Efficacy of Chromium Supplementation and Nutrition Counseling on Glycemic Index and Lipid Profile in Male NIDDM Patients

Kanchan Sandhu[*] and Rajbir Sachdeva

*[*]KVK Nurmahal (Punjab Agriculture University), Jallandhar City, Punjab, India
Telephone: 91-0181-9417203777, Mobile: 91-0181-2258000
E-mail: kanchansandhu@yahoo.com
Department of Food and Nutrition, College of Home Science, Punjab Agriculture University,
Ludhiana 141 004, Punjab, India*

ABSTRACT A total of ninety NIDDM male patients aged 35-50 years, were studied for this work and equally divided into three groups viz. Nutrition Counseling Group (NCG) that imparted nutrition counseling through lectures, demonstrations and visual aids etc. along with prescribed medication, Chromium Supplementation Group (CSG) that was given chromium picolinate (CrPic) capsules (200µg/day) along with prescribed medication and Only Medication Group (OMG) that was on prescribed medication. After a period of three months, a significant ($p \leq 0.01$) improvement in the fasting blood glucose and post prandial glucose levels was observed in both NCG and CSG patients. There was a significant decrease in HbA1c values among the subjects in NCG ($P \leq 0.01$) and CSG ($p \leq 0.05$). Serum analysis showed that the chromium content of 0.54 ± 0.14 ppb significantly ($p \leq 0.01$) increased to 2.42 ± 0.55 ppb after the study. The findings of the present study revealed that chromium supplementation and nutrition counseling, independently and significantly ($p \leq 0.01$) decreased TC, TG, LDL-C and VLDL-C and increased HDL-C in three months time. The reduction in TG and VLDL–C was less significant ($p \leq 0.01$) in CSG as compared to NCG. The HDL / TC ratio significantly ($p \leq 0.01$) improved in both the NCG (0.19 to 0.23) and CSG (0.21to 0.23), indicating the lower risk of heart attack. Hence, chromium supplementation is suggested in diabetes as it is effective in improving glycemic index and lipid profile and nutrition counseling should be intensively imparted for a longer period and delivered by a dietician.

INTRODUCTION

Non- insulin dependent diabetes mellitus (NIDDM) is a disorder of carbohydrate metabolism, characterized by high blood glucose level and glycosuria resulting from dysfunction of pancreatic beta cells and insulin resistance (Abate and Chandalia 2001). It is a global disease, which prevails all over the world, though the prevalence rate differs from country to country. According to World Health Organization (WHO), every fifth person in the world is suffering from diabetes directly or indirectly. The WHO has declared diabetes as an epidemic following an alarming rise in the number of diabetics in India, China and United States (Gupta 2000). India harbors the majority of diabetic people and by the year 2030 AD India will have the largest number of diabetic patients (Viswanathan 2010). The poorly managed diabetes can lead to a host of long-term complications like heart attacks, strokes, blindness, and kidney failure (King et al. 1998). A tight control on blood glucose level is important to delay diabetes related complications. The control over blood glucose can be checked by

[*]Address for correspondence:
Dr. Kanchan Sandhu
Assistant Professor (H.Sc.)

glycosated hemoglobin (HbA1C) which measures the amount of glucose that has bonded with the hemoglobin in red blood cells. HbA1c reveals average blood glucose levels over the past two to three months (Rajan et al. 2003).

The management of NIDDM not only requires the prescription of the appropriate pharmacological regimen by the physician but also intensive nutritional counseling of the patient. Diet plays a key role in the management of diabetes (Manson 2002). Proper guidance and education given regarding diet and diabetes care makes significant improvement in the life-style of diabetics, which is helpful for good glycemic control. Education to diabetic patients is more effective if the level of knowledge; attitude and practices are known (Badruddin et al. 2002).

