http://www.pjbs.org

PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

OPEN ACCESS Pakistan Journal of Biological Sciences

ISSN 1028-8880
DOI: 10.3923/pjbs.2020.719.725

Research Article
Prevalence of Metabolic Syndrome in Type 2 Diabetics and its Relation with Neck Circumference

[1]Khaled A. Alswat, [2]Ziyad O. Alsugair, [2]Lulwah M. Alharthy, [2]Shrooq T. Alkhodaidi, [2]Mohammed M. Alobaylan, [2]Mohammed K. Alharithy, [2]Omar R. Abdalgader, [2]Ahmed A. Bokhari, [3]Daifallah Almalki and [4]Ahmed Gaber

[1]Department of Medicine, School of Medicine, Taif University, Taif, Saudi Arabia
[2]Medical Residents, School of Medicine, Taif University, Taif, Saudi Arabia
[3]Department of Family Medicine, Prince Mansour Military Hospital, Taif, Saudi Arabia
[4]Department of Genetics, Faculty of Agriculture, Cairo University, Cairo, Egypt

Abstract

Background and Objective: Metabolic syndrome (MetS) is a cluster of conditions characterized by the presence of central obesity and glucose intolerance. Neck circumference (NC) was found to be positively correlated with waist circumference (WC) and MetS in patients with type 2 diabetes (T2D). The aim of the present research was to investigate the prevalence of metabolic syndrome in patients with type 2 diabetics and its relationship with neck circumference. **Materials and Methods:** Individuals with T2D who were at least 18 years old were included. Patients with type 1 diabetes, gestational diabetes, untreated hypothyroidism and goiter were excluded. MetS was defined using the International Diabetes Federation criteria. **Results:** A total of 662 T2D patients participated in the study. The mean age of the cohort was 59.1±11.5 years and 94.9% of the patients satisfied the criteria for MetS. Patients with MetS tended to be older ($p<0.001$), mostly male (p 0.008), with a higher body mass index (BMI) ($p<0.001$), a larger mean NC ($p<0.001$) and a larger mean WC ($p<0.001$). These individuals also tended to have hypertension and hyperlipidemia ($p<0.001$) and were more likely to be on statins ($p<0.001$). Except for retinopathy, all other microvascular and macrovascular complications were not more prevalent in individuals with MetS. **Conclusion:** Nearly all (94.9%) of the screened T2D patients had MetS. This finding is most likely due to the large WC of the patients and the high prevalence of hyperlipidemia and hypertension.

Key words: Type 2 diabetes, metabolic syndrome, waist circumference, neck circumference, hypertension, hyperlipidemia, gestational diabetes

Citation: Khaled A. Alswat, Ziyad O. Alsugair, Lulwah M. Alharthy, Shrooq T. Alkhodaidi, Mohammed M. Alobaylan, Mohammed K. Alharithy, Omar R. Abdalgader, Ahmed A. Bokhari, Daifallah Almalki and Ahmed Gaber, 2020. Prevalence of metabolic syndrome in type 2 diabetics and its relation with neck circumference. Pak. J. Biol. Sci., 23: 719-725.

Corresponding Author: Khaled A. Alswat, Department of Medicine, School of Medicine, Taif University, Taif, Saudi Arabia Tel: +966555449878

Copyright: © 2020 Khaled A. Alswat *et al.* This is an open access article distributed under the terms of the creative commons attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Diabetes mellitus (DM) is defined as a group of metabolic diseases that is caused by a defect in insulin secretion, action or both and characterized by hyperglycemia. Chronic hyperglycemia is associated with long-term damage to various organs, especially the eyes, kidneys, nerves, heart and blood vessels[1]. According to the World Health Organization (WHO), the prevalence of diabetes has risen globally from 4.7% in 1980 to 8.5% in 2014. However, the true incidence of type 2 diabetes (T2D) is still difficult to assess because it is often undiagnosed[2].

Type 2 diabetes (T2D) represents a major burden that must be addressed aggressively. In particular, the Eastern Mediterranean region has the highest prevalence of diabetes globally (13.7%) and the highest prevalence of inactivity[2]. A recent study conducted in Saudi Arabia revealed a diabetes prevalence of 25.4% for adults aged ≥30 years, the Makkah region took the lead nationally in terms of diabetes prevalence[3]. Type 1 diabetes (T1D), T2D and impaired fasting glucose (IFG) were found to increase with age and peak in individuals older than 65 years old[3].

