Association of Type 2 Diabetes Mellitus with Biometric Variables: A study in Sir Ganga Ram Hospital, Lahore

HUSSAIN S.[1], HUSSAIN I.[2], SANA B.[3], WAHEED K.[4], QAISERA S.[4]
Address for Correspondence: *Dr. Seemeen Hussain, Associate Professor Medicine, FJMC, Lahore*

Introduction: Diabetes mellitus is closely linked to obesity as measured by body mass index (BMI) and is especially related to abnormal fat distribution as indicated by an increased waist/hip ratio and waist/thigh ratio. Central obesity is known to be associated with diabetes mellitus type 2; however limb circumferences may also have a strong association.

Objective: To compare various biometric variables in type 2 diabetics and non-diabetics.

Design: Cross-sectional analytical study.

Place and Time: Once a week, Outpatient Clinic, Department of Internal Medicine, Sir Ganga Ram Hospital, Lahore, from June 2007 to June 2008.

Statistical Tests: SPSS 12 (Statistical Package for Social Sciences) used. Includes student's t-test and logistic regression analysis.

Methodology: One hundred and sixty type 2 diabetics out of which eighty eight are women are compared with one hundred and fifty non-diabetics matched for age, sex and socioeconomic status. Diabetics in this study are known diabetics and those with 2 hour post-prandial blood glucose levels in excess of 140mg/dl. Anthropometric measurements, including waist, hip, thigh, calf and upper arm circumferences, BMI, waist/hip and waist/thigh ratios, of all subjects were taken and the student's t-test was applied to find out if they were significant differences between the measurements in diabetics and non-diabetics. Logistic regression analysis was used to show association of these biometric variables/anthropometric measurements with blood glucose levels.

Results: The mean blood glucose level in the diabetics group is 251mg/dl, with mean duration of disease more than five years. Type 2 diabetes mellitus is associated with thinner thighs and calves in both men and women ($p < 0.05$). On regression analyses a negative association of thigh and calf circumference is demonstrated with high blood glucose. Thigh and calf measurements show an inverse linear correlation ($r = -0.45$) and ($r = -0.68$) respectively. The coefficient of determination ($r^2 = 0.2$ and $r^2 = 0.5$) suggests that thigh and calf circumferences have a 20% and 50% dependence on blood sugar respectively. Diabetic biometric measurements were found to be: mean waist circumference of 102 ± 16 cm in men and 92 ± 16 cm in women, mean BMI of 28 ± 5 kg/m^2 in men and 28.7 ± 7 kg/m^2 in women and mean waist/hip ratio of 0.99 and 0.93 in men and women respectively. However there was no significant difference in waist, hip circumference, body mass index, waist/thigh and waist/hip ratio between diabetics and non-diabetics.

Discussion: Our focus is on how the biometric measurements of diabetics differ from non-diabetics in the South Asian population. The significant inverse relationship between thigh and calf circumference and high blood glucose level can be used as an observational clinical screening tool to quickly identify patients with poorly controlled blood sugar in a typical out-patient setting. Further study is required to determine whether these biometric changes are due to the diabetes itself; or whether having a certain body shape predisposes to diabetes mellitus; and also whether these changes can be reversed with good glycemic control.

Conclusion: In our study sample type 2 diabetes mellitus is associated with significantly thinner thighs and calves than non-diabetes whereas central adiposity is prevalent in both diabetics and non-diabetics.

Key Words: Type 2 diabetes mellitus, biometric variables, anthropometric measurements, BMI, thigh, calf, waist, waist/hip ratio. waist/thigh ratio.

Introduction

Diabetes mellitus is a metabolic disorder which has a profound influence on carbohydrate, lipid and protein metabolism[1]. The dramatic increase in the incidence of type 2 diabetes worldwide remains unclear but may be linked to body shape and obesity, which is in turn attributed to increased visceral fat accumulation.[1,2] A number of studies over the past 15 years have re-emphasized a notion introduced in the mid-forties that complications commonly found in obese patients are more closely related to where the excess fat is rather than excess weight per se[3]. This high risk form of obesity, termed android in contrast to gynoid obesity, was first described by French physician Dr. Jean Vague. Subsequently several studies have confirmed android obesity as a major risk factor for coronary heart disease and T_2DM (Type 2 diabetes mellitus) while preferential accumulation of body fat in the gluteo-femoral region, as described by Vague, did not prove to be a major threat to cardiovascular health.[2-5]

