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EVALUATION OF PERFORMANCE OF LIPID ACCUMULATION PRODUCT (LAP) FOR DIAGNOSING TYPE 2 DIABETES MELLITUS OVER OTHER ANTHROPOMETRIC PARAMETERS (BMI, WC, WHtR)

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ABSTRACT
The prevalence of overweight and obesity is significantly increasing worldwide, with a consequent increase in the incidence of disease such as type 2 diabetes mellitus (T2 DM). One of the major modifiable risk factors for T2 DM is obesity. Clinical evidence indicates a stronger association of diabetes with central obesity than general obesity. In the attempt to identify an anthropometric index able to assess visceral obesity independently of total adiposity, some non-traditional anthropometric indicators have been investigated. The present study is conducted to compare the association between T2 DM and different anthropometric measurements and evaluate the usefulness of these measurements in clinical practice. In this case-controlled study, we enrolled 110 individuals of which 50% cases diagnosed with T2 DM (≥ 22 years age) patients and 50% controls who were screened negative for T2 DM. Anthropometric measurements (BMI, WC, WHtR and LAP) and biochemical estimations were carried out. Simple logistic regression and receiver-operating characteristic (ROC) analyses were conducted. The proportion of cases with high lipid accumulation product (LAP) cut off was 63.6% as compared to 30.9% healthy individuals and this association was statistically significant ($p < 0.05$, OR = 3.91). A strong association between obesity indices and diabetes was identified. LAP showed the highest prediction accuracy among adiposity measures with an area under the ROC curve (AUC) of 0.853. This was significantly higher than the adiposity measure of BMI (AUC= 0.723), WC (AUC= 0.748), and WHtR (AUC= 0.754). The cutoff for LAP was 50.5 with Sensitivity of 71.2%, Specificity of 78.3% and Youden index 0.495. LAP was found to be an accurate and simple predictor of T2DM and had significantly higher predictability than other adiposity measures tested. LAP could be used in clinical practice for suggesting life style modifications.

KEYWORDS: Type 2 diabetes mellitus, Central obesity, Anthropometric indices, Cutoff value, ROC curves.

INTRODUCTION

Diabetes mellitus (DM) is one of the most important public health challenges of the twenty-first century. The prevention and treatment of diabetes is a public health concern in many health systems. There are 380 million people in the world expected to have diabetes by 2025 [1]. By 2035 the prevalence of T2 DM will increase by 55% worldwide with an alarming pace in developing countries such as those in the Middle East and North Africa region (approximately 96.2% increase in prevalence in 20 years). The prevalence of DM among adults in Saudi Arabia is 30% and that figure is expected to be more than double by 2030. Half of the people over 30 years of age are prone to diabetes[2,3]. Saudi Arabia ranks seventh worldwide and the first in the Gulf in terms of diabetes rates [4]. There is a substantial literature referring to obesity as a major risk factor in the development of diabetes. We are in the midst of an obesity pandemic. According to recent statistics on obesity made by the World Health Organization (WHO), over 1.9 billion adults aged 18 years and older worldwide are overweight. Of these 650 million are obese. The worldwide prevalence of obesity nearly tripled between 1975 and 2016. Overall, about 13% of the world's adult population (11% of men and 15% of women) was obese in 2016[5]. In 2010, approximately 35 million overweight children were living in developing countries, compared to 8 million in industrialized countries. The estimated economic burden of obesity in developed countries ranges between 2% and 7% of health care costs, and is higher in developing countries [6,7]. Obesity is fast turning out to be a major cause of concern for the Kingdom with seven out of 10 Saudis suffering from obesity, and 37% of Saudi women facing problems related to overweight. Overweight and obesity affect more than 75% of the total population in Saudi Arabia. Almost all age groups are affected in general and adults particularly[8]. Increased body weight is a major risk factor for the metabolic syndrome. Many previous studies have demonstrated that individuals with metabolic syndrome are at high risk for subsequent development of Type 2 diabetes mellitus (T2 DM). T2 DM is strongly associated with overweight and obesity. With the obesity epidemic on the rise, research on obesity has intensified. The association between obesity and type 2 diabetes mellitus has been reproducibly observed in both cross-sectional and prospective studies[9,10,11], and has been consistent across various populations[12]. Abdominal obesity has been proposed to be a strong risk factor for diabetes, and the current epidemics of these two conditions seem to be related. Several anthropometric measures are being used for screening obesity, diabetes and cardiovascular disease (CVD). Body mass index (BMI) is used as an indicator for generalized obesity and Waist circumference (WC), Waist hip ratio (WHR), Waist Height ratio (WHtR), skin fold thickness are measures of central obesity. Of these, WC is the most reflective indicator of diabetes risk [13]. Clinical evidence indicates a stronger association of diabetes with central obesity than general obesity[14]. Waist circumference is the most widely used measure to quantify central obesity. WC is the best measure of both intra-abdominal fat mass and total fat. WC, a more accurate measure of the distribution of body fat, has been shown to be more strongly associated with morbidity and mortality [15-17]. Central obesity, defined in terms of WC, is known to be a better predictor of many obesity-related health problems, such as hypertension, diabetes, and CVD, than traditional obesity, which is defined according to BMI [18]. However, WC does not account for differences in height, and could thus lead to overestimation or underestimation of risk for tall and short individuals, respectively [19].