Chromium is an essential mineral that potentiates insulin. NIDDM (Type 2 diabetes) is actually triggered by a chromium deficiency and results in elevated LDL cholesterol and impaired glucose tolerance. Without ample chromium in the body blood sugar and fat cannot be properly regulated resulting in food cravings, obesity, heart disease and diabetes. As chromium is associated with increased glucose tolerance and insulin sensitivity, chromium supplementation is neces-

sary (Osorio and Castro 2001). A correlation exists between low circulating levels of chromium and the incidence of type 2 diabetes (Hummel et al. 2007).Very few controlled studies have been conducted in India on the beneficial effects of chromium supplementation in NIDDM patients. Considering the effect of chromium supplementation and nutrition counseling in minimizing blood glucose swings, improving insulin sensitivity and blood lipid profile, the present study was undertaken.

MATERIAL AND METHODS

Selection of Subjects

A sample of 90 male NIDDM patients was selected and studied from SAS Mediscan Grewal Hospital, Deep Hospital and ECHS (Ex-Servicemen Contributory Health Scheme), located in Ludhiana, Punjab, North-West India in the year 2004-2005. The subjects were equally divided into the three groups viz. Nutrition Counseling Group (NCG), Chromium Supplementation Group (CSG) and Only Medication Group (OMG). The subjects of NCG were imparted nutrition counseling via charts, discussion and demonstration by individual (after every 15 days) and group contacts (once every month) along with prescribed medicines for a period of three months. The counseling was planned so as to cover basic nutrition knowledge regarding chromium rich and fiber rich foods, and knowledge about the disease, its causes, risk factors, symptoms, precautions, complications and its management by diet and exercise etc. A special emphasis was given to make them aware regarding the distribution of meals, small and frequent meals, more consumption of chromium rich foods, fibrous foods, increase of activity and weight reduction as major goals of treatment. Subjects of CSG were given chromium supplementation in the form of chromium picolinate (CrPic) capsules (200ug/day) along with medical prescription for a period of three months. Subjects of OMG were only on medication, no supplementation or nutrition counseling was given. Each group was treated as its own control for a period of one month.

Serum Analysis

The serum was analyzed for glycemic index, chromium and lipid profile. Serum glucose, to-

tal cholesterol (TC), high density lipoprotein cholesterol (HDL-C) and triglycerides (TG) were also estimated. Low density lipoprotein cholesterol (LDL-C) was calculated based on the Friedwald 'equation' and Serum Very Low Density Lipoprotein Cholesterol (VLDL-C) was calculated based on: VLDL=Triglycerides/5. Glycosylated Hemoglobin (HbA1c) was analyzed following Nathan (1984). A sub sample of seven subjects was selected in CSG and their serum was analyzed for chromium content using atomic absorption photo spectrometer (AOAC 2000) before and after the study.

Statistical Analysis

The data of blood parameters was analyzed statistically. The mean, standard error, percentages, analysis of variance, CD value, paired t – value and their test of significance was calculated using a computer programme package (Singh et al.1998).

RESULTS AND DISCUSSION

As per the demographic information of the present study, maximum number of the patients was in the age group of 40-45 years in all the three groups. Majority of the subjects studied up to high school, that is, 46.67, 63.33 and 36.67 percent in NCG, CSG and OMG, respectively. Majority of the subjects, that is, 66.67 percent, 66.67 percent and 83.33 percent, respectively were businessmen, followed by ex-service men: 23.33, 20 and 10 percent, in NCG, CSG and OMG, respectively. Maximum number of the subjects: 53.33, 56.67 and 56.67 percent in the three groups, respectively were in the income group of Rs. >10,000 per month. The mean per capita income was Rs 3059, 2628 and 2841 per month in NCG, CSG and OMG, respectively. The per capita income at constant price in Punjab was Rs. 15210 (Anonymous 2003).The mean duration of diabetes was 4.15, 4.89 and 7.39 years in NCG, CSG and OMG, respectively. Further, mode of onset of disease was by typical symptoms among 50, 43.33 and 56.67 percent subjects in NCG, CSG and OMG, respectively. The most common symptoms observed in all three groups were tiredness, excessive thirst, frequent urination, frequent hunger and excessive sweating. It was observed that in NCG 43.37 percent of the subjects had a positive family history of

Table 1: Mean fasting and post prandial blood glucose levels of NIDDM patients (Mean ± SE) before and after the study

