Summary and Conclusions
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India is experiencing a rapid health transition, with large and rising burdens of chronic diseases, which are estimated to account for 53% of all deaths and 44% of disability-adjusted life-years (DALYs) lost in 2005. Earlier estimates, from the Global Burden of Disease Study, projected that the number of deaths attributable to chronic diseases would rise from 3.78 million in 1990 (40.4% of all deaths) to 7.63 million in 2020 (66.7% of all deaths) (Murray and Lopez 1996). Many of these deaths occur at relatively early ages. Compared with all other countries, India suffers the highest loss in potentially productive years of life, due to morbidity and mortality from NCDs. These advancing epidemics are propelled by demographic, economic, nutritional and social factors, of which urbanization, industrialization, and globalization, are the main determinants. The Indian economy is growing at 7% per year. With increasing life expectancy, the proportion of the population older than 35 years is expected to rise from 28% in 1981 to 42% in 2021 (Reddy 1993). The proportion of people in urban residence, presently around 30%, is expected to rise to about 43% in 2021. During the decade 1991–2001, the population grew by 18% in the rural areas and 31% in urban regions (Census of India 2001). Urbanization and industrialization are changing the patterns of living in ways that increase behavioural and biological risk factor levels in the population. Substantial variations exist between different regions, but risk levels are rising across the country, most notably in urban areas of demographically and economically more advanced states of India.

An excess risk of death and disability from NCDs has been observed in men and women of South-Asian origin, by comparison with other ethnic groups, and there is a progressive rise in the risk from rural to urban to migrant environments (Bhatnagar et al 1995, Patel et al 2005). The increased risk of cardiovascular problems noted in Indian migrants is a portent of the further rise in risk that Indians are likely to experience alongside the developmental transition of their country. A high frequency of diabetes, central obesity, and other features of the metabolic syndrome (especially the characteristic dyslipidemia of reduced HDL cholesterol and raised triglycerides) have been reported in migrant and urban Indian population groups.
Comparisons between migrant and non-migrant groups and rural and urban populations have also highlighted the importance of conventional risk factors like smoking, blood pressure, plasma cholesterol, and BMI (Reddy 1993, Bhatnagar et al 1995). India also has the highest prevalence of diabetes in the world, with an estimated 19.3 million in 1995 and projected 57.2 million in 2025 (King et al 1998). The prevalence of type 2 diabetes in urban Indian adults has been reported to have increased from less than 3.0% in 1970 to about 12.0% in 2000 (Ramachandran 2005). On the basis of recent surveys, the ICMR estimates the prevalence of diabetes in adults to be 3.8% in rural areas and 11.8% in urban areas. Thus, diabetes is a major cause of prolonged morbidity and premature death.

The constantly rising prevalence of NCDs makes an effective case to endorse their prevention and control, especially, type 2 diabetes poses a major public health challenge for the Indian health sector in the 21st century. At the population level, programs for prevention and control should ideally involve a judicious mix of (a) Promoting physical activity and regular exercise (b) Health promoting diet (Energy Intake; moderation in the intake of saturated fat, salt, and refined sugar; increasing intake of fresh fruit and vegetables; fish in preference to red meat in non-vegetarian diets) and (c) Use of dietary supplements, functional foods, plants and their derivatives. These approaches have singularly or in a combination shown to be beneficial for a wide range of NCDs like CVD, diabetes, hypertension, cancer, etc. In this study, we have attempted to look at the efficacy and effectiveness of novel NCD prevention as well as a NCD management program using the above mentioned techniques.

Main treatment goals of type 2 diabetes are maintenance of good metabolic control, prevention of complications and improvement of quality of life. Exercise is known to improve glycemic control and overall health, thus it is a vital component in the triad of diabetes management. Developed countries have conducted successful trials and interventions modifying physical activity behaviour to manage type 2 diabetes, but such studies based in the Indian scenario are scanty. Thus, there is a need to study the pathobiochemistry of the disease to generate information to design new management strategies specific to the Indian population. This prompted us to study the pathobiochemistry of diabetes and development of secondary complications using a battery of Clinico - biochemical parameters and study the influence of physical activity on the disease.
Phase 1

Diabetes mellitus is a metabolic disorder that precipitates when there is glucose intolerance due to defective action and/or secretion of insulin, which is responsible for an array of associated derangements and altered fuel utilization. Hyperglycemia, is the clinical manifestation of the disease, and the same triggers off a cascade of metabolic imbalances from cell to organ level that potentially accelerate the development of secondary complications that include progression of vasculopathies (micro and macro) in diabetic patients.

Exercise along with medication and diet is considered one of the vital cornerstones of diabetes care programs (Thomas et al 2009, Marwick et al 2009). Physicians and healthcare workers generally consider it the patient's personal responsibility to increase physical activity levels. Despite a substantial body of evidence showing the benefits of exercise, its clinical application is still underrated and underutilized. Thus, we planned to study the role of physical activity or exercise in pathophysiology and pathobiochemistry of diabetes. Metabolic control has direct repercussions on the precipitation of secondary complications of diabetes, as literature suggests that exercise improves glycemic control thereby, reducing the occurrence and severity of complications, the study also looked into the influence of physical activity on the development of vasculopathies.