Metabolic syndrome (MetS) is a cluster of conditions characterized by the presence of central obesity, glucose intolerance, dyslipidemia and hypertension[4]. Compared with people who do not have MetS, patients with the syndrome have a five-fold greater risk of developing T2D[5]. In addition, patients with MetS are three times as likely to have a heart attack or a stroke and twice as likely to die from these afflictions[5]. Globally, roughly 20-25% of adults have MetS[5].

As shown by numerous studies, common complications of obesity, T2D, dyslipidemia and cardiovascular disease (CVD) were more related to the distribution of body fat rather than overall excess body fatness[6]. Waist circumference (WC) is used to assess central obesity. It is an effective yet simple and inexpensive method with high correlation with cardiovascular disease (CVD) risk[7]. Therefore, MetS definitions have established WC as the method that reflects central obesity. Other methods, such as the waist-to-hip ratio (WHR) and lower body circumferences are still reserved for research purposes[6].

Neck circumference (NC) is considered to be an index for upper-body subcutaneous fat distribution. In recent study, NC was found to be positively correlated with WC, body mass index (BMI) and MetS in patients with T2D[8]. Furthermore, NC has been shown to contribute to the prediction of cardiometabolic risks independently[9]. However, it is still unknown whether it is comparable or superior to other classic anthropometric methods.

Only a few studies have been conducted in Saudi Arabia to assess the association between NC and cardiometabolic risk. The aim of this study was to assess the prevalence of MetS in T2D patients and its relation with NC measurements.

MATERIAL AND METHODS

Study area: This cross-sectional study was conducted between September, 2015 and July, 2016 at the Diabetes and Endocrinology Center, Prince Mansour Military Hospital, Taif, Saudi Arabia. Adults with T2D were included in the study and individuals with T1D, gestational diabetes, untreated hypothyroidism and goiter were excluded.

Collecting data: The data were collected via interviews with patients at the time of their regular clinic visits. Patients were asked to participate and consent was obtained verbally. Socioeconomic and demographic variables, including sex, age, marital status, monthly income and education level, were self-reported. Lifestyle habits such as smoking and physical activity were also noted. Individuals who reported a monthly income of <1,335 (USD) were considered to be low income. Severe hypoglycemic episodes were defined by a blood glucose <55 mg dL^{-1} that required the assistance of others, this parameter was self-reported by the patients.

Clinical measurements: Anthropometric measurements included height, weight, WC and NC. Furthermore, BMI was calculated. Neck circumference was measured using an inelastic tape placed at the midpoint of the neck. For the WC measurements, the tape was placed on the midpoint between the iliac crest and the last rib. Laboratory variables were obtained from the patients' electronic medical records. The glomerular filtration rate (GFR) was calculated using the Modification of Diet in Renal Disease (MDRD) formula[10]. Normal albumin to creatinine ratio (ACR) value in the lab is <2.9 mg $mmol^{-1}$.

International Diabetes Federation (IDF) guidelines were used in this study to define MetS: central obesity (defined as WC ≥94 cm for men and ≥80 cm for women in addition to any two of the following four factors:

- Raised triglycerides (TG) level ≥150 mg dL^{-1} (1.7 mmol L^{-1}) or specific treatment for this lipid abnormality
- Reduced high-density lipoprotein (HDL) cholesterol <40 mg dL^{-1} (1.03 mmol L^{-1}) in males and < 50 mg dL^{-1} (1.29 mmol L^{-1}) in females or specific treatment for this lipid abnormality

- Raised systolic blood pressure (SBP) ≥130 or diastolic blood pressure (DBP) ≥85 mm Hg or treatment of previously diagnosed hypertension
- Raised fasting plasma glucose (FPG) ≥100 mg dL^{-1} (5.6 mmol L^{-1}) or a previous T2D diagnosis

Statistical analysis: The data were collected and analyzed using the statistical package for the social sciences (SPSS) software v20 (IBM Corp, Armonk, New York). Frequencies and percentages were used for each variable, the Chi-squared test was used to study the relation between variables and the t-test was used to compare between means.