T_2DM is strongly associated with obesity especially progressively increasing body mass index and increase visceral fat accumulation.[3-5] According to latest WHO guidelines a BMI (body mass index) of more than 23 kg/m^2 is considered over-weight in South Asians as compared to more than 25 kg/m^2 in Caucasians. There are many indications that in some ethnic groups, particularly those of Asian origin, the incidence of diabetes starts to increase rapidly at levels of BMI or waist circumference well into the acceptable range for Europeans.[3-6] It has been observed in the Hoorn study that the waist/hip ratio, not body mass index, is an important independent predictor of incident diabetes in 50-70 years olds.[7,8] The results indicate that fat distribution may be a better predictor for progression to type 2 diabetes than BMI, which is also suggested by studies that examined the waist/hip and waist/thigh ratios[9]. It has also been suggested that a larger hip circumference is associated with a lower prevalence of self reported T_2DM and a lower fasting glucose concentration independent of BMI.[10,11] However, waist circumference is positively associated with the incidence of diabetes whereas the hip and thigh circumferences are negatively associated with the incidence of diabetes after adjustment for age and BMI.[12]

We compared thigh, calf, upper arm and waist circumferences, as well as BMI, waist/hip ratios and waist/thigh ratios in a small South Asian diabetic population to non-diabetics in the same population to demonstrate whether the above biometric variables differed significantly between groups.

Subjects and Methodology

Study Design: Cross-sectional analytical study.

Place and Duration: The study took place in the Outpatient Clinic (OPD), Department of Internal Medicine, Sir Ganga Ram Hospital, Lahore. The duration of the study was one year, from June 2007 to June 2008, with subjects selected from Consultant clinic once a week.

Inclusion Criteria: New patients with Type 2 diabetes mellitus presenting at the once a week diabetic clinic in Sir Ganga Ram Hospital, Medical OPD between the ages of 25 years and 70 years. Non-diabetic controls from the vicinity of Sir Ganga Ram Hospital were matched for age, sex and socioeconomic status.

Exclusion Criteria: Type 1 diabetes mellitus, patients with age less than 25 years and more than 70 years, hospitalized patients with macro-vascular complications of diabetes i.e. stroke, acute myocardial infarction and renal failure, physically handicapped patients i.e. patients who are wheelchair bound and have joint problems/arthritis.

Methodology: A cross sectional analytical study was carried out in which one hundred and sixty type 2 diabetics were compared with one hundred and fifty non-diabetic controls, matched for age, sex and socioeconomic status. Non-diabetics in this study are defined as those with 2 hour postprandial blood glucose levels less than 140 mg/dl. .The diabetics were between the ages of 25 years and 70 years, were without macrovascular complications i.e. without acute myocardial infarction, stroke, or renal failure and were included on a purposive non-probability sampling basis. Eighty eight females and seventy two males are included in the sample and the same ratio of females to males is maintained in the control group. The mean ages of the cases (diabetic group) and the controls (non diabetic group) are 49.6 ± 9.1 years and 49.1 ± 9.1 years respectively. Informed verbal consent was obtained from all participants and ethical approval was obtained from the local ethics committee.

Both cases and controls underwent a thorough physical examination that included anthropometric measurements, blood pressure and two hour postprandial blood glucose level checked by the glucose oxidase-peroxidase method. Anthropometric measurements include waist, hip, thigh, calf and upper arm circumference measurements, body mass index (BMI), ratios of two measurements such as the waist/hip and waist/thigh ratios. The subjects (both cases and controls) were examined only once for their anthropometry, blood pressure and blood glucose levels.

Measurements of waist, hip, thigh, calf and upper arm circumference were taken with a standard flexible measuring tape in standard positions and at predefined points on the /body. Subjects were barefoot and wearing light clothes when weight and height were measured. Body weight was measured in kilograms to the nearest gram using a standard weighing machine and height was measured on a standiometer in centimeters. The body mass index is calculated by dividing the weight measured in kilograms by the square of the height measured in metres i.e. BMI = Weight (kg)/ Height $(m)^2$.

