Mean fall=0.68%, CI (0.25-1.11)) respectively, whereas in the control group it was 6.36% and 3.19% (Figures 4.13 & 4.14).

IMPACT OF BGP SUPPLEMENTATION ON THE LIPID PROFILE OF T2DM SUBJECTS

The effect of BGP supplementation on the lipid profile of the experimental and control group is given in Table 4.56. With supplementation of BGP for a period of two months a significant change was observed in the lipid profile of the diabetic subjects. There was a 5.1% decrease in the total cholesterol (TC) values (195 mg/dl vs 185 mg/dl) (Mean fall=9.85 mg/ dl, CI (0.96-18.74)). The atherogenic lipoprotein LDL-C decreased by about 8.2% (122 mg/dl vs 112 mg/ dl) (Mean fall=9.97 mg/ dl, CI (1.05-18.89)) and HDL-C increased by about 5.0% (40 vs 42 mg/ dl) (Mean rise=2.17 mg/ dl, CI (0.62-3.72)). A 7.7%

TABLE 4.54

IMPACT OF BARLEY GRASS POWDER SUPPLEMENTATION ON THE FASTING BLOOD GLUCOSE AND HbA1C LEVELS OF MALE AND FEMALE T2DM SUBJECTS (Mean ± SD, mg/dl)

	CONTROL			EXPERIMENTAL		
	Pre	**Post**	**'t' value**	**Pre**	**Post**	**'t' value**
Males	**N=11**			**N=20**		
FBG	133 ± 21	118 ± 25	3.39** (0.0068)	152 ± 67	132 ± 42	1.61 (0.1241)
HbA1C (%)	8.2 ± 0.9	8.1 ± 0.8	0.91 (0.3827)	8.58 ± 1.19	8.04 ± 0.84	3.2** (0.0046)
Females	**N=12**			**N=16**		
FBG	173 ± 37	164 ± 55	0.66 (0.5207)	142 ± 38	131 ± 36	1.27 (0.2219)
HbA1C (%)	9.2 ± 1.1	9.0 ± 1.1	1.76 (0.1057)	8.32 ± 1.28	7.99 ± 0.92	1.79 (0.0943)

** Significantly different from baseline value at $p<0.01$

Values in parenthesis indicate p value

FIGURE 4.11

IMPACT OF BGP SUPPLEMENTATION ON THE FBG LEVELS OF THE EXPERIMENTAL T2DM SUBJECTS

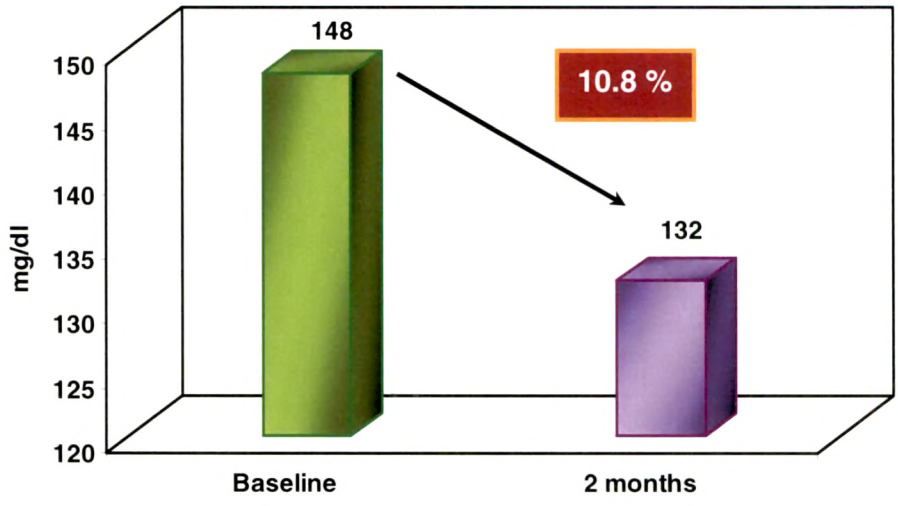


FIGURE 4.12

IMPACT OF BGP SUPPLEMENTATION ON THE HbA1c LEVELS OF THE EXPERIMENTAL T2DM SUBJECTS

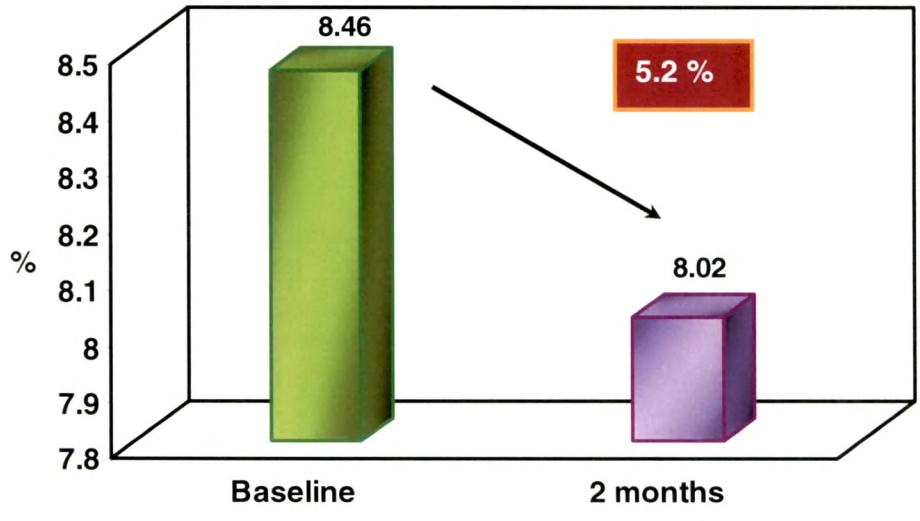


TABLE 4.55

IMPACT OF BARLEY GRASS POWDER SUPPLEMENTATION ON THE FASTING BLOOD GLUCOSE AND HbA1C LEVELS OF T2DM SUBJECTS BASED ON THE INITIAL FASTING BLOOD GLUCOSE VALUES

(Mean ± SD)

	CONTROL			EXPERIMENTAL		
	Pre	**Post**	**'t' value**	**Pre**	**Post**	**'t' value**
FBG <140 mg/dl						
	N=8			**N=20**		
FBG	117 ± 12	104 ± 19	3.12* (0.0168)	112 ± 24	113 ± 30	0.19 (0.8464)
HbA1C	7.5 ± 0.7	7.6 ± 0.7	0.22 (0.8263)	7.8 ± 1.0	7.54 ± 0.7	2.01 (0.0586)
FBG >140 mg/dl						
	N=15			**N=16**		
FBG	173 ± 29	162 ± 48	1.04 (0.3171)	193 ± 51	156 ± 35	2.51* (0.0237)
HbA1C	9.4 ± 0.8	9.1 ± 0.8	2.52* (0.0246)	9.3 ± 0.91	8.62 ± 0.66	3.11** (0.0071)

* Significantly different from baseline value at $p<0.05$

** Significantly different from baseline value at $p<0.01$

Values in parenthesis indicate p value

FIGURE 4.13

IMPACT OF BGP SUPPLEMENTATION ON THE FBG LEVELS OF THE EXPERIMENTAL GROUP SUBJECTS BASED ON THEIR INITIAL FBG LEVELS (FBG >140 mg/dl)

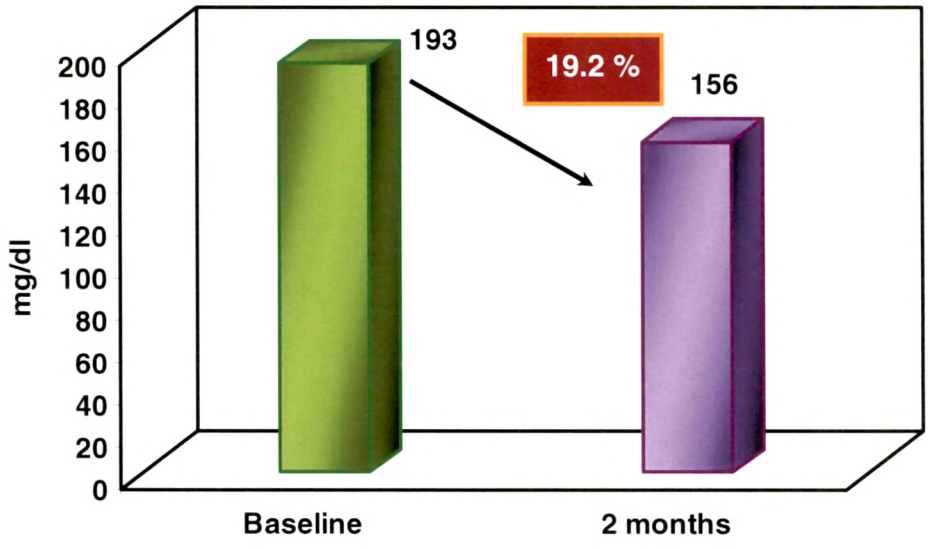


FIGURE 4.14

IMPACT OF BGP SUPPLEMENTATION ON THE HbA1C LEVELS OF THE EXPERIMENTAL GROUP SUBJECTS BASED ON THEIR INITIAL FBG LEVELS (FBG > 140 mg/dl)