RESULT

Baseline characteristics: A total of 662 T2D patients participated in the study (Table 1). The mean age of the cohort was 59.1±11.5 years and the group was mainly male, mostly married and characterized by long-standing uncontrolled T2D. The mean BMI of the group was in the obesity range and the mean NC of the patients was 40.2±4.5 cm. Hyperlipidemia was the most common comorbidity followed by hypertension. The most common microvascular complication was neuropathy followed by retinopathy. Metformin was the most commonly prescribed oral hypoglycemic agent and angiotensin converting enzyme (ACE) inhibitors/angiotensin II receptor blockers (ARBs) were the most commonly prescribed antihypertensive medication. Most of the patients were prescribed statins with mean lipid panel at goal levels. Half of the patients reported a sedentary lifestyle and 10% were active smokers.

Metabolic syndrome prevalence and characteristics: Nearly all (94.9%) of the patients met the criteria for MetS (Table 2). Compared with patients without MetS, individuals with MetS were older (p<0.001), mostly male (p<0.008) and characterized by a longer duration of T2D (p 0.038). They also had higher BMI (p<0.001), larger NC and WC measurements (p<0.001), higher mean SBP (p<0.001), were more likely to be married (p<0.001), less educated (p<0.005), more likely to have hypertension and hyperlipidemia (p<0.001), less likely to have T2D related to hospitalization (p<0.034), more likely to be on both oral agents and insulin (p<0.002), more likely to be on ACE inhibitors/ARBs (p<0.002) and more likely to be on statins (p<0.001).

Table1: Baseline characteristics of the whole cohort

Baseline characteristics (n = 662)	Variables
Mean age (years)	59.1±11.5
Male (%)	54.2
Mean diabetes duration (years)	13.4±8.6
Mean BMI (kg m^{-2})	32.2±6.0
Mean waist circumference (cm)	109.8±13.8
Mean neck circumference (cm)	40.2±4.5
Mean systolic blood pressure (mm Hg)	133.6±20.4
Mean diastolic blood pressure (mm Hg)	75.3±10.6
Socioeconomic	
Married (%)	94.4
Bachelor degree or higher (%)	10.6
Low income (%)	53.9
Comorbidities and complications	
Hypertension (%)	51.8
Hyperlipidemia (%)	79.0
Sever hypoglycemia (%)	33.1
T2D related hospitalization in the previous 6 months (%)	6.2
Retinopathy (%)	45.0
Neuropathy (%)	60.7
Renal failure (%)	5.1
Cardiac disease (%)	17.2
Stroke (%)	4.7
Medications	
Metformin (%)	84.3
Sulphonylurea (%)	33.8
DPP-4 inhibitors (%)	20.1
TZDs (%)	1.7
Insulin alone (%)	9.8
Oral hypoglycemic agents and insulin (%)	56.3
ACE inhibitors/ARB (%)	43.2
Calcium channel blockers (%)	10.3
Beta-blockers (%)	2.0
Diuretics (%)	8.5
Statin (%)	76.1
Laboratory data	
Fasting glucose (mmol L^{-1})	10.0±4.4
HbA1c (%)	8.9±2.1
Total cholesterol (mmol L^{-1})	4.6±1.8
LDL (mmol L^{-1})	2.7±0.9
HDL (mmol L^{-1})	1.0±0.3
Triglyceride (mmol L^{-1})	1.7±0.9
ACR (mg $mmol^{-1}$)	22.9±94.3
Calculated GFR (mL min^{-1} 1.73 m^{-2})	82.9±23.4
Lifestyle habits	
Sedentary lifestyle (%)	52.3
Exercise >150 min/week	16.6
Active smoking (%)	10.0
Passive smoking (%)	25.5

Except for retinopathy, all other microvascular and macrovascular complications were not significantly more common in individuals with MetS. Furthermore, patients with MetS were more likely to report a sedentary lifestyle and were less likely to be active or passive smokers. However, none of these trends were statically significant.