In order to assess the effect of physical activity on diabetics and to explore its interrelation with diabetes-related complications a retrospective cross-sectional study was designed. Two hundred and twelve, type 2 diabetics were enrolled from ‘Swasthya’, a tertiary care diabetic clinic based in Ahmedabad, Gujarat. On enrolment, one time data was collected on patient's history (age, gender, socio economic status, occupation, general habits, dietary practices, medical history, and treatment/medications) using a semi-structured questionnaire. Information was also elicited on self-reported physical activity (duration, frequency and type). The status of disease was assessed using a series of standard and specialized anthropometric, biophysical and biochemical tests. Complications of diabetes (Retinopathy, Neuropathy, Nephropathy and Cardiopathy) were diagnosed by specialized consultants. Both
incipient and overt signs and symptoms were combined to estimate the number of complications in each individual. The profile of the subjects was categorized based on different metabolic criteria, and also different statistical tests were employed to draw the following conclusions.

Subjects enrolled in the study were predominantly middle aged, and the mean age was 53.1 and 55.5 among males (n=134) and females (n=78) respectively and the mean duration of the disease was 7.5 yrs. Around 60% of the subjects were predisposed to diabetes due to their family history, and 30 – 35% were predisposed to hypertension and cardiovascular diseases. The nutrient intake revealed increased intake of fat in the form of fried snacks, along with reduced fruit and vegetable intake. Almost, 50% of the population consumed sweets despite their metabolic condition. The percent energy contribution of carbohydrates, fat and protein were 56.7%, 34.5% and 11.4% in males, and 57%, 34.9% and 11.6% in females respectively.

The anthropometric measurements of the subjects revealed 80% prevalence of overweight/obesity and an increased prevalence of abdominal obesity, wherein the incidence was higher in females. SBP was higher in both males and females. On an average glycemic control (FBS, PP2BS and HbA1c) was poor among all diabetics. Lipid indices (TC, LDL-C, VLDL, TG and TL) were also higher in this study group along with lower HDL-C levels. Tests conducted on a subsample revealed that Apo A1 levels were higher in females along with lower CRP levels. Males on the other hand had lower Apo A1 levels, and higher Apo B and CRP levels.

Clustering of obesity and hypertension has often been documented but the mechanisms interrelating these are unclear. Excess body fat has been implicated to increase insulin resistance which in turn predisposes the body to glucose intolerance and hypertension (Okosun et al 2001). Insulin resistance and hyperglycemia influence all lipid and lipoprotein fractions (Georg and Ludvik 2000).

We observed that glycemic control of a majority of subjects in this study was poor, thus the prevalence of secondary complications was high. The data revealed that percent prevalence of hypertension, dyslipidemia and CVD was 79.2%, 86% and 63.7% respectively. Prevalence
of other vasculopathies that include retinopathy, neuropathy, nephropathy and stroke were 17.9%, 19.8%, 25.5% and 3.8% respectively. Almost, 27.3% of the subjects were found to have non alcoholic fatty liver, usually this is associated with the use of insulin, but in this study it was found to be unrelated.

Subjects were classified under physically active and physically inactive categories based on CDC standards. The subjects in the physically active group were involved in some form of physical activity/exercise apart from routine chores for duration of 30 minutes or more for 5 or more days in a week in case of moderate intensity physical activity, or 20 minutes of vigorous intensity activity. By this classification around 60% of the subjects in this study were found to be sedentary or physically inactive (n=128), and the active group comprised of 84 individuals.

When the anthropometric, biophysical, biochemical and prevalence of secondary complications were compared for the physically active and inactive groups based on gender and different metabolic criteria we observed a typical pattern emerging, where, the physically active were found to have better metabolic status and control along with fewer complications as compared to their inactive counterparts. Each of these observations has been discussed in the following paragraphs.

The physically active group was found to have significantly lower WC, BMI, %fat, TC (p<0.05), VLDL (p<0.01), TG, TL (p<0.005), FBS, PP2BS and HbA1c (p< 0.001). A trend of lower weight, HC, SBP, LDL – C and MAU was also observed in the physically active diabetics. Diabetic complications of the subjects were pooled together to get a sum total of prevalent complications for each individual, average occurrences of these complications was found to be significantly lower (p< 0.000) among the active individuals. Apo A1, Apo B and CRP were analyzed in a sub-sample, and a trend of reduced Apo B and CRP was observed in the active group. Meta analysis of previously conducted RCTs has reported that exercise interventions can significantly lower glycated hemoglobin, visceral adipose tissue and plasma triglycerides but not plasma cholesterol and blood pressure among type 2 diabetics even without weight loss (Thomas et al 2009).
The present study revealed that males experienced more beneficial effects of exercise as compared to females, the difference could be due to the higher duration and intensity of exercise. Males performing physical activity were found to have significantly reduced weight, BMI, WC (p<0.05), FBS, PP2BS (p<0.001), HbA1c (p<0.000), VLDL (p<0.05), TG, TL (p<0.001) and MAU (p<0.05). Females also exhibited a reduction in anthropometric, biophysical and biochemical parameters, all changes except TL (p< 0.05) were non significant.

Obesity serves a standard predictor of diabetic status (Daniel 1999). Thus, the influence of exercise was studied based on BMI (South Asian standards). Although, normo-weight individuals experience benefits in terms of reduced anthropometric, biophysical and biochemical parameters especially significantly lower TL (p< 0.05), but the effect was more pronounced among the active overweight / obese diabetics. Physically active diabetics displayed significantly lower BMI (p<0.05), blood glucose (p< 0.000), HbA1c (p< 0.000), VLDL, TG (p<0.05) and TL (p<0.01) levels, and a trend of lower MAU, TC, LDL – C.