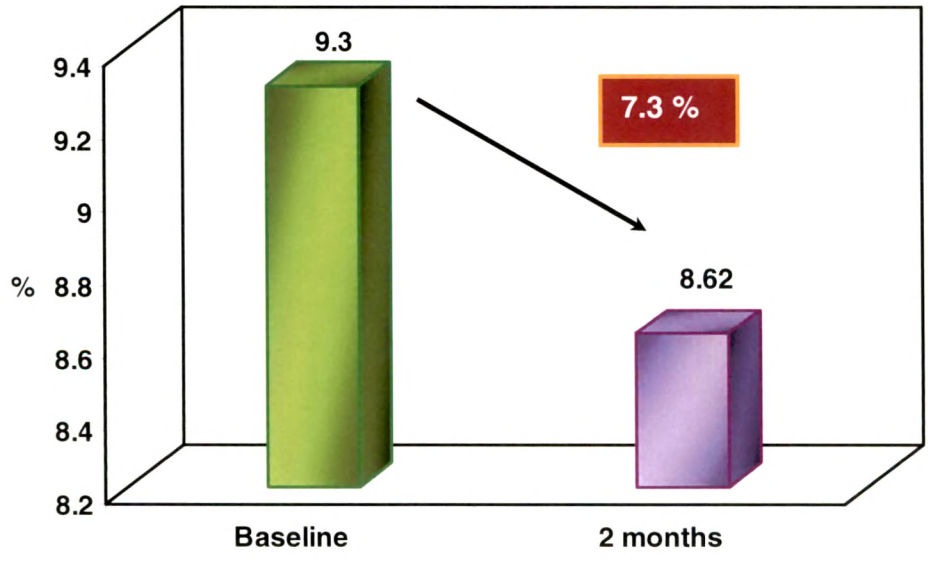


TABLE 4.56

IMPACT OF BARLEY GRASS POWDER SUPPLEMENTATION ON THE LIPID PROFILE OF T2DM SUBJECTS (Mean ± SD, mg/dl)

	CONTROL N=23			EXPERIMENTAL N=36		
	Pre	**Post**	**'t' value**	**Pre**	**Post**	**'t' value**
TG	148 ± 58	138 ± 29	1.04 (0.3105)	166 ± 88	156 ± 79	1.12 (0.2673)
TC	190 ± 46	179 ± 31	1.62 (0.1188)	195 ± 44	185 ± 42	2.17* (0.0366)
HDL-C	46 ± 10	42 ± 6	2.97** (0.0070)	40 ± 7	42 ± 6	2.75** (0.0093)
LDL-C	114 ± 37	109 ± 31	0.92 (0.3699)	122 ± 36	112 ± 37	2.19* (0.0351)
VLDL-C	30 ± 12	28 ± 6	1.04 (0.3105)	33 ± 18	31 ± 16	1.12 (0.2673)
Non HDL-C	144 ± 43	136 ± 30	1.14 (0.2678)	155 ± 44	143 ± 43	2.61* (0.0131)

* Significantly different from baseline value at $p<0.05$

** Significantly different from baseline value at $p<0.01$

Values in parenthesis indicate p value

(155 vs 143 mg/ dl) (Mean fall=12.02 mg/ dl, CI (3-21.04)) decrease was found in the Non HDL-C values which represents a mixture of atherogenic lipoproteins. There was a slight non significant reduction in the triglyceride values as well. In the control group the lipid profile remained unaltered with an exception of HDL which decreased significantly. Thus, BGP supplementation brought about significant reductions in TC and its atherogenic lipoproteins.

Table 4.57 gives the lipid profile of the male and female diabetic subjects before and after the supplementation. There was a significant reduction in the TC, LDL-C, and Non HDL-C values in the female diabetic subjects of the experimental group. In male diabetic subjects a significant rise in HDL-C values after BGP supplementation was noted. Thus favourable changes were noticed more in female subjects than in male subjects which could be due to lower mean TC, LDL-C and Non HDL-C values among male subjects than female subjects.

The lipid profile was studied in relation to the initial TC values and is given in Table 4.58. Diabetic subjects who had TC values ≥ 200 mg/dl showed a favourable change as compared to those having TC values < 200 mg/dl. The fall in TC (Mean fall=19.86 mg/ dl, CI (7.08-32.64)), LDL-C (Mean fall=17.39 mg/ dl, CI (2.97-31.81)) and Non HDL-C (Mean fall=20.42 mg/ dl, CI (6.6-34.24)) values was 8.3%, 10.9% and 10.1% respectively in subjects having TC ≥ 200 mg/ dl. A positive point was the significant rise in HDL-C (39 mg/dl vs 43 mg/dl) (Mean rise=3.19 mg/ dl, CI (1.26-5.12)) among subjects who had TC <200 mg/dl. On the contrary in the control group a fall in HDL-C was seen (44 mg/dl vs 41 mg/dl) in subjects having TC ≥ 200 mg/dl.

An attempt was also made to look into the impact of BGP supplementation on the lipid profile of the diabetic subjects in relation to their initial TG values (Table 4.59). In line with the TC data, hypertriglyceridemic subjects (TG values ≥ 150 mg/dl) showed significant changes in the lipid levels as compared to the normolipidemics. A 16.7% reduction was observed in TG (Mean fall=41.25 mg/ dl, CI (6.77-75.73)) values after two months of BGP supplementation in experimental hypertriglyceridemic subjects. Concomitantly

TABLE 4.57

IMPACT OF BARLEY GRASS POWDER SUPPLEMENTATION ON THE LIPID PROFILE OF MALE AND FEMALE T2DM SUBJECTS

(Mean ± SD, mg/dl)

	CONTROL			EXPERIMENTAL		
	Pre	**Post**	**'t' value**	**Pre**	**Post**	**'t' value**
Males	N=11			N=20		
TG	136 ± 58	140 ± 36	0.35 (0.7356)	154 ± 84	155 ± 92	0.1 (0.9168)
TC	195 ± 56	182 ± 37	1.09 (0.3005)	186 ± 52	184 ± 48	0.29 (0.7727)
HDL-C	46 ± 11	42 ± 6	2.39* (0.0382)	36 ± 5	39 ± 5	3.54** (0.0021)
LDL-C	121 ± 45	112 ± 36	1.00 (0.3390)	119 ± 40	114 ± 41	0.76 (0.4526)
VLDL-C	27 ± 12	28 ± 7	0.35 (0.7356)	31 ± 17	31 ± 18	0.1 (0.9168)
Non HDL-C	149 ± 51	140 ± 36	0.81 (0.4344)	149 ± 53	145 ± 49	0.76 (0.4521)
Females	N=12			N=16		
TG	159 ± 59	135 ± 22	1.58 (0.1417)	182 ± 92	158 ± 62	1.61 (0.1281)
TC	185 ± 37	176 ± 27	1.18 (0.2629)	207 ± 29	187 ± 35	3.03** (0.0082)
HDL-C	46 ± 11	43 ± 5	1.83 (0.0939)	44 ± 7	45 ± 6	0.79 (0.4380)
LDL-C	107 ± 29	106 ± 27	0.2 (0.8446)	126 ± 31	110 ± 33	2.6* (0.0198)
VLDL-C	32 ± 12	27 ± 4	1.58 (0.1417)	36 ± 18	32 ± 12	1.61 (0.1281)
Non HDL-C	139 ± 35	133 ± 25	0.76 (0.4637)	163 ± 31	142 ± 35	3.25** (0.0053)

* Significantly different from baseline value at $p<0.05$

** Significantly different from baseline value at $p<0.01$

Values in parenthesis indicate p value

TABLE 4.58

IMPACT OF BARLEY GRASS POWDER SUPPLEMENTATION ON THE LIPID PROFILE OF T2DM SUBJECTS BASED ON THE INITIAL TOTAL CHOLESTEROL VALUES (Mean ± SD, mg/dl)

	CONTROL			EXPERIMENTAL		
	Pre	Post	't' value	Pre	Post	't' value
TC< 200 mg/dl	N=15			N=22		
TG	130 ± 43	136 ± 26	0.59 (0.5659)	135 ± 77	128 ± 42	0.76 (0.4543)
TC	165 ± 20	165 ± 26	0.01 (0.9935)	167 ± 25	163 ± 34	0.59 (0.5587)
HDL-C	44 ± 8	41 ± 5	2.24* (0.0416)	39 ± 7	43 ± 6	3.23** (0.0039)
LDL-C	96 ± 19	97 ± 26	0.25 (0.8035)	100 ± 23	95 ± 34	0.92 (0.3666)
VLDL-C	26 ± 9	27 ± 5	0.59 (0.5659)	27 ± 15	26 ± 8	0.76 (0.4543)
Non HDL-C	122 ± 20	124 ± 26	0.41 (0.6879)	127 ± 24	121 ± 34	1.13 (0.2702)
TC ≥ 200 mg/dl	N=8			N=14		
TG	182 ± 70	142 ± 36	2.03 (0.0820)	215 ± 83	200 ± 102	0.81 (0.4308)
TC	236 ± 47	203 ± 26	2.43* (0.0452)	240 ± 28	220 ± 29	3.04** (0.0093)
HDL-C	51 ± 13	45 ± 6	2.04 (0.0808)	40 ± 7	41 ± 5	0.45 (0.6564)
LDL-C	148 ± 40	130 ± 29	1.58 (0.1581)	156 ± 26	139 ± 25	2.36* (0.0343)
VLDL-C	36 ± 14	28 ± 7	2.03 (0.0820)	43 ± 17	40 ± 20	0.81 (0.4307)
Non HDL-C	185 ± 44	158 ± 26	2.12 (0.0720)	199 ± 30	179 ± 29	2.89* (0.0124)