Waist-to-weight ratio (WHtR) is an easy and inexpensive adiposity index that reflects central obesity. Waist-to-height ratio (WHtR) is an alternative measurement for visceral fat. It corrects WC for height and is supported as an index that can be used in different ethnic, age and sex groups for central obesity screening[20]. A systematic review published in 2010 concluded that WHtR may be advantageous because it avoids the need for age-, sex-, and ethnicity-specific values[21]. Recent studies found that a WHtR cut-off value of ≥0.5 identified people with high adiposity and was strongly associated with cardiovascular disease. Associations between certain adiposity indexes (such as BMI, WC, WHR, and WHtR) and diabetic risk have been investigated in cross-sectional studies[19,21]; however, these studies have yielded inconsistent results.

Central obesity is the most prevalent manifestation of metabolic syndrome (MS). Recently, Kahn proposed the use of lipid accumulation product (LAP), a novel index of central lipid accumulation, to predict the risk of MS. LAP is a gender-specific index based on a combination of WC and serum triglyceride levels (TG) in its equation. Thus, it uses a physical and a simple laboratory parameter to predict the MS. It has given utmost importance to WC which is considered to be an integral and predominant determinant of cardiovascular outcomes. Thus LAP can be applied easily on a day to day clinical practice to predict MS[22,23]. The LAP is proposed as simple, accurate, and low-cost tool for the evaluation of visceral adipose tissue dysfunction and its associated cardio metabolic risk in adult population, even superior than simple anthropometric parameters (*e.g.*, BMI, WC). The LAP method was shown to predict diabetes[24-26] and recognize cardiovascular risk[27] better than BMI in previous studies. Lap is also associated with all-cause mortality in non-diabetic patients at high cardiovascular risk[28] and all-cause, cardiovascular and congestive heart failure mortality in postmenopausal women[29]. LAP has also been applied to the Chinese population for predicting diabetes. The results of receiver-operating characteristic (ROC) curves and areas under curves (AUCs) analysis indicated that LAP was able to predict diabetes better than WHR, WC, and BMI, in both men and women [30]. The aim of the present study was to compare the association between T2 DM and different anthropometric measurements reflecting obesity and evaluate the practicability and usefulness of these measurements in clinical practice and public health.

