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RESEARCH ARTICLE

ESTIMATION OF SUBCUTANEOUS FAT THICKNESS USING VARIOUS ANTHROPOMETRIC MEASUREMENTS AND CORRELATION OF OUTCOME VARIABLES WITH TYPE 2 DIABETES MELLITUS: A 1-YEAR CROSS-SECTIONAL STUDY

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ABSTRACT

Background: Diabetes mellitus is strongly associated with obesity. The anthropometric measurements are used as the predictors of diabetes mellitus and insulin resistance. Neck circumference, among the various anthropometric measurements, is a convenient method associated with metabolic syndromes such as diabetes mellitus.

Aim: To estimate the subcutaneous fat thickness using various anthropometric measurements and correlate the outcome variables with type 2 diabetes mellitus.

Methods: A total of 100 patients aged 18 years or more with type 2 diabetes mellitus were included in a cross-sectional study. Anthropometric dataincluding body mass index, waist circumference, waist-to-hip ratio, neck circumference, interscapular skin thickness and homeostatic model assessment to quantify insulin resistance (HOMA-IR) were collected for all patients. Based on the HOMA-IR values, patients were divided into two groups: HOMA-IR<2.41 (n = 44) and HOMA-IR>2.41 (n = 56). The data were analyzed using SPSS 21 and were compared using independent samplet-test. Pearson's correlation coefficient was used to find correlation.

Results: Increasedwaist-hip ratio and waist circumference were observed in 96% and 97% of the patients, respectively. The mean fasting blood sugar (FBS), postprandial blood sugar (PPBS), and glycated hemoglobin (HbA1c) levels were 163.67±70.87 mg/dL (range 82–536 mg/dL), 243.16±87.75 mg/dL (range101–625 mg/dL), and 8.72±2.08(range 6.1–15.4), respectively. Reduced (79%) high-density lipoprotein levels (34.09 ± 7.83 mg/dL) and elevated (46%) low-density lipoprotein levels (95.13 ± 39.87 mg/dL) were observed in the patients. Neck circumference, FBS, PPBS and HbA1c were significantly increased in patients with HOMA-IR>2.41 when compared to patients with HOMA-IR<2.41 ($p<0.050$). Among the anthropometric measures, only neck circumference was used to compare the other clinical characteristics including, blood glucose levels and HOMA-IR.A moderate positive correlation was observed between neck circumference and clinical characteristics including HOMA-IR, FBS, PPBS, and HbA1c($p< 0.050$).

Conclusion: Anthropometric measures, such as neck circumference, have a high significance in detecting the subcutaneous fat thickness. The ease of application and low cost of neck circumference measurement may allow its use in public health services. Neck circumference can serve as a straightforward and time-saving clinical screening method in determining the risk of insulin resistance.

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INTRODUCTION

Worldwide, 300 million people succumb to obesity. (Vazquez *et al*., 2007) Individuals weighing more than the recommended limit for their age and gender are termed as overweight and obese. (Hingorjo *et al*., 2012) Obesity is considered to be a significant risk factor in the implication of type 2 diabetes mellitus. Among the two variants, type 2 diabetes is accounted for 90% of the diabetic population in the world. (Federation, 2011) According to the International Obesity Taskforce (IOTF) Analysis 2010, approximately 1.475 billion adults are affected by diabetes. (IOTF. Strategic Plan For IOTF: International Obesity TaskForce; 2010) As estimated by the International Diabetes Federation, the incidence of diabetic cases is estimated to increase from 366 million in 2011 to 552 million in 2030. (Federation, 2011) People with diabetes in India, Bangladesh, and Sri Lanka make up 99% of South Asia's total adult diabetes population. Obesity and body composition are associated with diabetes mellitus, dyslipidemia, and insulin

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resistance. The obesity is measured by various imaging techniques including computed tomography, magnetic resonance and dual energy X-ray absorptiometry. Due to the high cost and reduced availability of imaging studies in remote areas, the noninvasive and easily performed anthropometric measurements are used. The anthropometric measurements performed in the clinical practice include, body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), and neck circumference (NC). Central obesity is measured by WC and waist-hip ratio, whereas, BMI is used to measure general obesity. (Vazquez *et al*., 2007; Molarius and Seidell, 1998) BMI, WC, and WHR have been shown to be associated with type 2 diabetes. (Vazquez *et al*., 2007) The ability of these obesity indicators to predict diabetes may differ by ethnicity, age, and sex. (Vazquez *et al*., 2007) Measurement of NC has recently been used to identify overweight and obese individuals, which has a good correlation with age, weight, waist and hip circumferences, WHR, and BMI in both the genders.