* Significantly different from baseline value at $p<0.05$

** Significantly different from baseline value at $p<0.01$

Values in parenthesis indicate p value

TABLE 4.59

IMPACT OF BARLEY GRASS POWDER SUPPLEMENTATION ON THE LIPID PROFILE OF T2DM SUBJECTS BASED ON THE INITIAL TRIGLYCERIDE VALUES (Mean ± SD, mg/dl)

	CONTROL			EXPERIMENTAL		
	Pre	Post	't' value	Pre	Post	't' value
TG <150 mg/dl	N= 14				N=22	
TG	111 ± 28	125 ± 25	1.53 (0.1500)	116 ± 28	126 ± 41	1.28 (0.2144)
TC	180 ± 26	177 ± 32	0.39 (0.7023)	175 ± 38	172 ± 38	0.59 (0.5599)
HDL-C	50 ± 9	44 ± 5	5.26*** (0.0001)	40 ± 8	43 ± 7	2.26* (0.0345)
LDL-C	108 ± 22	108 ± 33	0.09 (0.9240)	111 ± 33	104 ± 35	1.32 (0.2009)
VLDL-C	22 ± 6	25 ± 5	1.53 (0.1500)	23 ± 6	25 ± 8	1.27 (0.2145)
Non HDL-C	130 ± 23	133 ± 33	0.51 (0.6215)	135 ± 36	129 ± 37	0.99 (0.3328)
TG >150 mg/dl	N= 9				N=14	
TG	206 ± 44	158 ± 25	3.15* (0.0136)	245 ± 91	204 ± 99	2.34* (0.0355)
TC	205 ± 66	181 ± 32	1.86 (0.0992)	227 ± 34	207 ± 42	2.77* (0.0157)
HDL-C	40 ± 11	40 ± 6	0.04 (0.9725)	39 ± 6	41 ± 4	1.51 (0.1526)
LDL-C	124 ± 54	109 ± 29	1.43 (0.1892)	139 ± 35	125 ± 39	1.78 (0.0968)
VLDL-C	41 ± 9	32 ± 5	3.15* (0.0136)	49 ± 18	41 ± 20	2.34* (0.0355)
Non HDL-C	165 ± 57	140 ± 27	2.09 (0.0692)	188 ± 36	166 ± 42	3* (0.0101)

* Significantly different from baseline value at $p<0.05$

*** Significantly different from baseline value at $p<0.001$

Values in parenthesis indicate p value

a significant reduction in TC (8.8%) (Mean fall=20.26 mg/ dl, CI (5.94-34.58)), VLDL-C (16.3%) (Mean fall=8.25 mg/ dl, CI (1.35-15.15)) and Non HDL-C (11.7%) (Mean fall=22.23 mg/ dl, CI (7.73-36.73)) was also seen in these subjects. In subjects with normolipidemia an increase in HDL-C was seen which was significant (Mean rise=2.3 mg/ dl, CI (0.31-4.29)). Further surprisingly in the control hypertriglyceridemic group a significant fall in TG and VLDL-C was also noted.

IMPACT OF BGP SUPPLEMENTATION ON THE ATHEROGENIC INDICES OF T2DM SUBJECTS

Table 4.60 gives the atherogenic indices of the control and experimental groups. BGP supplementation had a significant positive impact on the atherogenic indices thus lowering the risk of CHD in the diabetic subjects. These improvements in the atherogenic indices were also reflected when the data was analyzed in relation to initial TC and TG values (Tables 4.61 and 4.62)

IMPACT OF BGP SUPPLEMENTATION ON THE FBG, HbA1C, LIPID PROFILE AND ATHEROGENIC INDICES OF T2DM SUBJECTS IN RELATION TO THEIR INITIAL BMI

The effect of BGP supplementation was also studied in relation to the initial BMI of the individuals. Table 4.63 shows the effect of the BGP supplementation on the FBG and HbA1C values of the subjects. Significant reductions in HbA1C levels were seen in overweight and obese subjects (N=30) in the experimental group as compared to those who had a BMI <23. Such a trend was not observed in the control group, depicting the beneficial effect of BGP even in overweight and obese individuals. BMI did not have any influence on the lipid profile of diabetic subjects in the experimental and control groups (Table 4.64).

However, irrespective of BMI, atherogenic indices in the experimental group showed positive changes reflecting the impact of BGP on lipid metabolism (Table 4.65).

TABLE 4.60

IMPACT OF BARLEY GRASS POWDER SUPPLEMENTATION ON THE ATHEROGENIC INDICES OF T2DM SUBJECTS

(Mean ± SD)

	CONTROL			EXPERIMENTAL		
	Pre	**Post**	**'t' value**	**Pre**	**Post**	**'t' value**
LDL/HDL	2.53 ± 0.74	2.59 ± 0.78	0.46 (0.6492)	3.16 ± 1.10	2.73 ± 1.01	3.25** (0.0025)
TC/HDL	4.22 ± 1.02	4.26 ± 0.84	0.21 (0.8283)	5.02 ± 1.36	4.49 ± 1.19	3.6*** (0.0009)
TG/HDL	3.48 ± 1.83	3.35 ± 1.07	0.48 (0.6328)	4.30 ± 2.38	3.81 ± 2.08	1.84 (0.0743)

** Significantly different from baseline value at $p<0.01$

*** Significantly different from baseline value at $p<0.001$

Values in parenthesis indicate p value

TABLE 4.61

IMPACT OF BARLEY GRASS POWDER SUPPLEMENTATION ON THE ATHEROGENIC INDICES OF T2DM SUBJECTS BASED ON THE INITIAL TOTAL CHOLESTEROL VALUES (Mean ± SD)

	CONTROL			EXPERIMENTAL		
	Pre	**Post**	**'t' value**	**Pre**	**Post**	**'t' value**
TC < 200 mg/dl	N=15			N=22		
LDL/HDL	2.26 ± 0.61	2.41 ± 0.73	0.86 (0.4054)	2.63 ± 0.76	2.27 ± 0.84	2.18* (0.0404)
TC/HDL	3.90 ± 0.80	4.09 ± 0.80	1.00 (0.3322)	4.33 ± 0.81	3.88 ± 0.85	2.55* (0.0183)
TG/HDL	3.18 ± 1.43	3.40 ± 0.99	0.83 (0.4222)	3.47 ± 1.88	3.06 ± 1.03	1.66 (0.1099)
TC ≥ 200 mg/dl	N=8			N=14		
LDL/HDL	3.02 ± 0.75	2.93 ± 0.78	0.37 (0.7239)	4 ± 1.06	3.45 ± 0.85	2.38* (0.0327)
TC/HDL	4.83 ± 1.16	4.58 ± 0.85	0.79 (0.4534)	6.12 ± 1.35	5.45 ± 1.02	2.49* (0.0266)
TG/HDL	4.06 ± 2.41	3.26 ± 1.26	1.38 (0.2087)	5.59 ± 2.56	5 ± 2.73	1.04 (0.3137)

* Significantly different from baseline value at $p<0.05$

Values in parenthesis indicate p value

TABLE 4.62

IMPACT OF BARLEY GRASS POWDER SUPPLEMENTATION ON THE ATHEROGENIC INDICES OF T2DM SUBJECTS BASED ON THE INITIAL TRIGLYCERIDE VALUES (Mean ± SD)

	CONTROL			EXPERIMENTAL		
	Pre	**Post**	**'t' value**	**Pre**	**Post**	**'t' value**
TG <150 mg/dl	N=14				N=22	
LDL/HDL	2.21 ± 0.53	2.53 ± 0.94	2.06 (0.0595)	2.83 ± 0.86	2.49 ± 0.88	2.08* (0.0492)
TC/HDL	3.67 ± 0.64	4.12 ± 0.98	2.99* (0.0105)	4.42 ± 0.93	4.10 ± 0.98	1.92 (0.0682)
TG/HDL	2.31 ± 0.76	2.91 ± 0.79	2.97* (0.0108)	2.94 ± 0.81	3.03 ± 1.20	0.42 (0.6786)
TG >150 mg/dl	N=9				N=14	
LDL/HDL	3.02 ± 0.78	2.67 ± 0.46	1.83 (0.1042)	3.68 ± 1.27	3.10 ± 1.13	2.51* (0.0259)
TC/HDL	5.08 ± 0.92	4.48 ± 0.52	2.51* (0.0365)	5.96 ± 1.43	5.11 ± 1.26	3.36** (0.0051)
TG/HDL	5.31 ± 1.43	4.04 ± 1.11	3.07* (0.0154)	6.43 ± 2.47	5.04 ± 2.57	2.71* (0.0177)

* Significantly different from baseline value at $p<0.05$

** Significantly different from baseline value at $p<0.01$

Values in parenthesis indicate p value

TABLE 4.63

IMPACT OF BARLEY GRASS POWDER SUPPLEMENTATION ON THE FASTING BLOOD GLUCOSE AND HbA1C LEVELS OF T2DM SUBJECTS IN RELATION TO THEIR INITIAL BMI (Mean ± SD, mg/dl)

	CONTROL			EXPERIMENTAL		
	Pre	**Post**	**'t' value**	**Pre**	**Post**	**'t' value**
BMI <23	N=7			N=6		
FBG	147 ± 43	129 ± 33	1.89 (0.1082)	132 ± 84	117 ± 38	0.66 (0.5332)
HbA1C	8.19 ± 1.0	8.13 ± 0.88	0.55 (0.6036)	8.37 ± 1.63	7.67 ± 0.66	1.61 (0.1667)
BMI >23	N=16			N=30		
FBG	157 ± 34	148 ± 54	0.94 (0.3613)	151 ± 50	135 ± 39	1.92 (0.0640)
HbA1C	8.96 ± 1.16	8.76 ± 1.08	1.89 (0.0786)	8.48 ± 1.15	8.09 ± 0.89	3.2** (0.0033)