The upper arm circumference was taken to be midway between the acromion and the olecrenon process with the elbow flexed at 90 degrees. The thigh circumference was taken to be midway between the anterior superior iliac spine and the upper border of the patella. Calf circumference was measured approximately 15 centimeters below the midpoint of the patella where the maximum bulk of the gastrocnemius muscle was felt. The waist measurement was taken midway between the lower end of the ribs in the midclavicular line and anterior superior iliac spine, which was approximately the level of the umbilicus if the abdomen was not pendulous. The hip measurement was taken at the level of the greater trochanters. These measurements were used to calculate the waist/hip and waist/thigh ratios. All measurements were made in centimeters using a standard flexible measuring tape.

Measurements of all cases and controls were taken by the same doctor to avoid inter-observational error and all bio-data was recorded on a form, including name, age, sex, occupation, address, blood pressure, two hour postprandial blood sugar and the biometric measurements mentioned above.

Statistical Analysis: Differences in baseline characteristics and biometric variables between men and women in the diabetic and non-diabetic group were tested by the student's t-test. The p-values obtained were used to determine whether there was significant differences between the diabetic group and the control group's anthropometric measurements.

Table 1: *Descriptive Statistics.*

	Age (years)	Blood Glucose Level (mg/dl)	Blood Pressure (mmHg)	Duration of diabetes (months)
Diabetics (n = 160)	49.6 ± 9.1	251 ± 42.3	136/86 ± 18/10	61 ± 33
Male	51.2 ± 8.9	218 ± 39.0	136/87 ± 18/10	68 ± 34
Female	48.3 ± 9.2	275 ± 42.3	136/85 ± 19/11	56 ± 31
Non-diabetics (n = 150)	49.1 ± 9.1	96.8 ± 7.6	120/80 ± 18/11	
Male	51.0 ± 9.1	92.0 ± 9.1	120/80 ± 18/10	
Female	47.5 ± 9.2	103.0 ± 6.5	120/80 ± 19/11	
p-value	> 0.05	< 0.001	< 0.01	

Logistic Regression Analysis was also performed to study the association of waist, hip, thigh, calf and upper arm circumferences, as well as other anthropometric measurements like BMI, waist/hip ratio and waist/thigh ratio, with the blood glucose level as an independent variable. The objective was to determine whether any significant differences found in the biometric measurements of diabetics compared to the general population are associated with high blood sugar levels.

Results

Table 1 shows the mean values in both diabetics and non-diabetics for age, blood pressure and blood glucose levels; as well as the average duration of diabetes in males and females in the diabetic group. The mean duration of diabetes of cases at presentation is 5 years and 8 months in men and 4 years and 8 months in women.

The mean blood glucose level is 251 ± 42.3 mg/dl and 96.8 ± 7.6 mg/dl for controls (p-value < 0.001). Diabetic women have a slightly higher mean two hour postprandial blood glucose level compared to men (275 ± 42.3 mg/dl to 218 ± 39.0 mg/dl respectively). At the time of examination 92.6% of diabetics had 2 hour postprandial blood glucose of more than 200 mg/dl. The mean blood pressure in diabetics was also significantly elevated, 136/86 ± 18/10 mmHg compared to 120/80 ± 18/11 mmHg in non-diabetics (p-value < 0.01).

Table 2 shows the mean anthropometric measurements of both diabetics and non-diabetics, as well as any significance in measurements as determined by the p-value.

Diabetics have statistically thinner thighs and calves compared to non-diabetics, indicated by p-values of < 0.05

Table 2: *Comparison of mean biometric variables of diabetics and non-diabetics.*