Blood glucose	Before	After	Percentage	Paired t-value	Normal Value #
Glucose(fasting)					
NCG	165.73 ± 6.61	139.63 ± 4.36	-15.75	09.37***	80-115
CSG	149.97 ± 5.93	138.67 ± 4.56	-7.53	6.65***	
OMG	168.47± 6.95	156.07 ± 5.83	-7.36	7.71***	
F- ratio	4.11**	5.86**			
CD	13.67	14.97			
Glucose (PP)					
NCG	257.20 ± 42.10	216.50 ± 31.17	-15.82	11.45***	120-160
CSG	256.03 ± 78.53	232.93 ± 63.34	-9.02	6.27***	
OMG	253.20 ± 61.14	236.60±62.18	-6.56	3.18***	
F- ratio	0.78	3.18			
CD	NS	10.85***			

Figures with different superscripts in a column differ significantly
*** Statistically significant at 1%,** Statistically significant at 5%,
# Raghuram et al. (1993)

the diabetes with a single diabetic parent whereas, in CSG 60 percent and in OMG 56.67 percent subjects had a positive family history of the diabetes.

Table 1 depicted mean fasting and post prandial glucose (GPP) levels of the NIDDM subjects. It was observed that there was a significant (p ≤ 0.01) improvement in the fasting blood glucose (FBS) and post prandial glucose (GPP) levels in both NCG and CSG after three months of nutrition counseling and chromium supplementation as shown by mean values of fasting and post prandial glucose levels which decreased significantly (p ≤ 0.01) from the initial values. Maximum change was observed in the values of subjects in NCG group, followed by CSG group. However, the mean value of FBG was higher initially and after the intervention in all the three groups as compared to the normal range (70-115 mg/dl). The present study indicated that though GPP levels significantly decreased after three months of intervention in all three groups, however, the levels were above normal range (120-160 mg/dl) before and after the study. Further, a significant (p ≤ 0.01) difference was observed in GPP levels among the subjects in the three groups after the study. Maximum change was observed in NCG, followed by CSG. The initial higher fasting blood glucose and post prandial values demonstrated a lack of metabolic control and need for improved nutrition counseling.

The improvement in GPP values in NCG might be due to the effect of counseling about low-fat, high-fiber diet which delays the glucose absorption after a meal, resulting in improved glucose tolerance. Further, subjects were counseled about the best sources of chromium that is brewer's yeast, liver, egg yolks, broccoli, whole-grain cereals, bran, and wheat germ, almonds and oysters etc. (Anderson 1992). They were also made aware about the facts that the foods high in sugars, processed foods and refined foods are not only low in chromium, but also stimulate chromium losses from body. However, improved GPP values in CSG could be due to the effect of chromium supplementation which is thought to make insulin work effectively.

Chromium, found naturally in foods in small amounts, is not well absorbed by the body. It is required for cellular uptake of glucose. Chromium supplementation may improve insulin sensitivity; thus, it has been used as adjunct treatment of diabetes mellitus in humans. In accordance with the present findings in an another study by Bahijiri et al. (2000), it was observed that supplementation by 23.3ug Cr / day to the diabetic patient, resulted in a significant decrease in fasting and post prandial glucose levels and triglycerides. Osorio and Castro (2001) reported that chromium is referred to as the "master regulator," as its main action is thought to be the regulation of blood sugar levels in the body. Chromium improved impaired glucose tolerance; decreased elevated blood lipid concentrations and resulted in weight loss and improved body composition.

Table 2 shows the effect of chromium supplementation and nutrition counseling on glycosylated hemoglobin (HbA1c). There was a significant decrease in HbA1c values among the

Table 2: Mean HbA1c Values of NIDDM patients before and after the study

HbA1C	Before	After	% age	t-value	HbA1c value @
NCG	7.98 ± 0.32	7.21 ± 0.26	-9.65	9.58***	4.2-5.5 %1
CSG	7.99 ± 0.46	7.58 ± 0.40	-5.13	5.29***	5.5-6.8 %2
OMG	9.35 ± 0.68	8.88 ± 0.57	-5.03	3.62***	6.8-7.6 %3
F- ratio	2.57	1.94	-	-	>7.6 % 4
CD	NS	NS	-	-	-

*** Statistically significant at 1% , **Statistically significant at 5%
1Normal values, 2Good control   3Fair control, 4Poor control, @ Nathan et al. (1984)

subjects in NCG (p ≤ 0.01) and CSG (P ≤ 0.05) groups. Maximum change in HbA1c value was observed among the subjects in NCG group (9.65 percent), followed by CSG group (5.13 percent).However, the change in the OMG was not significant after the study, indicating that chromium supplementation improved the chromium status in the body which helped to potentiate insulin action, thereby improving and leading to a better glycemic control.