** Significantly different from baseline value at $p<0.01$

Values in parenthesis indicate p value

TABLE 4.64

IMPACT OF BARLEY GRASS POWDER SUPPLEMENTATION ON THE LIPID PROFILE OF T2DM SUBJECTS IN RELATION TO THEIR INITIAL BMI (Mean ± SD)

	CONTROL			EXPERIMENTAL		
	Pre	Post	't' value	Pre	Post	't' value
BMI <23	N=7			N=6		
TG	153 ± 75	144 ± 34	0.45 (0.6715)	147 ± 79	123 ± 35	1.2 (0.2833)
TC	203 ± 67	186 ± 27	1.03 (0.3438)	197 ± 58	179 ± 56	2.2 (0.0781)
HDL-C	48 ± 11	44 ± 5	1.44 (0.1986)	34 ± 6	39 ± 7	3.02* (0.0293)
LDL-C	124 ± 55	113 ± 25	0.90 (0.4007)	134 ± 47	116 ± 52	1.96 (0.1069)
VLDL-C	31 ± 15	29 ± 7	0.45 (0.6714)	29 ± 16	25 ± 7	1.2 (0.2832)
Non HDL-C	155 ± 62	142 ± 26	0.88 (0.4124)	163 ± 60	140 ± 58	2.51 (0.0537)
BMI >23	N=16			N=30		
TG	146 ± 52	135 ± 27	0.92 (0.3704)	170 ± 90	163 ± 84	0.74 (0.4637)
TC	184 ± 35	175 ± 33	1.21 (0.2460)	195 ± 43	186 ± 40	1.59 (0.1217)
HDL-C	46 ± 10	42 ± 6	2.54* (0.0228)	41 ± 7	43 ± 5	1.83 (0.0762)
LDL-C	110 ± 28	107 ± 34	0.43 (0.6733)	120 ± 34	111 ± 35	1.62 (0.1160)
VLDL-C	29 ± 10	27 ± 5	0.92 (0.3705)	34 ± 18	33 ± 17	0.74 (0.4637)
Non HDL-C	139 ± 32	134 ± 33	0.71 (0.4904)	154 ± 41	144 ± 40	1.9 (0.0672)

* Significantly different from baseline value at $p<0.05$

Values in parenthesis indicate p value

TABLE 4.65

IMPACT OF BARLEY GRASS POWDER SUPPLEMENTATION ON THE ATHEROGENIC INDICES OF T2DM SUBJECTS IN RELATION TO THEIR INITIAL BMI (Mean ± SD)

	CONTROL			EXPERIMENTAL		
	Pre	**Post**	**'t' value**	**Pre**	**Post**	**'t' value**
BMI <23	N=7			N=6		
LDL/HDL	2.63 ± 0.84	2.59 ± 0.51	0.28 (0.7884)	4.09 ± 1.63	3.09 ± 1.65	2.96* (0.0315)
TC/HDL	4.34 ± 1.21	4.26 ± 0.66	0.31 (0.7636)	6 ± 2.07	4.75 ± 1.85	3.11* (0.0262)
TG/HDL	3.54 ± 2.34	3.39 ± 1.25	0.32 (0.7578)	4.55 ± 2.70	3.28 ± 1.16	1.65 (0.1582)
BMI >23	N=16			N=30		
LDL/HDL	2.48 ± 0.72	2.59 ± 0.88	0.60 (0.5591)	2.98 ± 0.89	2.66 ± 0.86	2.31* (0.0281)
TC/HDL	4.17 ± 0.96	4.26 ± 0.92	0.39 (0.7007)	4.83 ± 1.12	4.44 ± 1.05	2.63* (0.0134)
TG/HDL	3.46 ± 1.64	3.33 ± 1.02	0.36 (0.7246)	4.25 ± 2.35	3.92 ± 2.22	1.19 (0.2426)

* Significantly different from baseline value at $p<0.05$

Values in parenthesis indicate p value

Thus the positive trend as seen in the reduction of HbA1C and atherogenic indices in the experimental group, substantiates the beneficial role of BGP supplementation in the carbohydrate and lipid metabolism of overweight and obese diabetic subjects.

IMPACT OF BGP SUPPLEMENTATION ON THE FBG, HbA1C, LIPID PROFILE AND ATHEROGENIC INDICES IN T2DM SUBJECTS WITH HYPERTENSION AS A COMPLICATION

BGP supplementation brought about a significant reduction in HbA1C values in both hypertensive ($p<0.01$) and normotensive ($p<0.05$) subjects in the experimental group (Table 4.66). The levels of FBG and HbA1C remained unaltered in the control group. When the effect of BGP supplementation was studied in hypertensive diabetics no significant changes were observed in the lipid profile values (Table 4.67). However, there was a significant increase in HDL-C values in normotensive subjects in the experimental group post intervention.

Table 4.68 depicts the supplementation effect on the atherogenic indices of the normotensive and hypertensive diabetic subjects. Atherogenic indices were significantly lowered in both normotensives and hypertensives after the BGP supplementation. Two of the atherogenic indices L/H and TC/H showed significant improvements in the normotensive experimental group whereas in the hypertensive experimental group, the positive significant change was seen only with regard to TC/H. Thus even in the presence of hypertension appreciable changes were reflected in the atherogenic indices.

Since BMI and hypertension can have an influence on the response to supplementation, the data on the carbohydrate metabolism and lipid profile was looked in relation to both BMI and hypertension (Table 4.69, 4.70 and 4.71). As can be seen from the tables, BGP supplementation had a significant impact on the HbA1C values of diabetic subjects who were overweight / obese and hypertensive. The lipid profile of the subjects did not vary significantly. The decreasing trend however, calls for multiple strategies to bring about the beneficial effects.

TABLE 4.66

IMPACT OF BARLEY GRASS POWDER SUPPLEMENTATION ON THE FASTING BLOOD GLUCOSE AND HbA1C LEVELS OF T2DM SUBJECTS WITH HYPERTENSION AS A COMPLICATION (Mean ± SD, mg/dl)

	CONTROL			EXPERIMENTAL		
	Pre	**Post**	**'t' value**	**Pre**	**Post**	**'t' value**
NORMOTENSIVES						
	N=13			N=17		
FBG	152 ± 29	145 ± 55	0.68 (0.5119)	144 ± 51	130 ± 43	1.27 (0.2204)
HbA1C (g %)	8.6 ± 1.0	8.5 ± 0.9	1.08 (0.3008)	8.49 ± 1.54	7.94 ± 0.94	2.39* (0.0289)
HYPERTENSIVES						
	N=10			N=19		
FBG	156 ± 46	138 ± 41	1.93 (0.0859)	151 ± 61	133 ± 35	1.57 (0.1334)
HbA1C (g %)	8.9 ± 1.3	8.7 ± 1.2	1.69 (0.1252)	8.44 ± 0.88	8.08 ± 0.82	2.96** (0.0082)

* Significantly different from baseline value at $p<0.05$

** Significantly different from baseline value at $p<0.01$

Values in parenthesis indicate p value

TABLE 4.67

IMPACT OF BARLEY GRASS POWDER SUPPLEMENTATION ON THE LIPID PROFILE OF T2DM SUBJECTS WITH HYPERTENSION AS A COMPLICATION

(Mean ± SD, mg/dl)

	CONTROL			EXPERIMENTAL		
	Pre	Post	't' value	Pre	Post	't' value
NORMOTENSIVES		N=13		N=17		
TG	132 ± 58	125 ± 23	0.45 (0.6636)	163 ± 92	151 ± 60	0.79 (0.4399)
TC	196 ± 54	182 ± 31	1.27 (0.2295)	193 ± 42	182 ± 41	1.66 (0.1159)
HDL-C	50 ± 10	45 ± 5	3.25** (0.0069)	39 ± 7	42 ± 6	2.54* (0.0215)
LDL-C	120 ± 44	112 ± 29	0.81 (0.4359)	121 ± 38	109 ± 41	1.91 (0.0732)
VLDL-C	26 ± 12	25 ± 5	0.45 (0.6636)	33 ± 18	30 ± 12	0.79 (0.4399)
Non HDL-C	146 ± 50	137 ±31	0.83 (0.4221)	154 ± 43	139 ± 42	2.05 (0.0562)
HYPERTENSIVES		N=10		N=19		
TG	169 ± 55	154 ± 30	1.17 (0.2720)	169 ± 85	161 ± 94	0.78 (0.4416)
TC	181 ± 34	174 ± 33	1.11 (0.2974)	197 ± 47	189 ± 44	1.38 (0.1844)
HDL-C	41 ± 10	40 ± 5	0.82 (0.4340)	41 ± 7	42 ± 5	1.25 (0.2243)
LDL-C	107 ± 28	104 ± 34	0.4 (0.6970)	123 ± 36	115 ± 35	1.21 (0.2385)
VLDL-C	34 ± 11	31 ± 6	1.17 (0.2719)	34 ± 17	32 ± 19	0.78 (0.4415)
Non HDL-C	140 ± 33	135 ± 31	0.83 (0.4268)	157 ± 46	147 ± 44	1.59 (0.1289)