Table 2: Baseline characteristics based on MetS diagnosis

Baseline characteristic	MetS	Without MetS	p-value
Number of patients (%)	94.9	5.1	n/a
Mean age (years)	59.4±11.1	52.3±16.0	<0.001
Male (%)	53.0	76.5	0.008
Mean diabetes duration (years)	13.6±8.6	10.4±7.8	0.038
Mean BMI (kg m^{-2})	32.5±5.9	26.4±4.5	<0.001
Mean waist circumference (cm)	110.8±13.0	91.0±14.7	<0.001
Mean neck circumference (cm)	40.4±4.4	37.5±5.4	<0.001
Mean systolic blood pressure (mm Hg)	134.3±20.4	121.6±14.6	<0.001
Mean diastolic blood pressure (mm Hg)	75.5±10.5	72.5±12.2	0.112
Socioeconomic			
Married (%)	93.8	79.4	<0.001
Bachelor degree or higher (%)	9.7	26.5	0.005
Low income (%)	54.8	38.2	0.141
Comorbidities and complications			
Hypertension (%)	53.5	20.6	<0.001
Hyperlipidemia (%)	80.6	50.0	<0.001
Sever hypoglycemia (%)	33.0	35.3	0.778
T2D related hospitalization in the previous 6 months (%)	5.7	14.7	0.034
Retinopathy (%)	44.4	55.9	0.191
Neuropathy (%)	60.8	58.8	0.816
Renal failure (%)	5.4	0.0	0.164
Cardiac disease (%)	17.4	14.7	0.690
Stroke (%)	4.8	2.9	0.622
Medications			
Metformin (%)	84.7	76.5	0.198
Sulphonylurea (%)	34.1	29.4	0.576
DPP-4 inhibitors (%)	20.4	14.7	0.421
TZDs (%)	1.6	2.9	0.549
Insulin alone (%)	9.4	17.6	0.002
Oral hypoglycemic agents and insulin (%)	57.3	38.2	
ACE inhibitors/ARB (%)	44.6	17.6	0.002
Calcium channel blockers (%)	10.4	8.8	0.775
Beta-blockers (%)	2.0	0.0	0.397
Diuretics (%)	8.4	8.8	0.938
Statin (%)	77.9	44.1	<0.001
Laboratory data			
Fasting glucose (mmol L^{-1})	10.0±4.4	9.6±4.4	0.662
HbA1c (%)	8.9±2.1	8.7±2.7	0.631
Total cholesterol (mmol L^{-1})	4.6±1.8	4.5±1.1	0.879
LDL (mmol L^{-1})	2.7±0.9	2.8±0.9	0.501
HDL (mmol L^{-1})	1.0±0.3	1.1±0.3	0.106
Triglyceride (mmol L^{-1})	1.8±0.9	1.6±1.1	0.252
ACR (mg $mmol^{-1}$)	23.7±96.3	4.0±8.8	0.288
Calculated GFR (mL min^{-1} 1.73 m^{-2})	82.5±23.2	89.7±26.0	0.087
Lifestyle habits			
Sedentary lifestyle (%)	52.7	44.1	0.331
Exercise >50 min/week	16.9	11.8	
Active smoking (%)	9.6	17.6	0.125

DISCUSSION

The Eastern Mediterranean region exhibited the largest increase in diabetes prevalence (13.7% in 2014)[2]. This fact raises great concern about the effectiveness of the current health strategies in the region. This study revealed that the prevalence of MetS is 94.9%. This high prevalence may be explained by the characteristics of the included patients as all those patients have T2D and most were hypertensive, hyperlipidemic and prescribed statins. The mean WC of the cohort was 109 cm. The prevalence of MetS in Italy and Albania was 75.6% in 2004 and 64.5% in 2015, respectively[10,11]. The prevalence of MetS in Cameroon was 71.7% in 2013, the corresponding prevalence in Ghana[12,13] was 58% in 2015. The prevalence of MetS in Bangladesh was 61% in 2011, 76.9% in Nepal[14-16] in 2013 and 66.2% in India in 2015. In Pakistan, the

prevalence[17,18] of MetS was 76% in 2008 and 86.7% in 2012. However, in Iran the prevalence of MetS was more comparable to that of other[19] countries: 63.2% in 2012. In Saudi Arabia, studies conducted with the general population revealed a decrease in the prevalence of MetS from 41.4% in 2005 to 28.3% in 2014 nationally and from 41.4-24.8% for the Western region[20,21]. However, it is difficult to compare the above findings with these other findings given that there have been almost no studies conducted targeting patients with T2D.