The data of the present study demonstrated that initially majority of the subjects in the three groups had poor control (that is >7.6) over blood glucose levels, however, fair control (that is > 6.8-7.6) and good control (5.5-6.8) was achieved by maximum percentage of subjects in NCG and CSG, respectively after three months as shown in Table 3. The decreased HbA1c level in CSG suggested that chromium supplementation was associated with increased glucose tolerance and insulin sensitivity. Findings of the present study were similar to the previous results in a study reported by Kleefstra et al. (2002) who found that in Chinese NIDDM population, supplementation of 1000 µg of chromium led to a fall in the glycosated hemoglobin level (HbA1c) by 2 percent. Further, Balk et al. (2007) reported that chromium supplementation improved glycosated haemoglobin levels by -0.6 percent and fasting glucose by -1.0mmol/l. Significant improvements in the HbA1c values in NCG proved that the nutrition counseling was

an important and essential tool in the management of NIDDM as it is associated with favourable trends in glycemic control. Results of the present investigation were in accordance with a previous study by Ziemer et al.(2003) which stated that in diabetic patients the HbA1c level decreased from 9.7 to 7.8 percent with the healthy food choices and from 9.6 to 7.7 percent with the an exchange-based meal plan in a period of six months. According to Broadhurst and Domenico (2006),13 of 15 clinical studies (including 11 randomized controlled studies) involving a total of 1,690 subjects (1,505 in CrPic group) reported significant improvement in glycemic control after chromium supplementation.

Serum analysis was done to see the effect of chromium supplementation and nutrition counseling on serum chromium. The findings of the present study revealed that the mean initial level of chromium was 0.54 ± 0.14 ppb which significantly (p p ≤ 0.01) increased to 2.42 ± 0.55 ppb. However, these results proved a better retention of chromium in the body when supplemented with 200 µg CrPic / day. The improved chromium status in CSG could be due to the chromium supplementation, which possibly enhanced the chromium retention in the body as depicted by increased chromium levels in serum. The general population ranges of chromium in serum were <0.75 mg - <0.6 mg / l (Liu and Morris 1996). Further, in another study, it was reported that Cr effects were greater for the dose of 1000

Table 3: Percent distribution of NIDDM patients according to their HbA1c level

NCG		CSG		OMG		HbAIc @ Range
Before	After	Before	After	Before	After	
2 (6.67)	4(13.33)	1 (3.33)	2 (6.66)	(0)	1 (3.33)	Normal (4.2-5.5)
7(23.33)	7(23.33)	9(30)	10(33.33)	4(13.33)	4(13.33)	Good (5.5-6.8)
3(10)	9(30.01)	9(30.01)	7(23.33)	6(20)	6(20)	Fair (6.8-7.6)
18(60)	10(33.33)	11(36.67)	11(36.67)	20(66.67)	19(63.33)	Poor (77.6)

Figures in parentheses are percentages of subjects, @ Nathan et al. (1984)

µg per day than 200 µg per day. HbA1c was reported 7.5 ± 0.2 percent in the 200 µg group and 6.6 ± 0.1 percent in the group of subjects receiving 1000 µg of Cr picolinate per day for four months (Anderson et al. 1997). Racek et al. (2006) reported that supplementation with 400 µg Cr/d as Crenriched yeast showed a significant increase in serum Cr.

Diabetes characterized by insulin resistance and elevated blood glucose levels can lead to hyperglycemia, dyslipidemia and dysproteinaemia. Persons with diabetes often have associated lipid disorder, particularly increased serum triglyceride levels (Ramachandran et al. 2002).