(Fauci *et al*., 2015) In addition, NC is anmarker of upper body subcutaneous (SC) adipose tissue distribution, which correlates positively with changes in systolic and diastolic blood pressure and components of metabolic syndrome such as, WC, fasting glucose, triglycerides, and high density lipoprotein (HDL) cholesterol. (Hingorjo *et al*., 2012; Ben-Noun and Laor, 2006; Ben-Noun and Laor, 2004) The increased free fatty acid release from the upper body SC fat, and insulin resistance in the adipocytes leads to dyslipidemia, associated with diabetes mellitus. (Silva *et al*., 2014) Considering the increased burden of type 2 diabetes mellitus, advantages of NC measurement, and the importance of obesity in the pathogenesis of diabetes, this study was undertaken to estimate theSC fat thickness using various anthropometric measurements including BMI, WHR, WC, NC, and interscapular skin thickness and to correlate these parameters with type 2 diabetes mellitus.

MATERIALS AND METHODS

Study Design

The study was conducted at the Department of Medicine, KLES Dr. Prabhakar Kore Hospital and Medical Research Centre, Belgaum. A1-year cross-sectional study was conducted from January 2015 to December 2015.A total of 100 patients aged 18 years or more with type 2 diabetes mellitus were enrolled in the study. Patients who werepreviously diagnosed with type 1 diabetes mellitus, thyroid disease, Cushing's syndrome, disorders of pituitary or adrenal gland, drug intake with corticosteroids, statins and glucocorticoids, and substantial weight gain/loss were excluded from the study. Before commencement of the study, an ethical clearance was obtained from the Institutional Ethical Committee. Data were recorded in a predesigned and pretested proforma.

Measurements of different parameters

Patients underwent investigations such as fasting blood sugar (FBS), postprandial blood sugar (PPBS), glycated hemoglobin (HbA1c), lipid profile, and serum insulin levels. The outcome was determined by the anthropometric measurements including, BMI, WC, WHR, NC, interscapular skin thickness, and homeostatic model assessment to quantify insulin resistance (HOMA IR). BMI was calculated according to standard protocol defined by the World Health Organization (WHO) and classified according to Overweight and Obesity by BMI in adult Asians. (Snehalatha *et al*., 2003) WC was measured using a standard measuring tape in centimeters, in whichWC>80 cm in women and WC >85 cm in men was considered abnormal. The WHR<0.9 in men and <0.85 in women was considered normal (Expert Panel on Detection E. Executive summary of the Third Report of the National Cholesterol Education Program (NCEP) expert panel on detection, 2001) The NC≥37 cm in men and ≥ 34 cm in women was considered normal (Ben-Noun and Laor, 2003) Harpenden calipers were used to measure interscapular skin thickness. Thickness ≥2.2 cm was considered abnormal in both men and women. (BROOK C. 3.4. Influences on the Growth of Adipose Tissue, 2013) For the determination of HOMA-IR, the insulin levels were assessed by the microparticle enzyme immune assay (MEIA). Insulin resistance was calculated and patients wereconsidered insulin resistant if HOMA-IR>2.41. (Chan *et al*., 2003; Momin *et al*., 2014) Based on the HOMA-IR values, patients were divided into two groups: HOMA-IR <2.41 (n = 44) and HOMA-IR >2.41 (n = 56).

Data Analysis

The data were coded and entered into a Microsoft excel spreadsheet and analyzed using SPSS 21. Continuous data were presented as mean ± SD and compared using independent samplet-test. Among the anthropometric measures, NC was used to compare with the other clinical characteristics including, blood glucose levels and HOMA-IR. Pearson's correlation coefficient was used to establish a correlation between NC and the clinical characteristics.

RESULTS

The baseline clinical characteristics of the study sample are asshown in Table 1. Of the 100 patients, 68% were men and 32% were women. Among them, most (41%) of the patients were aged between 51 and 60 years. The mean age ofpatients was 58.98 ± 9.86 years. BMI of patients revealed that, 63% and 20% of the patients were overweight and obese, respectively. The duration of diabetes mellitus was 4-6 years in 38% of the patients with a mean duration of 6.50 ± 3.23 years. Majority (96%) of the patients had an increasedWHR. Raised WC was observed in 97% of the patients. The mean values of the anthropometric measurements including BMI, WHR, WC, NC and interscapular skin thicknesswith range are shown in the Table 1. Majority of the patients in the sample had elevated FBS (69%) and PPBS (66%) levels.