	Diabetics (n = 160)			Non-Diabetics (n = 150)			p-value
	Male	Female	Total	Male	Female	Total	
Waist (cm)	102.0 ± 16.1	95.0 ± 16.5	98.0 ± 16.3	101.8 ± 13.2	95.0 ± 16.0	97.0 ± 14.5	> 0.11
Waist/hip ratio	0.99 ± 0.10	0.93 ± 0.20	0.95 ± 0.10	0.99 ± 0.09	0.93 ± 0.16	0.96 ± 0.13	> 0.05
Waist/thigh ratio	2.20 ± 0.40	2.10 ± 0.40	2.10 ± 0.40	2.10 ± 0.40	2.10 ± 0.40	2.10 ± 0.40	> 0.05
Thigh (cm)	48.0 ± 0.8	46.0 ± 0.8	47.0 ± 0.8	49.0 ± 0.7	51.1 ± 0.7	50.1 ± 0.7	< 0.05
Calf (cm)	32.2 ± 0.4	32.0 ± 0.5	32.1 ± 0.4	34.4 ± 0.4	33.5 ± 0.3	33.8 ± 0.4	< 0.02
Upper arm (cm)	29.0 ± 0.5	29.6 ± 0.6	29.4 0.5	28.9 ± 0.2	29.7 ± 0.2	29.3 ± 0.2	> 0.05
BMI (kg/m^2)	28.0 ± 4.9	28.7 ± 7.1	28.4 ± 5.6	28.0 ± 4.8	28.6 ± 7.0	28.3 ± 5.1	> 0.05
Hip (cm)	103.0 ± 13.0	102.0 ± 14.7	102.5 ± 14.2	103.0 ± 18.3	102.0 ± 14.6	102.5 ± 16.1	> 0.05

and < 0.02 respectively. The mean thigh circumference in the diabetic group is 47.0 ± 0.8 cm compared to 50.1 ± 0.7 cm in the control group; while the mean calf circumference is 50.1 ± 0.7 and 33.8 ± 0.4 in diabetics and non-diabetics respectively.

However differences in other biometric measurements such as waist, hip and upper arm circumferences, waist/hip and waist/thigh ratios, as well as BMI are proved to be statistically insignificant. It is of interest to note that the BMI of both groups is similar; 28.4 ± 5.6 and 28.3 ± 5.1 in diabetics and non-diabetics respectively; and is higher than the acceptable range. Cases and controls also have similar waistlines with both diabetic and non-diabetic women having a mean waist circumference of 95 ± 16 cm; while diabetic and non-diabetic men both have a waist circumference of approximately 102 ± 16 cm.

To examine the association of random blood glucose levels with biometric variables each variable was entered into a regression model where blood glucose was the independent factor. The relationship between blood glucose and anthropometric variables was analyzed and plotted on the scatter diagram to assess the relative association between the factors. The blood glucose levels and thigh measurements have an inverse linear relationship with a coefficient of correlation of: $r = -0.45$. The coefficient of determination ($r^2 = 0.2$) suggests that the thigh measurements decrease with rising blood sugar and their dependence is 20% mutually. The calf measurements also show a similar but stronger inverse correlation ($r = -0.68$); with a coefficient of determination of 0.5, which means there is a 50% dependence of calf measurements on blood glucose levels.

Discussion

The focus of our study is on how the biometric measurements of diabetics differ from non-diabetics in the South Asian population. To this effect our diabetic group has shown statistically thinner thighs and calves than our non-diabetic population, and the differences in circumferences have been more at higher blood sugar levels (inverse linear correlation). However, measurements that indicate obesity or central adiposity, such as body mass index and waist circumference, have been surprisingly similar for both diabetic and non-diabetic groups.

The Hoorn study (population based cohort study) shows that the waist/hip ratio and not body mass index is an important independent predictor of incident diabetes in fifty to seventy year olds.[8,9] It also supports baseline hip and thigh circumferences as being negatively associated with postprandial glucose concentration in women; and shows that large waist circumference is significantly and positively associated with high fasting blood glucose in both men and women.[10,11]

These results were only partially reproduced in our study with thigh and calf circumference both being negatively associated with two hour postprandial blood glucose levels in men and women. In contrast, there is no significant difference in waist/hip ratio or BMI in both groups, and the BMI in both groups is well above the acceptable range for Asians.