In the present study, 68 % of the males and 85% of the females were abdominally obese. Abdominal obesity causes increased insulin resistance and reduced insulin sensitivity and is an independent risk factor for cardiovascular events (Klein et al 2007). Physically active diabetics irrespective of gender displayed a trend of improved anthropometric, biophysical and biochemical indices.

Chronic hyperglycemia is the key factor responsible for the development of secondary complications of diabetes (Rossetti 2002). Hence, the subject’s clinical profile was looked into based on glycated hemoglobin which is a long term glycemic control marker and influence of physical activity on various parameters based on good, fair and poor control of diabetes. Although, all groups showed a positive trend in terms of anthropometric, biophysical and biochemical markers, but in the poorly controlled group VLDL, TG and TL were significantly (p<0.05) lower.

It has been established that longer the disease has been present; the greater is the likelihood of having complications (Constantini 2005). In the current study too, a strong correlation
(p<0.01) was observed between duration and number of complications observed. Physically active subjects with duration < 5 years were found to have a trend of reduced Weight, WC, BMI, MAU, HbA1c, TC, LDL – C, VLDL and TG and significantly lower FBS (p<0.05), PP2BS (p<0.001) and TL (p<0.05) levels. In the second group (duration 5 – 10 yrs), the physically active group was found to have significantly lower WC, SBP, DBP, FBS, PP2BS, HbA1c (p<0.05) and marginally reduced lipid indices. Physically active diabetics with duration greater than 10 years were found to have better anthropometric and biochemical profile with the TG, VLDL and TL levels significantly lower (p<0.005) than the inactive group. However, among the physically active diabetics irrespective of duration, average number of diabetic complications was lower than the inactive group and the difference was significant at p < 0.01 even with longer duration of disease (>10 yrs).

Subjects were categorized based on the number of complications present, and a similar trend was observed where the physically active were metabolically under better control as compared to the inactive group. The active group with less than three complications had significantly lower PP2BS (p< 0.005), HbA1c, VLDL, TG and TL (p<0.05) as compared to sedentary diabetics with similar number of complications. The anthropometric, biophysical and biochemical profile of the diabetics with three or more complications was more aberrated as compared to the diabetics with fewer complications. Thus, the magnitude of health benefits observed due to physical activity were also found to be higher as the physically active group with three or more complications displayed significantly lower weight (p<0.05), WC, BMI (p<0.01), PP2BS (p< 0.005), FBS, HbA1c (p<0.05), TG and TL (p< 0.05) levels as compared to their inactive counterparts.

In the present study, the occurrence of secondary complications was found to be significantly influenced by whether an individual is physically active or not (p< 0.005) by chi square test. We observed that as the glycemic control deteriorated there was an increase in the number of complications. Another interesting observation was that a pattern of complication prevalence appeared, where at similar glycemic control the physically active individuals were suffering from lesser number of complications. As a relationship between physical activity and occurrence of complications was established, the strength of association was analyzed using chi square test and Odds ratio. Prevalence of
Retinopathy ($p < 0.000$) and Neuropathy ($p < 0.05$) were found to be significantly associated
with physical inactivity and weak associations were observed between dyslipidemia ($p = 0.06$) and nephropathy ($p = 0.08$). By Odds ratio physically inactive diabetics were found to
have higher chances of developing Dyslipidemia (OR = 2.08), Retinopathy (OR = 6.67),
Neuropathy (OR = 2.21), Nephropathy (OR = 1.44) and Stroke (OR = 2.12). Associations
between Hypertension (0.98) and CVD (0.98) with physical activity could not be statistically
ascertained.

Thus, a role of confounding variables (based on previous literature) was suspected which
were assessed using simple statistical techniques. The occurrence of hypertension was
significantly influenced by weight ($p <0.01$), BMI ($p < 0.01$), WC ($p < 0.000$). CVD
occurrence was significantly affected by weight ($p < 0.05$), BMI ($p < 0.05$), WC ($p < 0.05$),
body composition / % fat ($p < 0.005$), TC ($p = 0.05$) and TL ($p < 0.05$). WC ($p < 0.05$) and
BMI ($p < 0.01$) were the variables affecting the precipitation of dyslipidemia among
diabetics.

The type of association of physical activity with the other variables like WC, BMI, % Fat,
FBS, PP, HbA1c, TC, VLDL, TG, TL and number of complications was determined by
correlation. These variables were also found to be significantly related to physical activity by
ANOVA. We also found a significant negative correlation between physical activity and all
these variables. Prevalence of complications was found to be related to the duration of the
physical activity performed ($p< 0.05$). The degree of influence of the independent variable
(physical activity) to the dependent variables was determined using multivariate analysis. We
noticed that physical activity would have a significant impact on occurrence of complications,
glycemic control, and a modest but significant impact on abdominal obesity and lipid indices (VLDL, TG and TL). BMI ($p = 0.07$) and TC ($p = 0.09$) were affected by
performance of physical activity but it was not statistically significant.

Extrapolation of the data to predict risk that physically inactive individuals are predisposed to
are; a 5 % higher risk of developing stroke, 16% higher risk of nephropathy, 17% higher risk
of neuropathy and the risk of developing dyslipidemia was 88%. Hence, we can conclude
that those diabetics who were physically active were found to have a better metabolic profile
in terms of anthropometric, biophysical and biochemical parameters. As physical activity has a significant impact on acute and chronic hyperglycemia, it could help retard the occurrence of secondary complications, thereby preventing premature death and disability and improving the quality of life.