Compared with patients without MetS, individuals with MetS were more likely to be male, married, have attained low levels of education and more likely to be on both oral hypoglycemic agents and insulin. This finding is inconsistent with the results of other studies in which females were more likely to be affected by MetS than males[11-19,22]. However, in Saudi Arabia using the same tools we used but applied to the general population, researchers demonstrated a higher MetS prevalence in males than in females[20]. Similarly, studies conducted in Japan and India yielded a higher prevalence of MetS in males as well[23,24].

Hyperlipidemia was reported as the first significant comorbidity that might be explained by dietary habits in Saudi. Furthermore, physical inactivity was reported by 52.3% of the included cohort. Active smoking was reported more in individuals without MetS compared with patients with MetS. In previous international studies, smokers had an increased risk for MetS compared with non-smokers[24]. Smokers tend to have a larger WHR despite their low BMI,[25-28] which might be explained by the increased level of cortisol found in smokers[29-31]. In addition, smoking was also found to be associated with insulin resistance, a decrease in high-density lipoprotein cholesterol (HDL-C), an increase in low-density lipoprotein cholesterol (LDL-C) and triglycerides as well as an increase in HbA1c levels[32-34]. However, the numbers of smokers with and without MetS varied in different studies[16,35-40].

Mean NC was found to be larger in individuals with MetS (40.4±4.4 cm) compared with patients without MetS (37.5±5.4 cm), which is consistent with the findings of other studies[8,41,42]. However, the above numbers appear to be higher than those of other studies conducted on patients with T2D. In China, the mean NC was 36.8±3.7 cm in patients with MetS compared with 35.3±3.4 cm in those without MetS[8]. In Turkey, the mean NC was 38.40±4.13 cm in patients with MetS compared with 35.15±3.48 cm in those without MetS, in India, the mean NC was 36.44 cm compared with 34.08 cm in those with MetS[41,42].

Future studies are needed to identify the appropriate NC cutoff for MetS diagnosis. Close assessment for T2D patients for the cardiovascular risk factors associated with MetS diagnosis is recommended in order to reduce the major adverse cardiovascular disease burdens in such patient's population.

CONCLUSION

It is concluded that 94.9% of the screened T2D patients had MetS. This finding is most likely due to the large WC of the patients and the high prevalence of hyperlipidemia and hypertension. The result showed that the NC in the individuals with MetS was larger than that reported in previous international studies. However, additional studies are needed to identify the proper cutoff points for the Saudi population.

SIGNIFICANCE STATEMENT

Metabolic syndrome is highly prevalent among type 2 diabetes patients and more aggressive management to the cardiovascular risk factors is needed.

ACKNOWLEDGMENT

The authors thank every one of the patients who were enrolled on this examination. Superior thanks to the nursing and medical staff at the participating hospital for their help.

REFERENCES

1. American Diabetes Association, 2004. Diagnosis and classification of diabetes mellitus. Diabetes Care, 27: S5-S10.
2. WHO., 2016. Global Report on Diabetes. World Health Organization, Geneva, Switzerland, ISBN: 9789241565257, Pages: 86.
3. Al-Rubeaan, K., H. Al-Manaa, T. Khoja, N. Ahmad and A. Al-Sharqawi *et al*., 2014. The Saudi abnormal glucose metabolism and diabetes impact study (SAUDI-DM). Ann. Saudi Med., 34: 465-475.
4. Isomaa, B., 2003. A major health hazard: The metabolic syndrome. Life Sci., 73: 2395-2411.
5. Stern, M.P., K. Williams, C. Gonzales-Villalpando, K.J. Hunt and S.M. Haffner, 2004. Does the metabolic syndrome improve identification of individuals at risk of type 2 diabetes and/or cardiovascular disease? Diabetes Care, 27: 2676-2681.
6. Cornier, M.A., J.P. Despres, N. Davis, D.A. Grossniklaus and S. Klein *et al*., 2011. Assessing adiposity: A scientific statement from the American Heart Association. Circulation, 124: 1996-2019.