Table 4 shows the effect of chromium supplementation and nutrition counseling on lipid profile. Data presented here, clearly showed that the chromium supplementation and nutrition counseling, independently and significantly ($p \leq$ 0.01) decreased TC, TG, LDL-C and VLDL-C and increased HDL-C in three months time. The mean values of TG before and after the study were on higher side in all the three groups than the desirable value of <150 (Raghuram 1993). A statistically significant decrease ($p \leq 0.01$) was observed in TC values after study period in both the NCG (183 .60 mg/dl) and CSG (178.70 mg/dl). The initially higher mean TC values were within the normal range in NCG and OMG, after three months. Further, the HDL / TC ratio significantly ($p \leq 0.01$) improved in both NCG (0.19 to 0.23) and CSG (0.21to 0.23) indicating the

Table 4: Lipid Profile of NIDDM patients before and after the study

Variable		Before values	After	% change	Paired t	Reference standard +
TC	NCG	207.30 ± 6.0	183.60 ± 6.02	-11.43	18.02***	<200
	CSG	190.27 ± 9.57	178.70 ± 9.22	-6.08	6.55***	
	OMG	200.07 ± 9.76	196.53 ± 9.35	-1.77	2.04**	
	F - ratio	0.98	1.22			
	CD	NS	NS			
TG	NCG	184.03 ± 13.85	170.33 ± 11.37	-7.44	3.61***	<150
	CSG	181.73 ± 20.13	162.33 ± 15.05	-6.01	1.83*	
	OMG	192.33 ± 17.98	183.87 ± 15.94	-4.40	2.67**	
	F - ratio	0.67	0.71			
	CD	NS	NS			
LDL-C	NCG	125.30 ± 6.21	109.60 ± 5.45	-12.53	6.25***	80-160
	CSG	98.80 ± 7.16	91.03 ± 5.99	-7.86	4.94***	
	OMG	108.57 ± 8.74	102.37 ± 7.93	-5.71	5.70***	
	F - ratio	3.24	2.47			
	CD	20.92	NS			
HDLC	NCG	38.37 ± 1.47	41.57 ± 1.49	8.34	10.91***	40-70
	CSG	36.60 ± 1.48	38.70 ± 1.51	5.74	6.11***	
	OMG	41.33 ± 1.20	41.77 ± 1.15	1.06	1.75*	
	F - ratio	2.98	1.51			
	CD	NS	NS			
VLDL	NCG	36.81 ± 2.77	34.15 ± 2.27	-7.23	3.61***	<40
	CSG	36.35 ± 4.03	34.16 ± 3.01	-6.02	1.83*	
	OMG	38.49 ± 3.59	36.77 ± 3.19	-4.47	2.74***	
	F - ratio	1.18	1.54			
	CD	NS	NS			
HDL/TC	NCG	0.19 ± 0.09	0.23 ± 0.012	21.05	12.26***	> 0.24
	CSG	0.21 ± 0.13	0.23 ± 9.52	9.52	6.02***	
	OMG	0.22 ± 0.01	0.23 ± 0.01	0	2.48**	
	F- ratio	2.29	0.23			
	CD	NS	NS			
TG/HDL	NCG	0.25 ± 0.025	0.27 ± 0.20	8.00	2.63***	< 2
	CSG	0.25 ± 0.027	0.27 ± 0.21	4.00	1.40 NS	
	OMG	0.27 ± 0.02	0.27 ± 0.02	0	0.10 NS	
	F- ratio	0.98	0			
	CD	NS	NS			

Figures with different superscripts in a column differ significantly
***Statistically significant at 1%, **Statistically significant at 5%,
NS=Non significant, +Raghuram et al. (1993)

lower risk of heart attack, while there was no improvement in HDL / TC ratio in OMG. The TG / HDL-C ratio improved significantly (p ≤ 0.01) in NCG after a period of three months, but a non significant change was observed in the TG / HDL-C ratio in CSG and OMG. The decrease in lipid profile was at par among the patients in the three groups after the study. An improved lipid profile of NCG and CSG was observed after three months of counseling which indicated that chromium supplementation and nutrition counseling independently and significantly gave a better control of glucose and HbA1c, and helped in improving lipid profile. Though the reduction in TG and VLDL–C was less significant (p ≤ 0.01) in CSG.