* Significantly different from baseline value at $p<0.05$

** Significantly different from baseline value at $p<0.01$

Values in parenthesis indicate p value

TABLE 4.68

IMPACT OF BARLEY GRASS POWDER SUPPLEMENTATION ON THE ATHEROGENIC INDICES OF T2DM SUBJECTS WITH HYPERTENSION AS A COMPLICATION (Mean ± SD)

	CONTROL			EXPERIMENTAL		
	Pre	**Post**	**'t' value**	**Pre**	**Post**	**'t' value**
NORMOTENSIVES						
	N=13			N=17		
LDL/HDL	2.41 ± 0.68	2.56 ± 0.77	0.88 (0.3981)	3.25 ± 1.19	2.67 ± 1.08	2.64* (0.0177)
TC/HDL	3.96 ± 0.88	4.14 ± 0.86	0.80 (0.4380)	5.11 ± 1.42	4.40 ± 1.18	2.72* (0.0150)
TG/HDL	2.76 ± 1.40	2.87 ± 0.73	0.29 (0.7743)	4.35 ± 2.57	3.67 ± 1.62	1.45 (0.1637)
HYPERTENSIVES						
	N=10			N=19		
LDL/HDL	2.67 ± 0.82	2.62 ± 0.82	0.24 (0.8136)	3.09 ± 1.05	2.78 ± 0.98	1.9 (0.0734)
TC/HDL	4.56 ± 1.13	4.42 ± 0.82	0.55 (0.5950)	4.94 ± 1.34	4.57 ± 1.23	2.46* (0.0240)
TG/HDL	4.43 ± 1.95	3.97 ± 1.15	1.07 (0.3130)	4.25 ± 2.26	3.94 ± 2.46	1.09 (0.2874)

* Significantly different from baseline value at $p<0.05$

Values in parenthesis indicate p value

TABLE 4.69

IMPACT OF BARLEY GRASS POWDER SUPPLEMENTATION ON THE FASTING BLOOD GLUCOSE AND HbA1C LEVELS OF T2DM SUBJECTS WITH BMI >23 AND HYPERTENSION AS A COMPLICATION

(Mean ± SD, mg/dl)

	CONTROL (N=7)			EXPERIMENTAL (N=16)		
	Pre	**Post**	**'t' value**	**Pre**	**Post**	**'t' value**
FBG	155 ± 42	143 ± 45	1.12 (0.3051)	165 ± 56	142 ± 31	1.79 (0.0936)
HbA1C	9.2 ± 1.4	8.9 ± 1.4	2.32 (0.0591)	8.63 ± 0.81	8.23 ± 0.79	2.83* (0.0125)

* Significantly different from baseline value at $p<0.05$

TABLE 4.70

IMPACT OF BARLEY GRASS POWDER SUPPLEMENTATION ON THE LIPID PROFILE OF T2DM SUBJECTS WITH BMI >23 AND HYPERTENSION AS A COMPLICATION (Mean ± SD, mg/dl)

	CONTROL (N=7)			EXPERIMENTAL (N=16)		
	Pre	Post	't' value	Pre	Post	't' value
TG	160 ± 43	148 ± 24	0.75 (0.4805)	182 ± 84	170 ± 99	0.94 (0.3607)
TC	177 ± 39	174 ± 40	0.33 (0.7520)	201 ± 44	193 ± 37	1.02 (0.3216)
HDL-C	41 ± 11	40 ± 6	0.75 (0.4808)	42 ± 7	42 ± 4	0.84 (0.4119)
LDL-C	103 ± 33	105 ± 41	0.13 (0.9010)	123 ± 32	116 ± 26	0.80 (0.4348)
VLDL-C	32 ± 9	30 ± 5	0.75 (0.4805)	36 ± 17	34 ± 20	0.94 (0.3606)
Non HDL-C	135 ± 36	134 ± 37	0.13 (0.8990)	159 ± 42	150 ± 36	1.16 (0.2603)

TABLE 4.71

IMPACT OF BARLEY GRASS POWDER SUPPLEMENTATION ON THE ATHEROGENIC INDICES OF T2DM SUBJECTS WITH BMI >23 AND HYPERTENSION AS A COMPLICATION (Mean ± SD)

	CONTROL (N=7)			EXPERIMENTAL (N=16)		
	Pre	Post	't' value	Pre	Post	't' value
LDL/HDL	2.58 ± 0.88	2.64 ± 0.96	0.19 (0.8491)	2.97 ± 0.72	2.75 ± 0.56	1.25 (0.2273)
TC/HDL	4.42 ± 1.12	4.41 ± 0.89	0.01 (0.9934)	4.87 ± 1.04	4.57 ± 0.89	1.76 (0.0984)
TG/HDL	4.17 ± 1.68	3.85 ± 1.03	0.61 (0.5618)	4.48 ± 2.24	4.1 ± 2.6	1.19 (0.2505)

PERCENTAGE OF SUBJECTS ATTAINING NORMOGLYCEMIA AND NORMOLIPIDEMIA AFTER BGP SUPPLEMENTATION

With BGP supplementation 25% of the subjects attained normal FBG levels and 21.4% of the subjects attained normal TC and TG levels. It was noted that around 30-40% of the subjects showed improvements in their glycemic and lipemic status in response to BGP supplementation (Tables 4.72 and 4.73). These improvements were also observed by a leftward shift in the frequency distribution curves for these indicators (Figures 4.15, 4.16, 4.17 and 4.18).

DISCUSSION

The rapidly increasing global prevalence of diabetes is a significant cause for concern. Treatment of Type 2 diabetes is complicated by several factors inherent to the disease process, typically, insulin resistance, hyperinsulinemia, impaired insulin secretion, reduced insulin-mediated glucose uptake and utilization (De Fronzo 1997, Polonsky et al 1996, Groop et al 1989).

Despite the recent surge in new drugs to treat and prevent the condition, its prevalence continues to soar. Progress in understanding the metabolic staging of diabetes over the past few years has led to significant advances in regimen for treatment of this devastating disease. The most challenging goal in the management of patients of diabetes mellitus is to achieve blood glucose level as close to normal as possible. In addition, postprandial hyperglycemia or hyperinsulinemia are independent risk factors for the development of macrovascular complications of diabetes mellitus.

Traditional medicinal plants with various active principles and properties have been used since ancient times by physicians to treat a great variety of human diseases. Phytochemicals, a large group of non-nutrient secondary metabolites in plants which provide much of the colour and taste in fresh or processed fruits and vegetables, are thought to play a significant role in the health effects of plant-based diets. The beneficial multiple activities like manipulating carbohydrate metabolism by various mechanisms, preventing

TABLE 4.72

PERCENT SUBJECTS ATTAINING NORMOGLYCEMIA AND NORMOLIPIDEMIA AFTER BGP SUPPLEMENTATION (%)

Indicator	Normoglycemic & Normolipidemic
FBG	25
HbA1C	0
TC	21.4
TG	21.4

TABLE 4.73

PERCENT SUBJECTS SHOWING IMPROVEMENT IN GLYCEMIC AND LIPEMIC STATUS AFTER BGP SUPPLEMENTATION (%)