Studies have shown that South Asian have more insulin resistance and thus a higher risk of developing diabetes and coronary heart disease compared to Caucasians of comparable BMI and age.[12-14] Recently there is considerable interest in body fat distribution as an important determinant of NIDDM and cardiovascular disease it is recognized that intra-abdominal or visceral adipose tissue has a strong correlation with insulin resistance.[16-18] The risk of developing NIDDM increases progressively with rising body mass index, and there is added risk with high waist/hip ratio indicating central fat deposition. BMI in the range of 18.5 – 24.0 kg/m^2 is considered normal and carries the lowest mortality rates. Prevalence of obesity is high worldwide, with 20% adults in UK and 30% in USA with a body mass index > 30 kg/m^2, which poses significant risk for developing diabetes and cardiovascular disease.[6,17,18]

In our study both diabetic and non-diabetic men and women have a mean BMI of more than 28 kg/m^2 and a waist circumference of 102 ± 16 cm in men and 95 ±16 cm in women (Table 2). It has been previously reported that a waist circumference of more than 94 cm in men and more than 80 cm in women identifies subjects who have a BMI higher than the normal range.[18,19] Although expected in the diabetic group, this fact was also noticeable in our non-diabetic control group.

The pathogenesis of Type 2 diabetes mellitus is hyperglycemia, hyperinsulinaemia, and insulin resistance.[1,2,20] The mechanisms underlying intra-abdominal obesity are unknown but may relate to the fact that intra-abdominal adipocytes are more lipolytically active than other fat depots. Femoral and gluteal subcutaneous fat has high lipoprotein lipase activity and low rate of lipolysis compared to abdominal fat.[21] The protective role of larger thighs in non-diabetic women may be explained by this regional difference in lipoprotein lipase activity.[20-22] Visceral fat releases fatty acids into portal circulation with adverse metabolic effects, whereas femoral and gluteal fat may protect the liver and muscles from higher exposure to free fatty acids through uptake and storage.[22] Free fatty acids can impair glucose utilization in skeletal muscles, promote glucose production by liver and impair beta cell function. Lactate and amino acids are released from skeletal muscles during gluconeogenesis resulting in muscle protein degradation.[21,23]

Normal physiology requires the presence of insulin for entry of glucose into skeletal muscles as compared to other non-insulin dependant organs. In diabetics therefore, the skeletal muscles have greater impairment of non-oxidative glucose usage i.e. glycogen formation, than in oxidative glucose metabolism through glycolysis. This explains why lower limbs with the greatest muscle bulk may exhibit more muscle break down as a result of reduced glucose substrate entering them.

Large and small vessel disease in diabetes causes relative ischaemia of the lower extremities more so than upper limbs and may also contribute to the relative thinness of the lower limbs. Upper limbs are significantly thinner in subjects presenting with myocardial infarction as demonstrated in a previous study suggesting that ischaemia is probably a contributory factor.[24]

Our study demonstrates thin thighs and calves in diabetics irrespective of sex .Majority of these diabetics exhibited poor diabetic control with a mean blood glucose level of 251 mg/dl with duration of diabetes for at least five years. The significant inverse relationship between thigh and calf circumference and high blood glucose level can be used as an observational clinical screening tool to quickly identify patients with poorly controlled blood sugar in a typical outpatient setting. Further investigation by way of a multicentric cohort study is required to determine whether these biometric changes are due to the diabetes itself; or whether having a certain body shape predisposes to diabetes mellitus. It would also be of interest is find out whether these changes can be reversed with good blood glucose control.

We stress on observation in clinical examination with a view to check biometric variables. There should be suspicion of NIDDM in light of our findings. A person who appears fuller around the waist with thin legs should be checked for NIDDM. Lifestyle interventions should focus on weight control combined with decrease in waist circumference and increase in thigh and calf circumference through increased physical activity.

Acknowledgements

Special thanks to Syed M. Asim Hussain for his help in typing and data management and Prof. Amanullah for his assistance in statistical evaluation.