The present results are in line with those of Hovarth (2008) who observed that the lipid imbalance and insulin resistance was corrected by the cholesterol-lowering action of chroimium picolinate (CrPic). Similarly, Bahijiri et al. (2000), observed that the chromium (Cr) supplementation (200µg Cr/day) for a period of eight weeks resulted in a significant decrease in the means of TG levels in type 2 diabetes patients Whereas, in another study by Anderson et al. (1997) it was observed that the plasma total cholesterol decreased in the subjects receiving 19.2 µmol /day Cr after four months, proving the significant beneficial effects of chromium in individuals with NIDDM. Replacement of saturated fat in the diet with carbohydrates from whole grains, legumes, salads and fruits reduced total cholesterol, LDL-C, VLDL-C and HDL-C. The nutrition transition as a result of counseling towards unrefined foods, chromium rich foods like whole cereals, legumes, spinach, apple with peel, mushrooms and high fiber foods played important role in curbing the high glucose and lipid levels in the blood and in improving chromium status in serum. Subjects were also taught to consume small and frequent meals, low glycemic index foods and do more physical activity. The findings of the present study are in accord with studies of Gulati (2002) who reported that nutrition counseling not only reduced the risk of secondary complications in diabetic subjects but also significantly decreased the post prandial glucose level and lipid profile and Sook et al. (2001) who reported significant decreased mean serum glucose and atherogenic index in the diabetic and hyperlipaemic subjects after nutrition education was reported (Table 5).

Table 5: Serum chromium levels in NIDDM patients before and after the study

Before	After
0.95	4.97
0.3	1.45
0.79	2.68
0.52	1.59
0.9	3.77
0	1.11
0.29	1.35

CONCLUSION

Chromium picolinate (CrPic) could be an excellent agent to be considered in the treatment and prevention of hyperglycemia and hyperlipidemia as chromium supplementation was associated with increased glucose tolerance and insulin sensitivity. Further, the counseling about more consumption of chromium rich foods, decreased consumption of highly processed foods and chromium as a regulator of blood sugar that potentiates insulin which influences carbohydrate, lipid and protein metabolisms could be the reason for the improved blood lipid profile in NCG after three months Besides that counseling about chromium and fiber rich foods, less saturated fat intake and inclusion of physical activity to bring about a behavioral change could also have helped in curbing glucose levels and lipid profile in NCG group. Therefore, chromium supplementation and nutrition counseling favourably influenced serum lipoproteins and glycemic index and importantly decreased the risk of coronary artery disease in NIDDM patients.

RECOMMENDATIONS

The nutrition counseling programme should be multiprolonged, interesting and based on individual needs. Family of the NIDDM patient must also be counseled regarding food and nutrient intake. To be effective, nutrition counseling should be delivered by a dietician based on individual needs and for a longer period. Chromium supplementation should be suggested to the patients for improved chromium status in the body.

REFERENCES

Abate N, Chandalia M 2001. Ethnicity and type 2 diabetes: Focus on Asian Indians. *J Diabetes Complications,* 6: 320-327.

Anderson RA 1992. Dietary chromium intake: Freely chosen diets, institutional diets, and individual foods. *Biol Trace Elem Res*, 32: 117-121.

Anderson RA, Cheng N, Bryden NA, Polansky MM, Cheng N, Chi J, Feng J 1997. Elevated intakes of supplemental chromium improve glucose and insulin variables in individuals with type 2 diabetes. *J Diabetes,* 11: 1786-1791.

AOAC 2000. *Official Methods of Analysis*. 17th Edition. Association of Official Analytical Chemistry, Arlington, Virginia, USA, pp. 999-1000.

Anonymous 2003. *Statistical Abstract of Punjab*. Govt. of Punjab, India; Publication No. 884: 187-89.

Badruddin N, Abdul B, Zafar M, Hydrie I, Hakeem R 2002. Knowledge, attitude and practices of patients visiting a diabetes care unit. *Pakistan J of Nutr*, 2: 99-102.

Bahijiri SM, Mira S A, Mufti A M, Ajabnoor M A 2000.The effects of inorganic chromium and brewer's yeast supplementation on glucose tolerance, serum lipids and drug dosage in individuals with type 2 diabetes. *Saudi Medical J*, 9: 831-837.