Indicator	Decrease from baseline
FBG	33.3
HbA1C	33.3
TC	41.7
TG	36.1

PRE AND POST FREQUENCY DISTRIBUTION CURVES OF SELECTED INDICATORS IN T2DM SUBJECTS

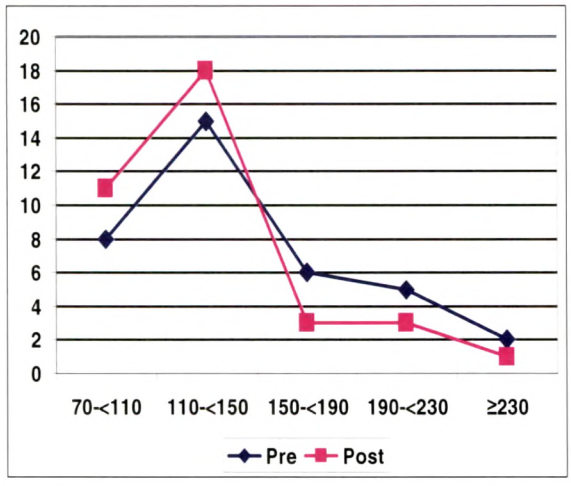


FIGURE 4.15
FASTING BLOOD GLUCOSE

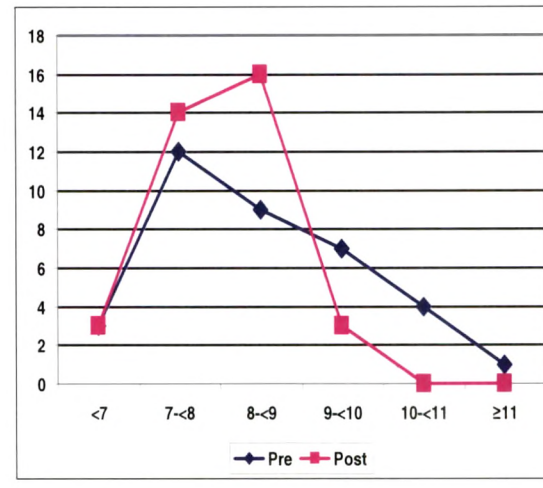


FIGURE 4.16
HbA1C

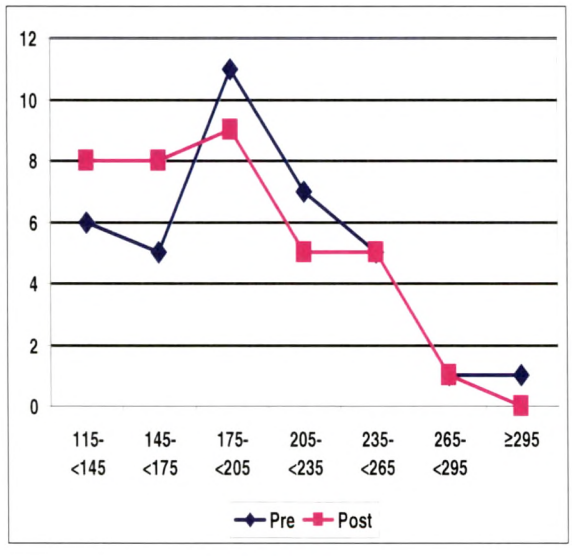


FIGURE 4.17
TOTAL CHOLESTEROL

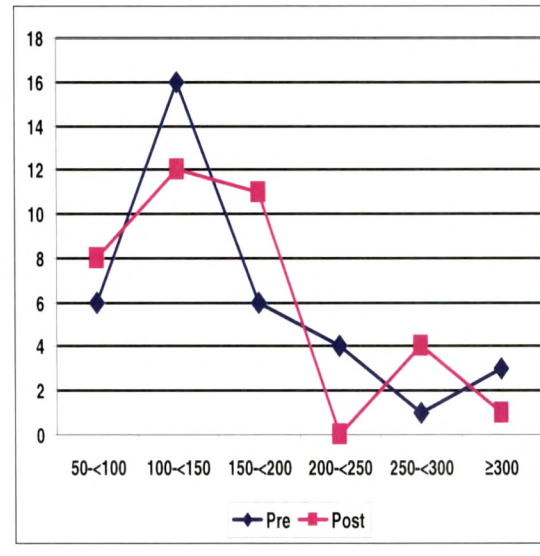


FIGURE 4.18
TRIGLYCERIDE

and restoring integrity and function of β-cells, insulin-releasing activity, improving glucose uptake and utilization and the antioxidant properties present in medicinal plants offer exciting opportunity to develop them into novel therapeutics.

Regulation of the postprandial glucose by inhibiting starch digestion, delaying the gastric emptying rate and reducing active transport of glucose across intestinal brush border membrane is one of the mechanisms by which diet can reduce the risk of type 2 diabetes.

(1) By inhibiting digestive enzymes

Recent studies have reported the potential of antidiabetic medicinal plants on inhibition of carbohydrate hydrolyzing enzymes, α-amylase and α - glucosidase and manipulation of glucose transporters. The potential effect of phytochemicals in inhibiting α –amylase (Kim et al 2000) and α –glucosidase (Watanabe et al 1997) is supported by literature.

Tea polyphenolics, also have been reported to inhibit α - amylase and sucrase, and have been shown to be the principle substance for suppressing post prandial hyperglycemia (Hara and Honda 1990, Matsumato et al 1993, Valsa et al 1997).

(2) By inhibiting active transport of glucose across intestinal brush border membrane

Tea polyphenolics also inhibit glucose transport across the intestine by inhibiting sodium glucose co-transporter-1 (S-GLUT-1). Catechin, Epicatechin, Epigallocatechin and Epicatechin gallate, isoflavones from soybeans, polyphenolic compounds, tannic acid, chlorgenic acid, crude saponin fractions from *Gymnema sylvestre* and other saponins from several plant extracts have been shown to possess potent S-GLUT-1-mediated inhibition of glucose and antihyperglycemic activity (Kobayashi et al 2000, Vedavanam et al 1999, Welsh et al 1989, Murakami et al 1996, Yoshikawa et al 1997, Yoshikawa et al 1996, Yoshikawa et al 1997).

The manipulation of S-GLUT-1-mediated transport along with α -amylase and α -glucosidase inhibitory activity by plant phenolics make them very exciting candidates in the control and management of hyperglycemia.

(3) By delaying the gastric emptying rate of gastrointestinal content.
The water-soluble dietary fibres, guar gum, pectin, polysaccharides contained in plants have been reported to increase the viscosity of gastrointestinal content, thereby decreasing the gastric emptying rate and suppressing/delaying the digestion and absorption of carbohydrates (Nelson 1989, Johnson 1981, Yuan et al 1998, Kakuda et al 1996).

Anthocyanins, a significant group of polyphenols in bilberries and other berries, may also prevent type 2 diabetes and obesity. Anthocyanins from different sources have been shown to affect glucose absorption and insulin level/secretion/action and lipid metabolism in vitro and in vivo (Jayaprakasam et al 2005, Martineau et al 2006). Blueberry extracts were found to be potent inhibitors of starch digestion, and more effective inhibitors of the a-glucosidase/maltase activity than extracts from strawberry and raspberry.

It was reported that extracts from the high bush blueberry (V. angustifolium) also increase glucose uptake by the muscle cells in the presence of insulin and protect the neural cells from the toxic effects of high glucose levels in vitro (Martineau et al 2006). Other in vitro studies with pancreatic cells have shown that pure anthocyanins (glucose conjugates) such as delfinidin glucosides, cyanidin glycosides and cyanidin galactosides can increase the excretion of insulin in primary cell cultures(Martineau et al 2006).

Tsuda and his co-workers studied the colourful extract of purple corn (PCC) containing anthocyanins with respect to its possible effects in obesity and diabetes (Tsuda et al 2003). Purple corn colour contains high amounts of cyanidin glucoside (70 g/kg). They fed mice for 12 weeks with a high fat diet (HFD) or a normal diet with or without 2 g/kg cyanidin glucosides. The animals fed with HFD had higher body weight and weights of brown and white adipose tissues (hypertrophy) and increased triglycerides and total fat content in liver,

but not in serum. Serum insulin, leptin and TNF- α (mRNA) were also increased after feeding with this diet. All of these effects of HFD feeding were decreased in mice fed a diet with PCC.

Similar effects have been observed with high fat diets rich in anthocyanins from Cornelian cherries and black rice (Martineau et al 2006, Johnston et al 2003). A human study on anthocyanins showed that consumption of chokeberry, a berry that contains as much anthocyanins as bilberries, decreases fasting glucose and serum cholesterol and decreases HbA1C in type 2 diabetic patients (Jahromi & Ray 1993).

Some of the medicinal plants have been shown to possess β-cell regeneration and insulin releasing activity. A crude extract of *Pterocarpus marsupium*, (an Ayurvedic medicinal plant), in the form of water decoction has been reported to have protective and restorative effect on β cells in alloxan-induced diabetic rats. The active principle isolated from *Pterocarpus marsupium* for these properties was epicatechin.

GS4 (400 mg/day) extracted from leaves of *Gymnema sylvestre R. Br.,* was administered to type II diabetic patients for 18-20 months as a supplement to the conventional oral drugs. During GS4 supplementation, the patients showed a significant reduction in blood glucose, glycosylated haemoglobin and glycosylated plasma proteins, and conventional drug dosage could be decreased. The data suggested that pancreatic beta cells may be regenerated and/or repaired in type II diabetic patients on GS4 supplementation. This was supported by the appearance of raised insulin levels in the serum of patients after GS4 supplementation (Baskaran et al 1990). GS4 was also administered (400 mg/day) to 27 patients with insulin-dependent diabetes mellitus (type I). GS4 therapy appeared to enhance endogenous insulin release, possibly by regeneration/revitalisation of the residual beta cells (Shanmugasundaram 1990).

The antidiabetic and antihyperlipidemic effect of *Zizyphus jujuba* in alloxan

induced diabetic rats have been reported, which was found to be fairly comparable to that of glibenclamide (Ignacimuthu and Amalraj 1998). It was proposed that an alkaloid barberine present in the leaves of the plant may be responsible for its hypoglycemic activity and that chemical constituents in *Z. jujuba* may have the ability to release insulin from pancreatic β-cells and also have the potential to protect it from alloxan-induced damage.

Aldose reductase has been a drug target because of its involvement in the development of secondary complications of diabetes such as neuropathy, cataract, nephropathy and retinopathy. Suryanarayana et al (2004) demonstrated the inhibition of aldose reductase by the active constituent of *E. officinalis,* tannoids. The tannoids prevented the aldose reductase activation in rat lens organ culture and also prevented sugar induced osmotic changes. Flavanone and flavonol glucosides isolated from a plant popularly known as 'plant insulin' (*Myrcia multiflora* – a Brazalian medicinal plant) have been reported to possess aldose reductase inhibition, α- glucosidase inhibition and potential for hypoglycemic activity in alloxan-induced diabetic animals (Yoshikawa, et al 1998).

Diabetes is associated with oxidative stress due to hyperglycemia and hyperlipidemia (Baynes and Thorpe 1999). Hyperglycemia and dyslipidemia induce inflammatory-immune responses and oxidative stress reactions, and generation of free radicals accounts for the cardiovascular complications and mortality of obesity and type 2 diabetes. The depletion of antioxidants and its contribution to cardiovascular complications in diabetes is well documented (Baynes & Thorpe 1999, Pickup 2004). Several studies have demonstrated significant decrease of plasma antioxidants such as of α- and γ-tocopherol, β- and α carotene, lycopene, β-cryptoxanthin, lutein, zeaxanthin, retinol, as well as ascorbic acid in the course of diabetes and its associated complications such as endothelial dysfunction and atherosclerosis(Polidori et al 2000, Price et al 2001, Valabhji et al 2001, Polidori et al 2001). Thus the rationale for the therapeutic use of antioxidants in the treatment and prevention of diabetic complications is strong.