Also, 39% of the patients had HbA1c levels > 8.5 and 4% had HbA1c between 5.6 and 6.5. The mean values of the glucose triad including, FBS, PPBS and HbA1c were 163.67 ± 70.87 mg/dL (range 82-536 mg/dL), 243.16 ± 87.75 mg/dL (range-101-625 mg/dL) and 8.72 ± 2.08 (range 6.1-15.4), respectively. The total cholesterol level was normal in 83% of the patients; however, elevated levels were observed in 17% of the patients with a mean level of 165.67 ± 41.35 mg/dL. Reduced levels ofHDL (34.09 ± 7.83 mg/dL) were observed in 79% of the patients. However, elevated levels of low density lipoprotein (LDL) (95.13 ± 39.87 mg/dL) and triglycerides (185.43 ± 77.17 mg/dL) were observed in 46% and 61% of the patients, respectively. Among the otheranthropometric outcome variables, increased NC (84%) and interscapular thickness (23%) were observed with a mean of 38.33±2.25 cm and 1.86 ± 0.52 cm, respectively.

The insulin resistance index—HOMA-IR was increased in 56% of the patients with a mean of 4.20 ± 4.98 was observed. A comparison between the baseline clinical characteristics and HOMA-IRwas performed in all the patients. The meanNC(38.9 ± 2.20 cm vs. 37.65 ± 2.14 cm; p=0.006) and levels of FBS (195.1 ± 79.2 mg/dL vs. 123.61 ± 24.60 mg/dL; p<0.001), PPBS (727.60 ± 95.00 mg/dL vs. 196.77 ± 47.44 mg/dL; p<0.001) and HbA1c (9.60 ± 2.20 vs. 7.65 ± 1.22; p<0.001) were significantly increased in patients with HOMA-IR>2.41as compared to patients with HOMA-IR<2.41 (Table 2). Among the anthropometric parameters, NC was significantly increased in the study sample. Therefore, NC was used to compare the other variables including HOMA-IR, FBS, PPBS, and HbA1c. A moderate positive correlation (p<0.001) was observed between NC and the variables including HOMA-IR (r=0.4196), FBS (r=0.441), PPBS (r=0.4995), and HbA1c (r=0.4181; Table 3).

Table 1. Baseline clinicalcharacteristics of the study sample

Variables	Distribution (n = 100)	
	Mean ± SD	Range
Age	58.98 ± 9.86	31–80
Diabetic duration	6.50 ± 3.23	1–16
Height (cm)	166.77 ± 6.31	143–182
Weight (kg)	76.93 ± 9.26	60–98
Body mass index (kg/m^2)	28.34 ± 7.28	21.8–94
Waist circumference (cm)	96.90 ± 7.77	80–112
Hip circumference (cm)	81.78 ± 10.15	60–112
Waist hip ratio (cm)	1.19 ± 0.16	0.9–1.7
Respiratory rate (per minute)	14.26 ± 1.97	11–18
Pulse (perminute)	74.33 ± 10.95	50–100
Systolic (mmHg)	135.21 ± 16.99	90–178
Diastolic (mmHg)	82.60 ± 10.72	56–114
FBS (mg/dL)	163.67 ± 70.87	82–536
PPBS (mg/dL)	243.16 ± 87.75	101–625
HbA1c	8.72 ± 2.08	6.1–15.4
Total cholesterol (mg/dL)	165.67 ± 41.35	75–314
HDL (mg/dL)	34.09 ± 7.83	23–65
LDL (mg/dL)	95.13 ± 39.87	26–214
Triglycerides (mg/dL)	185.43 ± 77.17	54–369
Serum insulin	8.81 ± 4.73	3.2–26
Neck circumference (cm)	38.33 ± 2.25	33–44
Inter-scapular skin thickness (cm)	1.86 ± 0.52	0.8–3.0
HOMA-IR	4.20 ± 4.98	0.7–34.4

FBS, fasting blood sugar; PPBS, post prandial blood sugar; HDL, high density lipoprotein; LDL, low density lipoprotein; HOMA-IR, homeostatic model assessment to quantify insulin resistance.