7. De Koning, L., A.T. Merchant, J. Pogue and S.S. Anand, 2007. Waist circumference and waist-to-hip ratio as predictors of cardiovascular events: Meta-regression analysis of prospective studies. Eur. Heart J., 28: 850-856.
8. Yang, G.R., S.Y. Yuan, H.J. Fu, G. Wan and L.X. Zhu *et al*., 2010. Neck circumference positively related with central obesity, overweight and metabolic syndrome in Chinese subjects with type 2 diabetes: Beijing community diabetes study 4. Diabetes Care, 33: 2465-2467.
9. Zhou, J.Y., H. Ge, M.F. Zhu, L.J. Wang and L. Chen *et al*., 2013. Neck circumference as an independent predictive contributor to cardio-metabolic syndrome. Cardiovasc. Diabetol., Vol. 12, No. 1. 10.1186/1475-2840-12-76.
10. Ahmed, A., T.E. Khan, T. Yasmeen, S. Awan and N. Islam, 2012. Metabolic syndrome in type 2 diabetes: Comparison of WHO, modified ATPIII & IDF criteria. J. Pak. Med. Assoc., 62: 569-574.
11. Bruno, G., F. Merletti, A. Biggeri, G. Bargero and S. Ferrero *et al*., 2004. Metabolic syndrome as a predictor of all-cause and cardiovascular mortality in type 2 diabetes: The casale monferrato study. Diabetes Care, 27: 2689-2694.
12. Jacob, B., A.T. George, R. Jose, T.P. Antony and S.R. Sebastain, 2015. Prevalence of metabolic syndrome in newly detected type 2 diabetes mellitus. Acad. Med. J. India, 3: 8-12.
13. Janghorbani, M. and M. Amini, 2012. Incidence of metabolic syndrome and its risk factors among type 2 diabetes clinic attenders in Isfahan, Iran. Int. Schol. Res. Notices, Vol. 2012. 10.5402/2012/167318.
14. Kengne, A.P., S.N. Limen, E. Sobngwi, C.F. Djouogo and C. Nouedoui, 2012. Metabolic syndrome in type 2 diabetes: Comparative prevalence according to two sets of diagnostic criteria in sub-Saharan Africans. Diabetol. Metabolic Syndrome, Vol. 4, No. 1. 10.1186/1758-5996-4-22
15. Nsiah, K., V.O. Shang, K.A. Boateng and F.O. Mensah, 2015. Prevalence of metabolic syndrome in type 2 diabetes mellitus patients. Int. J. Applied Basic Med. Res., 5: 133-138.
16. Nahar, S., M.Z. Rahman, M. Ullah, B.C. Debnath, N. Sultana and C.M.R.Q. Farhad, 2011. Prevalence of metabolic syndrome in newly diagnosed type 2 diabetes mellitus. Cardiovasc. J., 4: 17-25.
17. Tamang, H.K., U. Timilsina, S. Thapa, K.P. Singh, S. Shrestha, P. Singh and B. Shrestha, 2013. Prevalence of metabolic syndrome among Nepalese type 2 diabetic patients. Nepal Med. Coll. J., 15: 50-55.
18. Shehu, A., E. Thengjilli, A. Doko and F. Toti, 2015. The prevalence of metabolic syndrome in patients with diagnosed type 2 diabetes. Endocrine Abstracts, 37: 350-350.
19. Aljohani, N.J., 2014. Metabolic syndrome: Risk factors among adults in Kingdom of Saudi Arabia. J. Family Commun. Med., 21: 170-175.
20. Al-Nozha, M.M., A. Al-Khadra, M.R. Arafah, M.A. Al-Maatouq and M.Z. Khalil *et al*., 2005. Metabolic syndrome in Saudi Arabia. Saudi Med. J., 26: 1918-1925.
21. Nasir, A., A. Nasir, A. Tauqir, J.H. Syed and J. Muhammad, 2010. Frequancy of metabolic syndrome in patients with type-2 diabetes. J. Ayub. Med. Coll. Abbottabad, 22: 139-142.
22. Thiruvagounder, M., S. Khan and D.S. Sheriff, 2010. The prevalence of metabolic syndrome in a local population in India. Biochemia Medica, 20: 249-252.
23. Shimajiri, Y., K. Tsunoda, M. Furuta, Y. Kadoya, S. Yamada, K. Nanjo and T. Sanke, 2008. Prevalence of metabolic syndrome in Japanese type 2 diabetic patients and its significance for chronic vascular complications. Diabetes Res. Clin. Pract., 79: 310-317.
24. Shimokata, H., D.C. Muller and R. Andres, 1989. Studies in the distribution of body fat: III. Effects of cigarette smoking. J. Am. Med. Assoc., 261: 1169-1173.
25. Bamia, C., A. Trichopoulou, D. Lenas and D. Trichopoulos, 2004. Tobacco smoking in relation to body fat mass and distribution in a general population sample. Int. J. Obes., 28: 1091-1096.
26. Barrett-Connor, E. and K.T. Khaw, 1989. Cigarette smoking and increased central adiposity. Ann. Internal Med., 111: 783-787.
27. Canoy, D., N. Wareham, R. Luben, A. Welch, S. Bingham, N. Day and K.T. Khaw, 2005. Cigarette smoking and fat distribution in 21, 828 British men and women: A population based study. Obes. Res., 13: 1466-1475.
28. Seyler Jr, L.E., J. Fertig, O. Pomerleau, D. Hunt and K. Parker, 1984. The effects of smoking on ACTH and cortisol secretion. Life Sci., 34: 57-65.
29. Steptoe, A. and M. Ussher, 2006. Smoking, cortisol and nicotine. Int. J. Psychophysiol., 59: 228-235.
30. Xue, Y., M. Morris, L. Ni, S.K. Guthrie and J.K. Zubieta *et al*., 2010. Venous plasma nicotine correlates of hormonal effects of tobacco smoking. Pharmacol. Biochem. Behav., 95: 209-215.
31. Clair, C., A. Bitton, J.B. Meigs and N.A. Rigotti, 2011. Relationships of cotinine and self-reported cigarette smoking with hemoglobin A1c in the US: Results from the National Health and Nutrition Examination Survey, 1999-2008. Diabetes Care, 34: 2250-2255.
32. Facchini, F.S., C.B. Hollenbeck, J. Jeppesen, Y.D.I. Chen and G.M. Reaven, 1992. Insulin resistance and cigarette smoking. Lancet, 339: 1128-1130.
33. Lee, W.Y., C.H. Jung, J.S. Park, E.J. Rhee and S.W. Kim, 2005. Effects of smoking, alcohol, exercise, education and family history on the metabolic syndrome as defined by the ATP III. Diabetes Res. Clin. Pract., 67: 70-77.
34. Calo, W.A., A.P. Ortiz, E. Suárez, M. Guzmán, C.M. Pérez and C.M. Pérez, 2013. Association of cigarette smoking and metabolic syndrome in a Puerto Rican adult population. J. Immigrant Minor. Health, 15: 810-816.