A strong negative correlation between polyphenol consumption and CAD and stroke has been documented (Manach et al 2005). There is increasing evidence of potential benefits of polyphenols in the regulation of cellular processes such as redox control and inflammatory responses as established in animal models or cultured cells. In the apoE KO mice model, polyphenols from red wine and green tea were shown to prevent the formation of atherosclerotic plaques (Norata et al 2007). This antiatherosclerotic effect may be associated both with modification of oxidative stress and/or with lipid-lowering effect of the polyphenols (Hayek et al 1997, Waddington et al 2004). Beneficial immune responses have been shown in human endothelial cells upon exposure to anthocyanin metabolites at doses comparable to those found in plasma after blueberry and cranberry administration (Youdim et al 2002). One key transcription factor in obesity related inflammation is NF-kB. The effects of anthocyanins in inhibition of NF-kB has been studied in a human intervention study using a blackcurrant and bilberry supplementation product "Medox" with 300 mg/d (Karlsen et al 2007).

It appears therefore, that apart from acting on carbohydrate metabolic targets compounds present in medicinal plants alone or in combination, possess a variety of beneficial activities and have the potential to impart therapeutic effect holistically in complicated disorders like diabetes and its complications.

Barley grass consists of the young green leaves of the barley plant. Barley grass is available commercially in dried and powdered form prepared from the whole leaves or juice obtained by milling the leaves. A wide spectrum of vitamins, minerals, amino acids, have been isolated from barley grass. Barley grass contains abundant chlorophyll, antioxidants, antioxidant enzymes, and other phytochemicals that neutralize free radicals. Many claims have been made regarding the health benefits of barley grass supplements. Suggested benefits include prevention and cure of cancer, treatment of HIV infection, cholesterol lowering, detoxification of pollutants, protection against solar and other forms of radiation, and boosting energy and immunity. However, objective evidence supporting many of these claims is lacking.

According to available literature one of the active ingredients present in barley grass is proanthocyanidin. Proanthocyanidins are secondary plant metabolites having substantial antioxidant activity. They are prevalent in some foods and dietary supplements including several berries, red grapes and their wines, and seeds, baking chocolate, cinnamon, pycnogenol, and *Ginkgo biloba*. Several types of investigations support improved vascular health after short- or long-term consumption of proanthocyanidins or foods and supplements that contain them. These effects include vasodilation, presumably as a result of increased NO production, decreased platelet aggregation, reduced sensitivity of low-density lipoproteins (LDL) to oxidation, and modulation of several reactions associated with inflammation.

The French have one of the lowest incidences of coronary heart disease in the Western world despite a diet with a relatively high fat content. This phenomenon that has puzzled researchers worldwide for more than a decade is known as the 'French paradox' and has been linked to the high consumption of red wine in France. Red wine is rich in the complex polyphenols, the proanthocyanidins (Renaud & de Lorgeril 1992). These compounds have recently attracted attention as potential cardiac-protective compounds.

A study by Tomaru et al (2007) examined whether dietary supplementation with cacao liquor proanthocyanidins (CLPr) could prevent elevation of blood glucose levels in mice with diabetes mellitus and obesity. Diabetic obese mice and control mice were fed a diet containing 0%, 0.5% and 1.0% (w/w CLPr) from age 3 wk to age 6 wk. In the diabetic obese mice, a diet containing 0.5% or 1.0% CLPr decreased the levels of blood glucose and fructosamine compared with that containing 0% CLPr. The findings suggested that dietary supplementation with CLPr can dose-dependently prevent the development of hyperglycemia in diabetic obese mice.

Grape seed proanthocyanidin extracts are known to exhibit a broad spectrum of chemopreventive and cardioprotective properties against oxidative stress. In a study, the efficacy of grape seed proanthocyanidin extract (GSPE)

supplementation in hamsters fed a high cholesterol diet was examined. Atherosclerosis (% of aorta covered with foam cells) was reduced by approximately 50% and 63% following supplementation of the animals with 50 mg/kg and 100 mg/kg of GSPE, respectively. GSPE exerted a pronounced effect on the cholesterol, and triglyceride levels, as well as oxidative lipid damage. This data demonstrates that GSPE may provide significant health benefits by dramatically ameliorating the incidence of atherosclerosis as demonstrated by reducing the formation of foam cells (Vinson et al 2002).

A clinical trial in healthy human volunteers found that daily intake of 36 g of cocoa powder (containing 2610 mg of polyphenols) rich in proanthocyanidins for a period of two weeks reduced the susceptibility of low-density lipoproteins to oxidation (Osakabe et al 2001).

The cholesterol-lowering effects of barley grass have been attributed to the β-sitosterol fractions of barley leaf extract. Beta-sitosterol is a phytosterol or plant sterol. The structure of beta-sitosterol is similar to that of cholesterol. Beta-sitosterol is mainly known and used for its cholesterol lowering property. Regular intake of beta-sitosterol may reduce blood cholesterol levels by directly inhibiting the absorption of cholesterol. Beta-sitosterol also prevents the oxidation of LDL cholesterol thereby reducing the risk of atherosclerosis. It was recognized in the 1950s that plant sterols lower serum concentrations of cholesterol (Best et al 1954). Beta-sitosterol also prevents the oxidation of LDL-C thereby reducing the risk of atherosclerosis. Previous evidence shows that intake of 2 g/d of stanols or sterols reduced LDL-C by 10% (Katan et al 2003).

Vivancos and Moreno (2008) found that a synergistic action of polyphenols from olive oil and wine and beta-sitosterol led to the modulation of the effects of oxidized LDL on oxidative stress and prostaglandin E2 synthesis. It was observed that resveratrol and tyrosol revert H_2O_2 production, arachidonic acid release and PGE_2 synthesis induced by oxLDL. The presence of β-sitosterol was found to enhance these polyphenol actions.

When the intestinal absorption of cholesterol was compared with different plant sterols in 10 healthy subjects by an intestinal perfusion technique a negative correlation was found between the ratio of sitosterol to cholesterol and the mass of cholesterol absorption (Heinemann et al 1993).

In a study by Heinemann et al (1991) where the effects of two different plant sterols on intestinal cholesterol absorption were compared in normal volunteers by an intestinal perfusion study it was found that overall, cholesterol absorption declined during sitosterol infusion by almost 50% whereas sitostanol infusion caused a reduction of cholesterol absorption by almost 85%.

Tree nuts have a fatty acid profile that favourably affects blood lipids and lipoproteins. They are low in saturated fat and high in unsaturated fatty acids. Nuts also contain many nutrients and bioactive compounds that appear to contribute to the favourable effects on lipids and lipoproteins – these include plant sterols, dietary fibre and antioxidants. Because of their unique nutrient profile, nuts can be part of a diet that features multiple heart-healthy foods.

Pistachio nuts are rich in monounsaturated fat and phytosterols (199 mg of β - sitosterol/100g of nuts). Sheridan et al (2007) studied the effects of consuming 15% of the daily caloric intake in the form of pistachio nuts over a four week period on the lipid profiles of free-living human subjects with primary, moderate hypercholesterolemia. On the pistachio diet, statistically significant reductions were seen in TC/HDL-C, LDL-C/HDL-C and a statistically significant increase was seen in HDL-C. Similar results have been obtained by other studies (Edwards et al 1999 and Kocyigit et al 2006)

It has been documented that impaired homeostasis in diabetes mellitus is associated with increased production of reactive oxygen species and depletion of the antioxidant defense systems. Barley grass is purported to be rich in the antioxidant vitamin C. In the EPIC – Norfolk prospective study plasma ascorbic acid concentration was found to be inversely related to mortality from all-causes, and from cardiovascular disease, and ischemic

heart disease in men and women (Khaw et al 2001). Another study which examined the relation between vitamin C intake and risk of coronary heart disease in women found users of vitamin C supplements to be at a lower risk for coronary heart disease (Osganian et al 2003).

Few studies have reported the beneficial effects of barley grass. Yu et al, (2002) investigated the antioxidative and hypolipidemic effects of barley leaf essence (BL) in a rabbit model of atherosclerosis. Rabbits receiving the BL supplement (1% (w /w)) in combination with an atherogenic diet demonstrated reductions in plasma levels of serum triacylglycerol, total cholesterol, and low-density lipoprotein cholesterol compared with animals on the atherogenic diet alone. Histological examination of the thoracic aorta of these rabbits supported the findings in that atherosclerotic lesions covered 90% of the surface in animals fed only the atherogenic diet compared with 60% in animals receiving barley leaf extract plus an atherogenic diet. The lucigenin-CL and luminol-CL levels in whole blood were lower in the BL group than in the control group. The value of T50 of red blood cell hemolysis and the lag phase of low density lipoprotein oxidation increased in the BL group compared to the controls.

The major flavonoid antioxidants in young green barley leaves are the flavone-C glycosides, saponarin and lutonarin (Markham & Mitchell 2003). Natural plant flavonoids, saponarin/lutonarin, isolated from young green barley leaves were examined for their antioxidant activity using cod liver oil, ω-3 fatty acids (EPA and DHA), phospholipids (lecithin I and II), and blood plasma. The saponarin/lutonarin (S/L) mixture inhibited malonaldehyde (MA) formation from cod liver oil, ω-3 fatty acids, phospholipids and from blood plasma. The antioxidant activities obtained from the S/L mixture were comparable to those obtained from α-tocopherol and butylated hydroxy toluene (BHT) in all lipids tested (Benedet et al 2007).