**Salient features of the study**

- Physically active diabetics had a better anthropometric and biochemical profile as compared to the physically inactive diabetics.
- The average prevalence of secondary complications was also found to significantly lower as compared to their inactive counterparts.
- The benefits of exercise/physical activity were more pronounced in males.
- The benefits of exercise/physical activity were more pronounced among diabetics with higher risk groups like overweight/obese, abdominally obese, poor glycemic control etc.
- Duration of the disease was found to be significantly correlated with the number of complications present. In the same range of duration the average number of complications occurring in active diabetics was lower.
- Occurrence of diabetic complications was significantly related to glycemic control. But, physically active diabetics with similar glycemic control as their inactive counterparts had lesser complications.
- Occurrence of Retinopathy, Neuropathy and Nephropathy in diabetics is significantly propelled by physical inactivity.
- Physically inactive diabetics have significantly higher odds of developing Dyslipidemia, of Retinopathy, Neuropathy and Nephropathy.
- Role of confounding variables was indicated in the occurrence of hypertension and CVD due to which could not be linked entirely to physical activity.
- The confounding variables significantly influencing occurrence of hypertension were weight, BMI and WC. For CVD the confounding variables were BMI, WC, % fat, TC and TL. Dyslipidemia was influence by WC and BMI.
Various anthropometric, biophysical and biochemical parameters were inversely related to physical activity.

By multivariate analysis the dependent variables significantly influenced by physical activity identified were; occurrence of complications, glycemic control, abdominal obesity and lipid indices (VLDL, TG and TL).

Physically inactive diabetics are at a 5% higher risk of developing stroke, 16% higher risk of nephropathy, 17% higher risk of neuropathy and 88% risk of developing dyslipidemia.

As the results of the present retrospective study were positive, indicating exercise should be advised as an important aspect of diabetes management. Further, interventional studies could be carried out on the short term and long term effect of specific exercise programs, so that simple, convenient and cost effective modules may be developed to ensure sustenance throughout life. Also, studies specific to duration and intensity of physical activity must be carried out as each form of exercise delivers specific benefits in the body. Under explored variables that are exercise-related and have a strong patient focus like quality of life, attitudes of diabetics, cardiorespiratory health and reduction in health costs should be studied to give a holistic perspective about physical activity.

These results also reiterate that glycemic control achieved by any comprehensive strategy would help improve metabolic control among type 2 diabetics. Nutrition therapy has proven to be a cost effective strategy in achieving the formidable goal of glycemic control. This has sparked interest into food based approaches in tackling diabetes, which includes probiotics, antioxidants, nutraceuticals and designer foods. Plants are used to treat many ailments and India has about 45,000 plant species have been found to possess medicinal properties. Plants, as folk remedies, are widely used to treat diabetes mellitus however, in modern allopathic medicine their role is limited. Thus, searching for a novel antidiabetic drug from plants should be advocated, since plants are well recognized as an important source of providing new drugs. Keeping these aspects in mind a study was planned to study the efficacy of Gymnema sylvestre - a local herb in the dietary management of diabetes.
Phase 2

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. Lately a lot of emphasis has been given to nutritional therapy to manage diabetes, This uses food based approaches like, use of function foods, herbs, plants and plant derivates to alleviate the symptoms of diabetes and improve metabolic control.

*Gymnema sylvestre*, an Indian medicinal plant, has long been known to possess antidiabetic activities. It is popularly known in Hindi as 'gurmar' meaning sugar destroyer. This name is attributed to its sweet-taste suppressing property. Extracts of this plant have been reported to possess a variety of actions related to the antidiabetic properties like reduction in insulin requirement possibly by enhancing endogenous insulin availability, improving blood glucose homeostasis, better control of hyperlipidemia associated with diabetes (Sidiqui *et al* 2000, Shanmughundarm *et al* 1990). The pioneering studies using GS have been successful in demonstrating it beneficial effects, but human studies using sensitive parameters to assess the efficacy of the herb are scanty.

Hence, we planned a quasi experimental trial where, 58 subjects were enrolled from the free-living population in Vadodara. They were counselled about the benefits of GS and requisites of the study that the diet, physical activity pattern and drug usage during the study period should remain unaltered. Then, based on their willingness to participate in the trial the subjects were divided into two groups; control (n=19) and the experimental (n=39) group purposively.

The questionnaire was also used to elicit information and qualitatively assess the commonly occurring symptoms in diabetic patients before and after intervention. The experimental group was given 250 mg of *Gymnema sylvestre*, in the form of capsules to be consumed twice a day before meals for a period of three months. Their anthropometric, biophysical and
biochemical parameters were assessed thrice - at the beginning of the study (baseline), after 2 months (60 days) and after three months (90 days). The control group received no supplementation or placebo and their anthropometric, biochemical and biophysical parameters were assessed twice - at baseline and three months after enrolment.

The subjects in both the groups were found to have comparable characteristics. The average age of the control group was 53 (± 9.5) and experimental group was 56 (± 7.5). The average duration of the disease in the control and experimental group was 8.1 and 8.6 years respectively. The experimental group had higher tobacco, cigarette and alcohol usage. 79% of the controls and 72% of the experimental group were physically active, and the level of activity was unaltered during the study period. The nutrient profile of the subjects indicated that the nutrient intake was almost similar pre and post intervention barring a few minor changes. The control group had a marginally lower energy due to slightly decreased carbohydrate intake. In the experimental group the energy, fat and protein intake was marginally higher.