35. Alzahrani, A.M., A.M. Karawagh, F.M. Alshahrani, T.A. Naser, A.A. Ahmed and E.H. Alsharef, 2012. Prevalence and predictors of metabolic syndrome among healthy Saudi adults. Br. J. Diabetes Vasc. Dis., 12: 78-80.
36. Bahijri, S.M., R.M. Al Raddadi, H. Jambi, M.N.A. Alaama and G. Ferns, 2013. The prevalence of metabolic syndrome in an apparently healthy, normotensive and non-diabetic population in Saudi Arabia by two definitions: Implications for local practice. Open J. Endocr. Metab. Dis., 3: 18-24.
37. Holme, I., S. Tonstad, A.J. Sogaard, P.G.L. Larsen and L.L. Haheim, 2007. Leisure time physical activity in middle age predicts the metabolic syndrome in old age: Results of a 28-year follow-up of men in the Oslo study. BMC Public Health, Vol. 7, No. 1. 10.1186/1471-2458-7-154.
38. Isezuo, S.A. and E. Ezunu, 2005. Demographic and clinical correlates of metabolic syndrome in Native African type-2 diabetic patients. J. Natl. Med. Assoc., 97: 557-563.
39. Kim, B.J., B.S. Kim, K.C. Sung, J.H. Kang, M.H. Lee and J.R. Park, 2009. Association of smoking status, weight change and incident metabolic syndrome in men: A 3-year follow-up study. Diabetes Care, 32: 1314-1316.
40. Gulmez, H. and A. Kut, 2012. Relationship between visceral fat and neck circumference in patients with metabolic syndrome. Endocrine Abstracts, 29: 1280-1280.
41. Kumar, N.V., M.H. Ismail, P. Mahesha, M. Girish and M. Tripathy, 2014. Neck circumference and cardio-metabolic syndrome. J. Clin. Diagn. Res., 8: MC23-MC25.
42. Mohanan, P.P., 2016. Metabolic syndrome in the Indian population: Public health implications. Hypertens J., 2: 1-6.