Table 2. Comparison of clinical characteristics of the study population with HOMA-IR

Variables	HOMA IR <2.41 (n=44) Mean ± SD	HOMA IR >2.41 (n=56) Mean ± SD	*p* value
Age (years)	59.48 ± 8.89	58.6 ± 10.6	0.650
Diabetic duration (years)	6.52 ± 3.19	6.5 ± 3.3	0.950
Height (cm)	166.80 ± 6.08	166.8 ± 6.5	0.971
Weight (kg)	77.09 ± 9.42	76.8 ± 9.2	0.879
Body mass index (kg/m^2)	29.18 ± 10.51	27.7 ± 2.8	0.359
Waist circumference (cm)	98.24 ± 7.95	95.8 ± 7.5	0.129
Hip circumference (cm)	81.49 ± 10.28	82.0 ± 10.1	0.804
Waist-hip ratio	1.21 ± 0.17	1.2 ± 0.1	0.311
Respiratory rate (per minute)	14.18 ± 1.92	14.3 ± 2.0	0.726
Pulse (per minute)	73.45 ± 9.14	75.0 ± 12.2	0.466
Systolic (mmHg)	134.73 ± 16.02	135.6 ± 17.9	0.800
Diastolic (mmHg)	82.95 ± 9.90	82.3 ± 11.4	0.767
FBS (mg/dL)	123.61 ± 24.60	195.1 ± 79.2	<0.001
PPBS (mg/dL)	196.77 ± 47.44	279.6 ± 95.0	<0.001
HbA1c	7.65 ± 1.22	9.6 ± 2.2	<0.001
Total cholesterol (mg/dL)	164.43 ± 40.19	166.6 ± 42.6	0.791
HDL (mg/dL)	33.82 ± 7.28	34.3 ± 8.3	0.756
LDL (mg/dL)	95.07 ± 40.61	95.2 ± 39.7	0.989
Triglycerides (mg/dL)	186.41 ± 75.74	184.7 ± 78.9	0.911
Serum insulin	5.46 ± 1.31	11.4 ± 4.8	<0.001
Neck circumference (cm)	37.65 ± 2.14	38.9± 2.2	0.006
Interscapular skin thickness (cm)	1.78 ± 0.49	1.9± 0.5	0.165

FBS, fasting blood sugar; *PPBS*, post prandial blood sugar; *HDL*, high density lipoprotein; *LDL*, low density lipoprotein; *HOMA-IR*, homeostatic model assessment to quantify insulin resistance

Table 3. Correlation of neck circumference with HOMA IR and blood glucose levels

Variable	Distribution (n=100)	
	Pearson correlation coefficient (r)	*p* value
NC with HOMA IR	0.4196	<0.001
NC with FBS	0.441	<0.001
NC with PPBS	0.4995	<0.001
NC with HbA1c	0.4181	<0.001

FBS, fasting blood sugar; *PPBS*, post prandial blood sugar; *HOMA-IR*, homeostatic model assessment to quantify insulin resistance