We observed that supplementation of Gymnema sylvestre not only improved the anthropometric, biophysical and biochemical profile, but was also effective in alleviating common symptoms of diabetes and reducing drug intake.

The medical and clinical data revealed that the percent prevalence of secondary complications like cardiovascular diseases (13%) and nephropathy (5.1%) did not change after intervention. On the other hand, in the control group the prevalence of cardiovascular diseases increased from 11 to 16%, and retinopathy increased from 5 to 11%, no change was observed in the prevalence of neuropathy (5%). After supplementation, 10.3% of the subjects from the experimental group were able to discontinue their conventional OHA therapy with their clinicians consent. On the other hand, 37% of the control subjects showed an increase in OHA, antihypertensive and statin drugs consumption. After intervention, the prevalence of fatigue in the experimental group reduced by 56.4%, and polyphagia and excessive hunger was suppressed in 21% of diabetics.
The anthropometric and biophysical parameters of the experimental group exhibited a shift towards better health profile, with a marginal reduction in weight, BMI, HC, % fat and significant decrease in WC (p<0.01), SBP (p< 0.001) and DBP (p< 0.05). The control group, on the other hand showed a significant increase (p<0.05) in weight, BMI, % fat and SBP. Animal studies have shown a reduction in weight in overweight and obese rats supplemented with GS extracts, due to inhibition of oleic acid absorption and the ability to lower triglycerides without any withdrawal or rebound symptoms (Luo et al 2006). Increase in visceral fat as indicated by waist circumference is an important component in development of insulin resistance (Goodpaster et al 2000). It is also a strong predictor of alterations in plasma lipids, lipoprotein, glucose concentrations, CHD and hypertension (Brochou et al 2000, DeNino et al 2001, Parikh et al 2002).

Active components of the herb like gymenemic acid and Conduritol A have been found to inhibit glucose absorption in the gut (Murakami et al 1996, Ishijima et al 2008, Miyatake et al 1993). In the current intervention study, a significant reduction was observed in the FBS (p< 0.005) and PP2BS (p < 0.000) which, consequently brought down the HbA1c levels (p < 0.000) significantly in the supplemented diabetic patients. The insulin values were higher during the second month of supplementation (15.5 ± 14.5), but were found to be comparable to the baseline (12.2 ± 10.0) levels at the end of the study. Significantly, lower G/I ratio (p< 0.01) indicates a decrease in insulin resistance, and increased I/G ratio (p= 0.15) indicates an improvement in the insulin secretion after supplementation. A decrease in insulin resistance was also indicated by homeostatic assessment of insulin resistance (HOMA IR) from 5.68 (± 4.9) to 4.81 (± 4.07), and increased β cell function as indicated by an increase in HOMA B values from 2.52 (± 2.26) to 3.03 (± 2.90) after supplementation.

Chronic oxidative stress due to hyperglycemia plays an important role in progressive β-cell dysfunction (Rossetti 2002). Therefore, improved glucose homeostasis as observed in this study may improve pancreatic cell function, insulin secretion and sensitivity.

It is vital that liver function is monitored during an herbal supplementation for assaying hepatotoxicity. In the present study, liver function improved and no case of hepatotoxicity
was observed. A marginal drop was observed in the liver enzymes (SGOT and SGPT) post supplementation.

A significant decrease in Apo B ($p<0.005$) and TG ($p<0.05$) levels, and a modest reduction in TC, LDL – C and L/H ratio was recorded along with a marginal rise in Apo A$_1$, indicating an improvement in the lipid profile of the subjects after supplementation. A significant improvement was reported in kidney function of the supplemented diabetics, as indicated by 47% lower MAU levels ($p<0.05$). Studies carried out among type 2 diabetics have established MAU as an integrated indicator for renal and cardiovascular risk (Araki et al 2007). Systemic inflammation is common among diabetics due to increased oxidative stress (Rossetti 2002), and is a strong predictor for cardiovascular events (Ridker 2003). A decrease in CRP levels was observed in the supplemented group in the present study.

The control group was found to have significantly higher FBS and HbA$_1c$ ($p<0.05$) as compared to baseline levels. After a period of ninety days no change was observed in the fasting insulin levels. These changes in the FBS and insulin resulted in a significant increase of HOMA IR levels ($p<0.05$) and elevated G/I ratio from an average of 31.1 to 34.0 indicating higher insulin resistance. All lipid indices including TC, LDL – C, HDL – C, except TG were found to be marginally lower in the control group in comparison to the baseline data. The MAU levels increased from 26.6 ($\pm$ 45.2) to 28.1 ($\pm$ 32.3), indicating although the levels are within normal limits there is deterioration in the metabolic profile.

These observations point towards improvement of the metabolic profile and reduction of metabolic risk of development of secondary complications among diabetics supplemented with Gymnema sylvestre.
Salient features of the study

- 21% reduction in the prevalence of polyphagia among the supplemented diabetics.
- 56.4% reduction in the prevalence of fatigue among the supplemented diabetics.
- Marginal reduction in the Weight, Waist Circumference, % fat and BMI in the supplemented group.
- A trend of reduction in Blood Pressure (SBP & DBP) in the supplemented group.
- Significant reduction in the Blood Glucose Levels (FBS & PP₂BS) and HbA₁c levels among the supplemented diabetics.
- Marginal reduction in insulin resistance and improvement in β cell function.
- Modest reductions observed in the atherogenic lipid indices like TC, LDL – C and L/H ratio.
- Absence of hepatotoxicity and improvement in SGOT and SGPT levels.
- Significant improvement in kidney function as indicated by MAU levels.
- Reduction in systemic inflammation due to reduction in inflammatory marker (CRP).