In another study, 36 type 2 diabetics were randomly assigned to receive daily supplements of young barley leaf extract (BL, 15 g), a combination of 200 mg each of vitamin C and E (CE) or a combination of young barley leaf extract

and vitamins C and E (BL+CE) for four weeks. Supplementation with BL was found to reduce the plasma levels of TC and LDL-C. The vitamin E contents in B-LDL (large, buoyant LDL molecules) and Sd-LDL (small, dense LDL molecules) were increased significantly following supplementation with each antioxidant treatment. Lag times of B-LDL and Sd-LDL increased significantly at week 4 as compared to week 0 in all three groups. It was also observed that BL decreased lucigenin- chemiluminescence and luminol-chemiluminescence levels in blood. These results suggested that the production of oxygen free radicals was effectively inhibited by BL. The ability of BL to scavenge free radicals was postulated to have been derived from its polyphenolic structure (Yu et al 2002).

The effect of young barley leaf extract and adlay on plasma lipids and LDL oxidation was studied in forty hyperlipidemic subjects, smokers and non smokers. Subjects received 15 g young barley leaf extract (BL) or 60 g adlay daily for four weeks. Plasma TC and LDL-C were significantly decreased in both BL and adlay groups, while HDL-C concentrations increased in the BL but not the adlay group. Furthermore, the lag phase of LDL oxidation increased after either supplementation. However, it was observed that BL had stronger antioxidative effect on the prevention of LDL oxidation than adlay. The results also indicated that the antioxidative effect was less pronounced in smokers than in non-smokers (Yu et al 2004).

Our study is also in line with the above findings where it was found that BGP supplementation for a period of two months brought about a significant favourable change in the carbohydrate and lipid metabolism of the T2DM subjects.

The risk of complications in patients with type 2 diabetes is strongly associated with hyperglycemia. In our study supplementation with BGP brought about a 5.2% reduction in HbA1c levels. The UKPDS 35 (Stratton et al 2000) reported that each 1% reduction in updated mean HbA1c was associated with reductions in risk of 21% for any end point related to diabetes, 21% for death related to diabetes, 37% for microvascular complications, 43%

for amputations and death from peripheral vascular disease, 14% for myocardial infarction, 12% for stroke, and 16% for heart failure. Thus, any reduction in HbA1c is likely to reduce the risk of complications.

From available literature barley grass contains many bioactive components such as β-sitosterol, proanthocyanidins, saponarin/lutonarin alongwith other components. The mixture of components may have modulated the carbohydrate and lipid metabolism in stable type 2 diabetics towards a favourable side.

With a control group, none of the subjects being on lipid lowering medication and no significant dietary changes noted before and after supplementation, our data indicate that improvements in lipids may be due to barley grass powder per se. Barley grass thus, has the potential to be used as a functional food. Figure 4.19 summarizes the salient observations of the study.

Looking into the hypolipidemic and hypoglycemic effects of BGP supplementation, further research needs to incorporate BGP into common recipes and to study its impact on carbohydrate and lipid metabolism. Also longer trials with BGP can be carried out to substantiate the evidence furnished by our study.

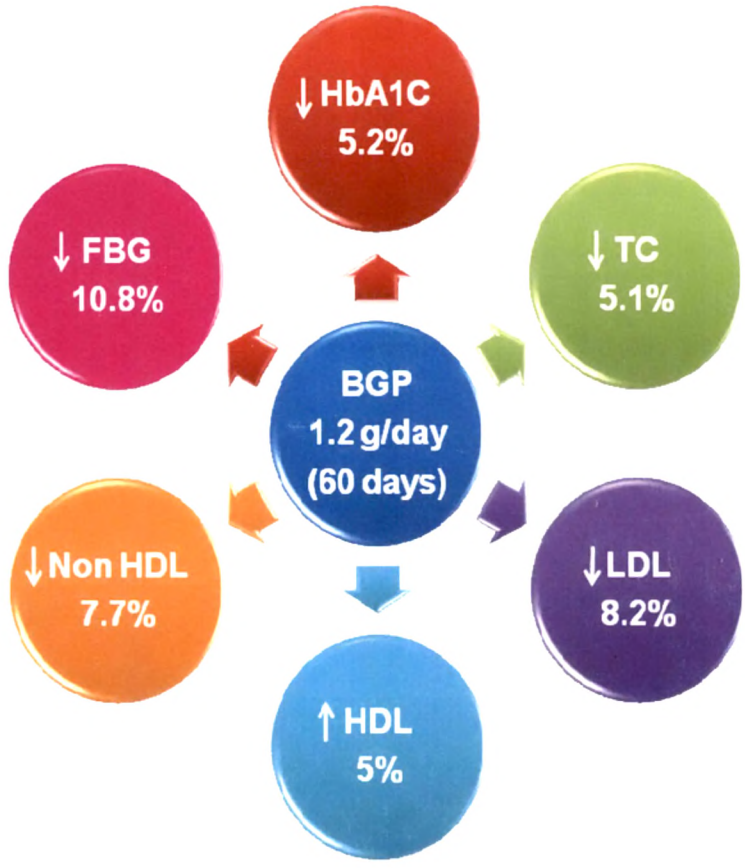
In our study, subjects consumed 1.2g of BGP daily which is equivalent to approximately 11g of barley grass. Our study findings add to the scientific basis supporting the cardioprotective role of barley leaf extract and/or barley leaves. Since plant foods are natural sources of phytosterols, supplementation of concentrated barley grass powder may be a novel approach to lower cardiovascular risk factors among T2DM subjects.

SALIENT OBSERVATIONS OF THE STUDY:

1. There was a significant fall in the FBG and HbA1C values in the experimental group with supplementation of BGP.

FIGURE 4.19

SUMMARY OF SALIENT OBSERVATIONS-BGP IMPACT STUDY



2. With BGP supplementation significant reductions in TC, LDL-C and Non HDL-C and increase in HDL-C levels were noted.
3. After 2 months of supplementation normal levels of FBG, TC and TG were attained by 25%, 21.4% and 21.4% subjects respectively.
4. Around 30-40% of the subjects showed improvements in glycemic and lipemic status after BGP supplementation.

Looking at the hypoglycemic and hypolipidemic effects of BGP future research needs to:

1. To look into the effect of BGP supplementation for a longer duration on the glycemic, lipemic and antioxidant status of T2DM subjects.
2. To incorporate BGP into various household recipes and to study their impact on carbohydrate and lipid metabolism.
3. To carry out in depth analysis of the active ingredients of barley grass to expand the clinical utility of barley grass in other conditions.

SUMMARY:

We feel that BGP has the potential to be marketed as a neutraceutical product to optimize the health of diabetic subjects. The cost of barley grain is Rs. 35/Kg. Therefore, advocacy measures to promote barley grass cultivation at household level and to incorporate fresh barley grass in various recipes should be encouraged as a cost effective health promotion strategy. With its hypoglycemic and hypolipidemic action BGP may be used as a supportive therapy in T2DM.

PHASE IV (b): TRANSLATIONAL RESEARCH: SCALING UP OF A BARLEY GRASS POWDER (BGP) FOOD PRODUCT (KHAKHRA) FOR CONSUMERS AT LARGE

In the field of food production, consumer demands have changed considerably in the last few decades. Consumers have started believing more in the direct contribution of food to their health (Mollet and Rowland 2002). Apart from satisfying hunger and providing necessary nutrients foods today are also intended to improve physical and mental well-being of the consumers and prevent nutrition-related diseases (Menrad 2003, Roberfroid 2000). Functional foods, in this regard, play an important role.

Typically, a food marketed as a functional food contains added, technologically developed ingredients with a specific health benefit (Niva 2007). Functional food development and marketing is a multistage process that requires input from commercial, academic and regulatory interests, with a critical need to achieve acceptance by the consumers (Jones and Jew 2007).

From the consumer point of view, the success of functional foods relies on a number of inter-relating factors, including the level of concern about general health and different medical conditions, the belief that it is possible to influence one's own health and awareness and knowledge of foods/ingredients that are supposed to be beneficial. Consumers are also increasingly reflective in matters of health and willing to adopt health-oriented changes in their eating habits (Niva 2007).

Based on the success with BGP product development and clinical trials in T2DM, we made an attempt to scale BGP khakhras. The BGP khakhras were prepared in bulk and kept in one of the health clubs in Vadodara (VLCC). The khakhras were distributed to 45 members of the club for sensory evaluation and acceptability. The feedback taken from the members were on the following aspects:

1. Taste of the BGP khakhra

2. Colour
3. Willingness to buy the product (if available in the market)
4. Maximum number that can be eaten at one time

The findings revealed the following observations:

1. Majority of the respondents (88.9%) liked the taste of the BGP khakhras.

2. Around 91.1% of the respondents found the green colour of the BGP khakhras to be acceptable.

3. Majority of the respondents (97.8%) reported that they would buy the BGP khakhras if they were to be available in the market.

4. About 51.1% of the respondents reported that they could consume 2 khakhras at one time and another 13.3% of the subjects reported that they could have upto three khakhras at one time.

BGP supplementation at the level of 1.2 g/day showed beneficial lipemic and glycemic effects. Each khakhra contained 1g of BGP. Thus the intake of a minimum of two khakhras would measure upto the amount of BGP that showed beneficial effects.

In view of these observations we feel that BGP khakhras can be scaled for consumers. Attempts in this direction are being worked out to commercialize BGP as a functional food for optimizing the health of the general population.