References

1. Hunter J, Boon N, Colledge N, Walker B, eds. Davidson's Principles and Practice of Medicine. 20th edn. New Delhi: Elsevier; 2006; 21: 808-13.
2. Pickup J, Williams G, eds. Textbook of diabetes, Vol 1: Obesity, body fat distribution and diet in the etiology of non-insulin dependent diabetes mellitus. 3rd edn. Hong Kong: Blackwell Scientific; 2003. 20: 186–88.
3. Despres J, Lemieux I, Prud'homme D. Treatment obesity: need to focus on high risk abdominally obese patients. BMJ; 2001; 322: 716-20.
4. Vega G, Huet B, Peshock R, et al. Influence of body fat content and distribution on variation in metabolic risk. J Clin Endocrinol Metab; 2006; 91 (11): 4459-66.
5. McKeigue M, Shah B, Marmoll G. Relationship of central obesity and insulin resistance with high diabetes prevalence and cardiovascular risk in South Asians. Lancet; 1991; 337: 382-86.
6. World Health Organization Expert Consultation. Appropriate body mass index for Asian populations and its implications for policy and intervention strategies. Lancet 2004; 363: 157-63.
7. McKeigue P, Prepaut T, Ferrie T, Marmoll M. Relationship of glucose intolerance to body fat pattern in South Asians and Europeans. Diabetologia; 1992; 35: 785-91.
8. Snijder M, Dekker J, Visser M, et al. Association of hip and thigh circumferences independent of waist with the incidence of type 2 diabetes: the Hoorn study. Am J Clin Nutr; May; 2003; 77 (5): 1192-7.
9. Snijder M, Dekker T, Visser M, et al. Large thigh and hip circumferences are associated with better glucose tolerance: the Hoorn study. Obes. Rep; 2003; 104-11.
10. De Vegt F, Dekker J, Jager A, et al. Relation of impaired fasting and postload glucose with incident type 2 diabetes in a Dutch population: The Hoorn study. JAMA; 2001; 285: 2109-13.
11. Kuk J, Janiszewski P, Ross R. Body mass index and hip and thigh circumference and negatively associated with visceral adipose tissue after control of waist circumference. Am. J Clinical Nutrition; June, 2007; 85 (6): 1540-44.
12. Vaxquez G, Dual S, Jacobs D Jr., Silvertoineu K. Comparison of body mass index, waist circumference and waist/hip ratio in predicting incidence diabetes: A meta-analysis. Epidemiological Rev; 2007; 29: 115-28.
13. Annasamy R, Seely E, Arky R, et al. Body fat distribution and insulin resistance in healthy Asian Indians and Caucasians. J Clin Endocrinol Metab; 2001; 86 (11): 5366-71.
14. Sarah E, Crabtree N, Clark P, et al. Ethnic differences in insulin resistance and body composition in United Kingdom Adolescents. J Clin Endocrinol Metab; 2005; 90 (7): 3963-69.
15. Seidell J, Han T, Feskens F, Lear M. Narrow hips and broad waist circumferences independently contribute to increased risk of non-insulin dependent diabetes mellitus. J Internal Medicine; 1997; 292: 901-6.
16. Pascol A, Despres JP, Lemieux I, et al. Contribution of visceral obesity to the deterioration of the metabolic risk profile in men with impaired glucose tolerance. Diabetologia; 2000; 43: 1126-1135.
17. Tomashig H, Boyko J, McNeely M, et al. Visceral Adiposity, not abdominal subcutaneous fat is associated with an increase in future insulin resistance in Japanese Americans. Diabetes; 2008 ; (57): 1269-75.
18. Han T, Van Leer E, Seidell J, et al. Waist circumference action levels in the identification of cardiovascular risk sample BMJ; 1995; 311: 1401-05.
19. Lee S, Bacha F, Guingor N, Arslaniau S. Waist circumference is an independent predictor of insulin resistance in black and white youths. J. Pediatrics; Feb 2006; 148 (2): 188-95.
20. Lundgren H, Bengtsson C, Blohme G, et al. Adiposity and adipose tissue distribution in relation to incidence of diabetes in women: Results from prospective popu-

lation study in Gothenburg, Sweden. Int J Obes; 1989 13: 413-23.
21. Rebuffe-Scrive M, Enk L, Crona N, et al. Fat cell metabolism in different regions in women: Effect of menstrual cycle, pregnancy and lactation. J Clin Invest; 1985; 75: 1973-76.
22. Carey V, Walters E, Colditz G, et al. Body fat distribution and risk of non-insulin-dependent diabetes mellitus in women: The nurses' health study. Am J Epidemiol; 1997; 145: 614-9.
23. Ohlson L, Larsson B, Svardsudd K, et al. The influence of body fat distribution on the incidence of diabetes mellitus: 13.5 years of follow-up of the participants in the study of men born in 1913. Diabetes; 1985; 34: 1055-8. (Abstract).
24. Hussain S, Hussain I, Hussain S A, et al. Biometric analysis and risk evaluation of myocardial infarction. Annals of KEMC; Apr-Jun; 2005; 11 (2): 123-26.