Health and medication costs due to diabetes have increased manifold over the past few decades and these costs have an increased bearing on both the family earnings as well as the countries economy. Thus, exploratory studies on different novel functional foods, plants and their derivatives efficacy and effectiveness studies need to be conducted. These herbal supplements like Gymnema sylvestre have immense potential to improve metabolic control in diabetes. Further, such novel therapeutic agents should be promoted by physician to popularize them amidst masses to ensure exploitation of their full potential.
Phase 3

As chronic disease epidemics gather pace in India and threaten to harm individuals, families, and the society at large, a comprehensive strategy for their prevention and control is needed. Some of the required elements are already in place, such as control programmes for tobacco use and cancer. In other areas, such as diet and physical activity, the process must move from contemplation to action. Health systems need to be reoriented to accommodate the needs of chronic disease prevention and control, by enhancing the skills of health-care providers and equipping health-care facilities to provide services related to health promotion, risk detection, and risk reduction.

Demonstration projects of health promotion and chronic disease risk reduction are in progress, in both community and industrial settings. School-based and workplace based projects have evolved successful models of health promotion (Reddy et al 2003, Toh et al 2002, Mani et al 2005, Prabhakaran et al 2009). Experiences from such projects will strengthen the design and delivery of a national program for chronic disease prevention and control.

The need of the hour is Health Promotion Programs targeting the inevitable requirement to create awareness and educate the masses about chronic NCDs, and lifestyle behaviour change among the individuals especially in terms of diet and physical activity. Keeping these aspects in mind a special multifaceted workplace nutrition health awareness program was designed to create awareness and promote healthy eating practices and physical activity. The study was planned in two stages to cater to the non executive at the factory site and executive staff at the head office of the same industry. The idea of designing two separate custom-made programs was to provide an intervention that would lead to sustainable behavioural change and at the same time takes into consideration aspects like the level of education, time on hand, access to modern technology, touring, area availability, etc. The study was designed to impart education on Diet and Exercise to create Awareness and constantly Reinforce it and baptized as DEAR study.
Stage 1

This stage of the DEAR study was designed especially for the non executive, non managerial staff of the industry. These employees were educated and their place of work was static. There was adequate space in the factory area, thus special exercise programs and lectures could be organized. This intervention was organized for the employees and their spouses. The key components of this study were; a) Building social awareness and support for new behavioural patterns in diet, physical activity and personal habits b) Behavioural reinforcement through constant reminders c) Setting goals for supervised focused physical activity and regular monitoring d) Structured problem solving geared for maintenance of behaviour change e) Prevention of relapse into sedentary behaviour f) Capacity building of an individual and organization to ensure sustained benefits and compliance.

For the study all the employees and their spouses were enrolled. Baseline data regarding the Socio Economic Status (SES), Knowledge Attitude and Practices (KAP), Medical history, Dietary consumption, Food frequency and Physical activity pattern was elicited using a semi structured questionnaire. A health camp was then organized to collect anthropometric measurements, biochemical and biophysical data. The data was analyzed and the risk factors were identified, and the employees and their spouses were given personal counselling on their current health status. Nutrition Health Education (NHE) was then imparted to the subjects using the following media; (a) Seminars (b) Focused physical activity (c) Practical sessions (d) Educational material. The NHE was given in the local dialect. Physical activity was promoted by creating a walking track within the industrial campus where, the employees were made to walk briskly for 30 minutes, 6 days a week. The physical activity was focused and supervised. After 3 months of nutrition health education the medical history, anthropometry, dietary consumption, physical activity pattern, biophysical and biochemical data were collected. After a wash out period of one year the anthropometric, biophysical and biochemical data of the employees was reassessed.

The employees (males) were high school educated with technician degree and belonged to the middle income group. Majority of their spouses (females) were high school educated and...
housewives. The mean age of males and females was found to be 39 (± 7) and 35 (± 5) years respectively. Both the employees and their spouses were found to have a strong family history of NCDs as a predisposing risk factor. 8.3% of the males were previously detected hypertensives and 4.2% were diagnosed with cardiovascular anomalies and were not on any medications. However, after the health camp the actual percent prevalence of NCDs was found to be much higher. In males 70.8% were overweight/obese, 50% had abdominal obesity, 38% hypertensive and 91.7% dyslipidemics. Females also reported a high prevalence with 53% overweight/obese, 33 % abdominally obese and 40 % dyslipidemic individuals.

With respect to personal habits 54.2%, 37.5% and 45.8% males were found to be tobacco chewers, smokers and alcohol consumers respectively. After intervention, the percent prevalence of substance abuse came down substantially to 33.3%, 20.8% and 8.3% respectively. 25% males were found to be physically inactive, 45.8% indulged in 10-15 min of activities like leisure walking, stretching, etc. 25% of the individuals were using cycles for transportation or involved in physically exertive jobs. Post intervention, they included some form of physical activity (like walking, yoga, stretching exercises) to their routine, apart from the regular brisk walk carried out at the company. Females routinely performed household chores (sweeping, mopping, washing, etc.) manually. After intervention, they decreased sedentary activities like TV viewing and included regular walks and stretches in their daily schedules.