MATERIALS & METHODS

The present study was a case control study comprising of 55 cases prospectively recruited from King Abdulaziz University health clinic, Jeddah in Saudi Arabia and 55 controls also recruited prospectively from the employees of the University (Case control in the ratio of 1:1).The study protocol was approved by institutional ethical committee. Written informed consent was obtained from each participant before data collection. Processes, including anthropometry measurements, questionnaire, and blood drawing, of this survey were all conducted in University health clinic. Demographic information was recorded. Cases were the patients diagnosed with T2 DM attending University health clinic. Inclusion criteria for cases was, age ≥ 22 years diagnosed with T2 DM at least since two years, willing to participate. Patients of T2 DM having severe co-morbidities like stroke, chronic renal diseases and chronic lung disease at the time of recruitment into the study, serious trauma, infection, and history of blood disorders were excluded from the study. Controls were the individuals not having T2 DM, selected from the university employees. Controls were defined as individuals, age ≥ 22 years, willing to participate and who were not suffering from T2 DM. Diabetes was ruled out by screening the participants at the time of enrolment into the study by random blood glucose (RBS) estimation using a glucometer (Accu-Chek Active Blood Glucose Monitoring System). Subjects with RBS < 7.8 mmol/l were eligible to be included as controls [31]. Participants came to the health service centers after an overnight fasting of 8-12h. Participants wore light clothes, without shoes when anthropometric indices were obtained. Weight, height, and WC were measured twice with the average taken, and these measurements were finished by the same examiner. Body weight was measured on an electronic body scale to the nearest 0.1kg. Height, and WC were measured by a measuring tape and recorded in centimeters, to the nearest 0.1cm in standing position. Waist measurements were made at the level of the umbilicus at the end of a normal expiration. We calculated BMI as bodyweight (kg) divided by squared height (m), and WHtR as WC (cm) divided by height (cm).

Blood pressure (BP) was measured by a standard mercury sphygmomanometer (Riester, Germany), after seating the subject for at least 15 minutes. BP was considered normal if systolic BP < 130 mmHg and diastolic BP < 85 mmHg, or high if systolic BP ≥ 130 mmHg and/or diastolic BP ≥ 85 mmHg[32]. Investigators completed questionnaires by asking participants questions about demographic characteristics, disease history, and family history. All surveys were performed by trained staff.

The following anthropometric classifications were used:

1). BMI: underweight <18.5 kg/m^2,normal 18.5 - 24.99 kg/m^2 , overweight ≥ 25 kg/m^2, obese ≥ 30 kg/m^2.

2). WC: normal ≤ 90 cm for men, high > 90 cm.

3) WHtR: normal < 0.5, high ≥ 0.5.

4) LAP: normal < 50, high ≥ 50.

Blood samples were taken for the determination of the fasting blood sugar, glycated hemoglobin (HbA1c) and lipid profile. Blood samples were collected after overnight fasting and serum was obtained. The serum was analyzed using an auto-analyzer (Roche Modular P-800, Germany) at King Abdulaziz University health clinic. LAP for men was calculated using the formula [24-27,30]:

$$\text{LAP} = [\text{waist circumference (cm)} - 65] \times [\text{triglycerides concentration (mmol/l)}]$$

Statistical analyses were performed using SPSS version 17.0 software. Receiver operating characteristic (ROC) curves were performed and the discriminating ability of BMI, WC, WHtR and LAP was estimated by determining area under the ROC curve (AUC) and its 95% confidence interval (95% CI) and the optimal cutoff value [32-34]. Diagnostic performance and the optimal cut-off value for each measures were determined using Youden index (J), calculated as: J = maximum (sensitivity + specificity -1) in ROC space [32-37]. Values for each AUC can be between 0 and 1, with values greater than 0.5 desirable. A value of 1 signifies perfect diagnostic accuracy. A parameter possesses accurate diagnostic sensibility when the AUC value is greater than 0.75 [36,38]. In statistical analysis, the values of p less than 0.05 were considered as a significant level.