Balk EM, Tationi A, Lichtenstein AH, Lau J, Pittas AG 2007. Effect of chromium supplementation on glucose metabolism and lipids: A systematic review of randomized controlled trials. *Diabetes Care*, 30(8): 2154-2163.PMID:17519436.

Broadhurst C Leigh, Domenico Philip 2006. Diabetes technology and therapeutics clinical studies on chromium picolinate supplementation in diabetes mellitus-A review. *Diabetes Technology and Therapeutics,* 8(6): 677-687.

Gupta R 2000. India the diabetic capital of the world. *Med Track: A Monthly Family Medical Advisor,* 2: 13-15.

Gulati R 2002. *Dietary Modification of Non-Insulin Dependent Diabetes Mellitus and Prevention of its Complications*. M.Sc. Thesis. Ludhiana: Punjab Agricultural University.

Hummel M, Standl E, Schnell O 2007. Chromium in metabolic and cardiovascular disease. *Horm Metab Res,* 39(10):743-51. PMID: 17952838 [Pub Med - indexed for MEDLINE]

Horvath EM, Tackett L, McCarthy AM, Raman P, Brozinick JT et al. 2008. Antidiabetogenic effects of chromium mitigate hyperinsulinemia-induced cellular insulin resistance via correction of plasma membrane cholesterol imbalance. *Mol Endocrinol,* 22(4): 937-950.

King H, Albert ER, Herman WH 1998. Global burden of diabetes, prevalence, numerical estimates and projections. *Diabetes Care*, 21: 1414-1431.

Kleefstra N, Bilo HJ, Bakker SJ, Houweling ST 2002.Chromium and insulin resistance. *J Nutr Biochem*, 11: 690-697.

Liu VJ, Morris J S 1996. Relative chromium response as an indicator of chromium status. *Am J of Clin Nutr,* 31: 972-76.

Manson Pamela 2002. Diet and diabetes. *The Pharmaceutical J,* 268: 499-500.

Osorio E, Castro VR 2001. Chromium and zinc in series of plants used in Portugal in the herbal treatment of non insulinized diabetes. *Acta Alimentaria*, 30: 333-342.

Nathan DM 1984.The clinical information value of the glycosylated assay. *The New England J Medicine,* 310: 314-346.

Rajan SK, Sivakumar R, Arunaprakash J 2003. The study on plasma glycosylated haemoglobin and fibrinogen levels in patients with type 2 diabetes mellitus and its complications. *Indian Practitioner,* 12: 783-786.

Racek J, Trefil L, Rajdl D, Mudrova V, Hunter D, Senft V 2006.Influence of chromium enriched yeast on blood glucose and insulin variables, blood lipids and markers of oxidative stress in subjects with type 2 diabetes mellitus. *Biol Trace Elem Res,* 109(3): 215-230. PMID: 16632892.

Raghuram TC, Pasricha S, Sharma RD 1993. *Diet and Diabetes*. Hyderabad: NIN, ICMR.

Ramachandran A, Snehalatha C, Vijay V 2002. Impact of poverty on the prevalence of diabetes and its complications in urban southern India. *Diabetic Med,* 19: 130–135.

Singh S, Bansal ML, Singh TP, Kumar R 1998.*Statistical Methods for Research Workers.* Ludhiana: Kalyani Publishers.

Sook M, Kim MJ, Son SM, Kim MJ 2001. The effect of nutrition education programme for various chronic diseases in elderly visiting public health center. *Korean J of Community Nutr*, 4: 668-677.

Tuomilehto J, Lindstrom J, Eriksson JG 2001.Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. *N Engl J Med,* 344: 1343–1350.

Viswanathan V 2010. Epidemiology of diabetic foot and management of foot problems in India. *Int J Low Extrem Wounds*, 9(3): 122-126.

Ziemer DC, Berkowitz KJ, Panayioto RM, ,Kebbi IM, Musey VC et al. 2003. A simple meal plan emphasizing healthy food choices is as effective as an exchange-based meal plan for urban African Americans with type 2 diabetes. *Diabetes Care*, 6: 1719- 1724.