Analysis of the nutrient intake revealed that the diets of both males and females were deficient in fruit, vegetable and milk consumption, but the oil, sweet and fried food consumption was alarmingly high. The diets were found to be energy dense and high in fats and carbohydrates, but the protein intake was close to RDA. Post intervention, fat and energy consumption reduced significantly (p < 0.05). The reason for higher caloric intake of men was determined by a situational analysis of the canteen menu where, the dietary composition was found to be faulty. The menu was revised to make it more wholesome by reducing oil usage, fried foods served and increasing use of vegetables, salads, buttermilk and low sodium salt.
KAP of the subjects revealed a significant change in the knowledge regarding health and healthy eating practices among both males and females (p < 0.000). Consequently, changes in dietary practices was observed as there was an increased consumption of fruits (51.3%), vegetables (56.4%) and milk (38.5%) was reported along with reduction in oil and ghee (60%) and sugar (53.8%) consumption. There was also a 69.2% reduced fried food consumption while 25% stopped it completely and 97.4 % reduced sweet intake. Red meat consumption was either decreased (12.5%) or stopped (81.3%). Reading practices improved in both the groups.

After the focused physical activity intervention, energy expenditure of males was found to be significantly higher (p<0.001). 66.7% females initiated some form of physical activity after NHE still, the energy expenditure was found to be marginally lower due to the lower BMR levels observed in this group. After intervention, the subjects reported an optimal health status which included a better sleeping pattern, increased mental alertness, better bladder and bowel status and reduced fatigue and ailments. Physical discomforts due to work posture like stiffness of back, shoulders and neck reported by males reported improvement after instruction and practice of stretching exercises.

Post intervention, males were found to have significantly lower weight (p< 0.05), WC (p< 0.000), HC (p< 0.005) and SBP (p< 0.05) along with a trend of reduced BMI, % fat and DBP. Females had significantly reduced WC (p< 0.05) and HC (p< 0.005) along with modestly lower weight, BMI, % fat, SBP, DBP. Reduction in WC with or without change in weight or BMI is known to bring about a reduction in insulin resistance and cardiometabolic risk (DeFronzo et al 1996, Yusuf et al 2005). An increase in BMI is associated with increased TG and LDL- C levels while HDL – C decreases (Austin and Selby 1995), thus a reduction in BMI would bring about a reduction in TG and LDL – C levels.

We also observed a concomitant improvement in the biochemical data where, FBS was significantly lower in both males (p< 0.000) and females (p<0.005). After intervention and HbA₁c levels in females were significantly decreased (p<0.005) but no such change was observed among males. Subjects also displayed a trend of lower insulin, TC, LDL-C, Non HDL-C and TG levels, wherein LDL – C levels (p< 0.05) in males were significantly
reduced. HOMA IR indicating insulin resistance was significantly lower, and HOMA B indicating increased β cell function was significantly improved in males (p< 0.000). HOMA B levels were significantly higher in females (p< 0.000) but insulin resistance was only marginally reduced post intervention. These positive shifts in anthropometric, biophysical and biochemical parameters were more pronounced in the high risk groups like the overweight/obese, hypertensives and dyslipidemics.

Efficacy of the program was assessed for the males after a one year period during which no intervention or reinforcement was given. The results revealed that the anthropometric parameters like weight, BMI and WC and a favourable biochemical profile was maintained. The consequences of NCDs on health and economy of individuals and nations have been emphasized time and again. Thus, prevention is the key to improve quality of life of the population. This intervention focused on prevention of NCDs by bringing about modifications in lifestyle practices, diet and physical activity pattern. The intervention brought about an improvement in the anthropometric, biophysical and biochemical profile which in turn brought about reduction in insulin resistance, improvement in β cell function and reduction in cardiovascular risk.

Salient features of the study

➢ Marked changes observed among subjects in their Personal habits & Lifestyle practices.
➢ Significant improvement in the Knowledge, Attitude and Practices of the individuals.
➢ Reduced fatigue, body aches, pains & ailments and improved stamina.
➢ Improvement in physical activity pattern.
➢ Improved Anthropometric and Biophysical profile.
➢ Favourable shift in the Glycemic control and Lipid profile of subjects.
➢ Major dietary shift towards conscious consumption of healthy foods.
➢ Significantly reduced Energy Intake and increased Energy Expenditure.
➢ The integrated approach brought about sustainable behavioural and lifestyle modifications among the subjects.
Stage 2

This stage of the DEAR study was designed especially for the executive staff of the industry. These employees were well educated, hard pressed for time and constantly on the move. There was also a space constraint in the office area hence special exercise programs could not be organized. This is the rapidly growing sector of workers and is at a higher risk of developing NCDs due to higher prevalence of risk factors. Innovative interventions must be designed to capture their attention to initiate sustainable behavioural modifications that would lead to healthier lifestyle practices.

Keeping these aspects in mind, we enrolled an entire executive population of the head office (n=21), general information about age, gender, socio economic status, occupation, general habits, dietary practices, physical activity pattern, medical history, treatment/medications, knowledge, attitude and practices were collected using a semi structured questionnaire. A health camp was organized to collect anthropometric, biophysical and biochemical data. During the camp a custom made website called 'e-sanjeevani.com' (in english) was launched to create awareness and educate the employees (males) about health and healthy practices. The employees accessed the site everyday for a period of three months after which post intervention data was collected on general habits, dietary practices, physical activity pattern, medical history, treatment/medications, knowledge, attitude, practices and knowledge retention. Anthropometric, biophysical and biochemical parameters were also reassessed after a period of three months.