RESULTS

The characteristics of 110 participants included in the analysis are presented in Table 1.The age of the study subjects ranged from 22 to 70 years, with a mean age (± standard deviation) of 45.36 ±4.92 years (44.69 ±6.90 in controls and 46.03 ±7.01 in controls). Prevalence of diabetes was inversely correlated with educational levels (p= 0.001) and the highest prevalence rate was observed in low educated groups (38.2% vs. 12.7% in primary and graduate and above educated, respectively) [Table 1]. Compared to controls, cases were more smokers and were more likely to have a family history of diabetes [Table 1].

TABLE 1. Descriptive characteristics of the study population

Characteristics	Controls (n=55)	Diabetes (n=55)
Socio-demographic data		
Age (years)	44.69 ± 6.90	46.03 ± 7.01
Sex	Male	Male
Education		
Primary	11.2 %	38.2 %
Intermediate	40.6 %	27.3 %
Secondary	43.2 %	21.8 %
Graduate & above	5.1 %	12.7 %
Marital status		
Married (%)	85.8 %	98.3 %
Unmarried (%)	14.2 %	1.7 %
Current smoker	66.2 %	87.6 %
Family history of diabetes (yes %)	27.5 %	71.3 %
Anthropometric data		
Hypertension (yes %)	39.9 %	57.1 %
Fasting blood glucose (mmol/l)	4.35 ± 0.86	10.21 ± 3.79
HbA1c (%)	5.34 ± 0.92	9.74 ± 2.35
Serum triglycerides, TG (mmol/l)	1.34 ± 0.80	2.10 ± 1.02
HDL-c (mmol/l)	1.37 ± 0.81	1.01 ± 0.31
Body mass index, BMI (kg/m^2)	25.06 ± 2.75	29.78 ± 3.75
Waist Circumference, WC (cm)	90.54 ± 9.43	99.62 ±10.93
Waist-to-height ratio, WHtR	0.53 ± 0.06	0.58 ± 0.08
Lipid Accumulation Product, LAP (cm.mmol/l)	48.91 ± 8.71	67.20 ± 10.29

Among 78% of the subjects, the duration of diabetes was less than ten years. Among the cases, the majority were on metformin-based medication or on combination therapy with sulphonylureas[39]. Hypertension (57.1%) was the most common co-morbidity among the cases as documented in our records. Our results revealed that none of the diabetic subjects had their blood glucose levels within the suggested normal limits, as per the test – fasting blood sugar (FBS), random blood sugar (RBS), and glycated hemoglobin (HbA1c). Patients with T2 DM had a significantly higher WC, BMI, WHtR, LAP and had a higher levels of TG as well as lower levels of HDL-c concentrations than non-diabetics (control subjects). We observed significant association of obesity indices with T2 DM.According to BMI categories (Table 2) the proportion of cases with BMI ≥25 kg/m^2 among cases was 65.4% as compared to controls among whom only 32.7% individuals had BMI ≥25 kg/m^2 and this association was found to be statistically significant, with the odds being highest when BMI was ≥30 ($p < 0.05$). The proportion of cases with more than normal waist circumference (Table 2) was 70.9% as compared to 41.8% healthy individuals and this association was also found to be statistically significant ($p<0.05$). Statistically significant association was also noted with WHtR (OR=3.66) and LAP (OR=3.91) (Table 2).

TABLE 2. Association between anthropometric indices among cases and controls

Anthropometric variables	Cases n (%)	Controls n (%)	Chi-square value	p-value	Odds ratio	95 % CI
BMI category (kg/m^2)						
Underweight (< 18.5)	4 (7.3)	7 (12.7)			0.54	0.09 – 1.59
Normal (18.5-24.99)	15 (27.3)	30 (54.6)	12.15	0.006	1.00	
Overweight (≥ 25)	23 (41.8)	13 (23.6)			2.32	0.88 – 4.50
Obese (≥30)	13 (23.6)	5 (9.1)			3.09	1.65 – 7.28
WC						
Normal	16 (29.1)	32 (58.2)	9.46	0.004	1.00	
Abnormal (≥ 90 cm)	39 (70.9)	23 (41.8)			3.39	1.78 – 8.25
WHtR						
Normal	16 (29.1)	33 (60)	10.63	0.002	1.00	
Abnormal (>0.50)	39 (70.9)	22 (40)			3.66	1.65 – 8.36
LAP						
Normal	20 (36.4)	38 (69.1)	11.82	0.001	1.00	
Abnormal (>50)	35 (63.6)	17 (30.9)			3.91	1.74 – 9.07