DISCUSSION

Obesity isassociated with an increased risk of insulin resistance, diabetes mellitus, and dyslipidemia. (Bouchi *et al*., 2015) The purpose of this analysis was to estimate the SC fat thickness utilizing various anthropometric measurements and to correlate them with type 2 diabetes mellitus. When compared to conventional anthropometric measurements, NC showed a moderate positive correlation with HOMA-IR and the blood glucose levels. The prevalence of diabetes is higher in men than in women. (Mathers and Loncar, 2006) In the present study a male preponderance was observed. Worldwide, the prevalence of diabetes is higher among the age-group of 40–59 years. (IDF. International Diabetes Federation Diabetes Atlas Sixth Edition 2013) In the present study, most of the patients were aged between 51 and 60 years followed by 61 to 70 years. According to a study conducted by Ramachandran *et al*., the young and the middle-aged adults are the most affected in the Asian countries. In India, 50.8 million adults (20–79 years) suffer from diabetes. (Ramachandran *et al*., 2010) With the progression of age, insulin resistance, beta cell dysfunction, and glucose intolerance develop in the elderly. Hence, type 2 diabetes mellitus is reported mainly in adults and the elderly. (Suastika *et al*., 2012) A majority of the patients had elevated FBS levels, followed by elevated PPBS, and HbA1c levels suggesting a poor glycemic control in the study population. HOMA-IR was elevated in more than half of the study population indicating insulin resistance. The pathogenesis of insulin resistanceinvolves ectopic lipid metabolite accumulation, activation of the unfolded protein response pathway and innate immune pathways. The resultant effect is impaired insulin signaling and insulin resistance leading to elevated blood glucose levels, obesity, and diabetes mellitus. (IDF. International Diabetes Federation Diabetes Atlas Sixth Edition 2013; Reaven, 1988) Over the past two decades, a rise in the incidence and prevalence of type 2 diabetes mellitus is related to obesity has been seen. (Eckel *et al*., 2011) In a study conducted in 113 type 2 diabetes mellitus patients, Jimoh *et al* reported 28.3% and 20.4% overweight and obese patients, respectively. (Jimoh *et al*., 2009) In the present study, comparable results were observed among the overweight and obese patients. According to the World Health Organization (WHO), men with WC>94 cm and women with WC >80 cm have increased risk of metabolic complications. (Organization, 2008) In addition, the WHO stated that an increase in the WHR ($\geq$ 0.90 in men and $\geq$ 0.85 in women) is associated with a substantial increase in the risk of metabolic complications. Present study revealed elevated values of WC, which reflect WC as an indicator of abdominal obesity. (López-Sobaler *et al*., 2016). Increased plasma triglycerides and LDL levels, and low HDL levels are representative of diabetic dyslipidemia. (Carr, 2001) A similar trend was observed in this study in which, majority of the patients had reduced HDL levels and elevated LDL and triglyceride levels. In an Iranian Isfahan Healthy Heart Program (IHHP) study (Sadeghi and Roohafza, 2004) and a San Antonio Heart Study (Wei *et al*., 1996), significantly low levels of HDL were reported in patients with type 2 diabetes. In a Palestinian study (Abdul-Rahim *et al*., 2001) and also in the Iranian IHHP study, (Sadeghi and Roohafza, 2004) 35%–40% of the diabetic population were found to have hypertriglyceridemia. Therefore, dyslipidemia status is representative of increased risk of obesity and insulin resistance in patients with type 2 diabetes mellitus. The upper body SC fat releases extensive amounts of free fatty acids, especially in the obese and overweight individuals. High levels of upper body SC fat are related to adverse metabolic outcomes including insulin resistance, diabetes, and elevated triglycerides. In lean individuals with less body obesity, the incidence of these adverse outcomes is low. SC fat plays an important role in determining obesity-related insulin resistance in type 2 diabetes mellitus and NC is considered asan index of upper body obesity. (Guo *et al*., 2012; Yang *et al*., 2010) In the present study, majority of the study population had significantly increased NC, FBS, PPBS, and HbA1c in patients with HOMA-IR>2.41 as compared to patients with HOMA-IR<2.41 (p<0.050). This suggests a higher rate of upper body obesity in patients with diabetes mellitus (p<0.050). In a similar study, Yang *et al*. (2010) reportedan association between NC, BMI, WC, and metabolic syndrome. Also, Joshipura *et al*. (2016) reported NC as a better marker to assess obesity and metabolic conditions such as insulin resistance and plasma glucose levels. A moderate positive correlation was observed between NCandclinical characteristics including HOMA-IR, FBS, PPBS and HbA1c (p<0.050). These findings were consistent with the recent studies conducted by Silva *et al*. (2014) and Androutsos *et al*. (2012) who presented a positive correlation between NC, insulin, and HOMA-IR. However, other anthropometric measurements including body mass index, WHR, WC, and interscapular skin thickness were comparable in patients with HOMA-IR>2.41 and in patients with HOMA-IR<2.41. Even though, WC and other conventional anthropometric measurements are most widely used, they possess certain limitations. The NC is devoid of these limitations and is a more simple and practical anthropometric measurement. The benefits of NC include reduced multiple accuracies and reliability measurements, and noninfluential measurement of time (fasting and postprandial). In addition, it is easy, convenient, and acceptable, especially in obese and overweight individuals. (LaBerge *et al*., 2009) The cross-sectional design of the present study is a limitation in the inference of the findings to a large population. Overall, the present study showed that, NC is a useful tool and a strong predictor of insulin resistance.

Conclusion

Anthropometric measures, such as NC, have a high significance in detecting the SC fat thickness. NC, FBS, PPBS, and HbA1c were significantly high in patients with HOMA-IR>2.41.A significant moderate positive correlation was observed between NCand HOMA-IR, FBS, PPBS, and HbA1c. The ease of application and low cost of NC may allow its use in public health services. In conclusion, NC can serve as a straightforward and time-saving clinical screening method in determining the risk of insulin resistance in type 2 diabetes mellitus. Further studies in larger sample sizes and different populations are warrantedto validate NC as an obesity-screening measure in different populations.

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Conflicts of interest: None declared.

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