We observed promising responses and results for the web based intervention not only in terms of increase in knowledge but also behaviour changes that resulted in favourable shifts in the metabolic profile of the subjects.

The employees were well educated and belonged to middle/ upper middle class socio economic status. Majority of them were young adults and the average age was 35 (± 12) years. Majority were also found to be predisposed to NCDs as they had a strong family history. 19% of the subjects were hypertensives, 9.5% were diabetics, and 4.8% of the
subjects were dyslipidemics and were on medications. After the health camp we discovered that the prevalence of NCDs was much higher, and many subjects were unaware of their medical condition. The prevalence as per our survey based on South Asian cut offs was that 71.4% were overweight/obesity and 52.4% were abdominally obese. 57.1% were hypertensives, 85.7% dyslipidemia and 19% of the subjects were detected with cardiovascular anomalies.

As the NCD prevalence was found to be alarmingly high a situational analysis of the risk factors was performed which revealed that 4.8% were tobacco chewers, 19.0% were smokers and 47.6% were alcohol consumers. Although 61.9% of the subjects were involved in some form of physical activity but the duration and intensity of the activities were insufficient to bring about desired results. Dietary pattern and composition of the subjects were also found to be erroneous. These risk factors coupled with the strong hereditary risk could be the plausible causes for the high prevalence.

We recorded a significant improvement the knowledge of the subjects. A significant increase (p< 0.000) was recorded in Knowledge Attitude and Practices regarding health and health practices. Knowledge retention was also significantly higher (p< 0.000) as the correct responses improved from a mere 37.6% before intervention to 70.5% post intervention. The subjects inculcated a habit to read the health columns in books, newspapers, websites, etc.

Concurrent with improvement in knowledge and awareness, changes in practices were also reported in the subjects. 90.5% subjects were involved in physical activity after intervention as compared to 62% that was recorded before intervention. There was also an improvement in the duration, type and intensity of the activities performed. It has been documented that even small improvements in physical fitness are associated with a significant lowering of metabolic risk of developing NCDs like diabetes, cardiovascular diseases, hypertension stroke and dyslipidemia (Warburton et al 2006).

Further, changes were also recorded in the dietary pattern and food frequency of the subjects. The oil consumption marginally came down from 5.9 litres to 5.4 litres. There was an increase in the consumption of millets (19%), milk and its products (38.5%), chicken (4.7%),
pulses (4.7%) and especially fruits (71.4%) and vegetables (57.1%). A reduced intake of red meat (19%), oil (28.5%) sugar (4.7%), cereals (4.7%), aerated beverages (23.4%) and bakery products (9.5%) was also reported. After intervention, a marginal drop was observed in the energy consumption of the subjects. The fat intake (p< 0.005) was significantly reduced whereas the carbohydrate intake increased marginally. A significant increase was also observed in the fibre (p< 0.05) intake of the subjects. Changes in fat intake and increase in fibre intake are known to reduce WC (Lovegrove 2007, Davis et al 2009) which in turn reduces the risk of developing dyslipidemia, diabetes and cardiovascular anomalies (Wang et al 2005, Yusuf et al 2005).

A considerable reduction was observed in the weight and WC of the individuals, while BMI and SBP were found to be marginally reduced. HC (p<0.000) and % fat (p< 0.05) of the subjects was significantly reduced post intervention.

We also observed an improvement in the biochemical profile of the subjects as there was a reduction in FBS and insulin levels. These, in turn reduced insulin resistance as indicated by HOMA IR. There was a significant reduction noticed in the TC (p<0.05), LDL- C (p<0.000) and L/H ratio (p<0.05). Literature suggests insulin resistance and hyperinsulinemia are the factors that are responsible for development of NCDs like diabetes, cardiovascular diseases and dyslipidemia especially among South Asians (Misra and Khurana 2008). Thus, a reduction in insulin resistance and increase in insulin sensitivity, as observed in this study would considerable reduce the risk of developing NCDs.

Web based intervention is a novel intervention technique which was well received by the subjects due to all time accessibility and convenience. As the intervention brought about favourable changes in anthropometric, biophysical and biochemical profile of the subjects, it brought about reduction in risk factors NCDs which if maintained would ultimately lead to prevention of NCDs.

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Salient features of the study

- Marked changes observed among subjects in the lifestyle practices of the subjects.
- Significant improvement in the Knowledge, Attitude and Practices of the individuals.
- Reduction in sedentary behaviour.
- Improved Anthropometric and Biophysical profile.
- Favourable shift in the Lipid profile of subjects.
- Marginal improvement in the FBS levels and HOMA IR (insulin resistance).
- Major dietary shift towards conscious consumption of healthy foods.
- Reduction in Energy Intake and increased Energy Expenditure.
- The integrated approach brought about sustainable behavioural and lifestyle modifications among the subjects.

To improve prevention strategies in the workplace set up Industrial Health Policy must be proactive and not reactive. Every industry should establish a Health and Nutrition Cell that formulates employee friendly policies for managerial as well as non managerial staff. The industries should also introduce avenues for both increased physical activity and relaxation. A non-discriminatory attitude of the management towards the employees should be encouraged. Health strategies that are planned should be a coordinated effort by management, employees and family towards healthy lifestyle practices. Prevention strategies are impossible to enforce and maintain without governmental support for promotion of health and welfare activities. The Government must lay down mandatory guidelines for Nutrition and Health Promotion activities in each and every set up. A mandatory NCD surveillance system must be established for early detection and prevention.