TABLE 3. Cutoff value, Sensitivity, Specificity, Youden's index, and AUC for different anthropometric measures among males

Anthropometric measure	Optimal cutoff value	Sensitivity	Specificity	Youden's index	AUC (95% CI)
BMI	25.6	0.654	0.771	0.425	0.723 (0.589 - 0.681)
WC	94.3	0.662	0.781	0.443	0.748 (0.608 – 0.692)
WHtR	0.52	0.606	0.857	0.463	0.754 (0.602 – 0.701)
LAP	50.5	0.712	0.783	0.495	0.853 (0.767 – 0.840)

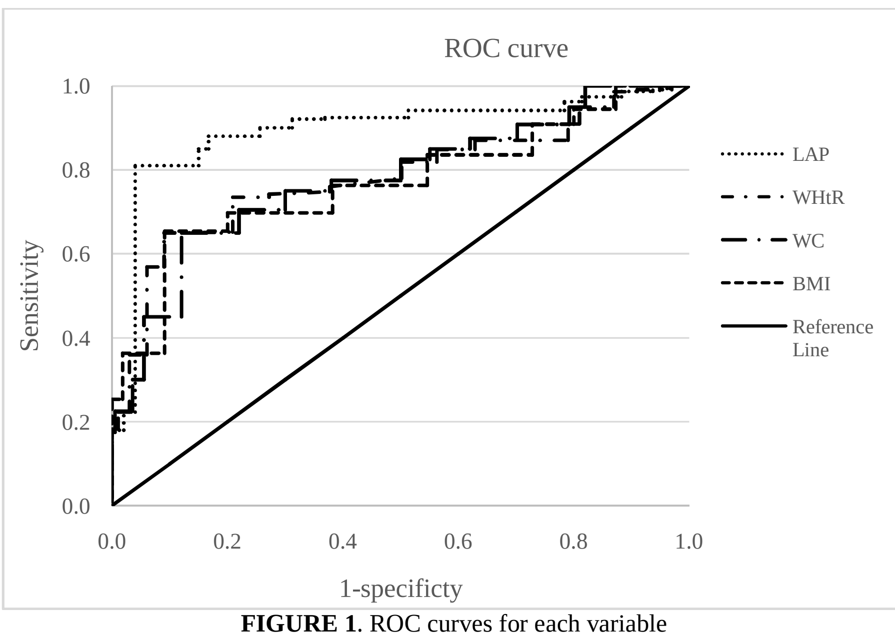

FIGURE 1. ROC curves for each variable
AUC - LAP: 0.853 (CI: 0.767 – 0.840); WHtR: 0.754 (CI: 0.620 – 0.701);
WC: 0.748 (CI: 0.608 – 0.692); BMI : 0.723 (CI: 0.589 – 0.681)

Figure 1 shows the ROC curves for BMI, WC, WHtR and LAP for detecting T2 DM in men. The area under ROC curves (AUC) was 0.723 (95% CI: 0.589 – 0.681) for BMI, 0.748 (95% CI: 0.608 – 0.692) for WC, 0.754 (95% CI: 0.620 – 0.701) for WHtR, and 0.853 (95% CI: 0.767 – 0.840) for LAP, as shown in Table 3. The LAP had the highest AUC value (AUC=0.853), followed by WHtR, WC and BMI. Optimal cut-off points of obesity indices for type 2 diabetes mellitus are shown in Table 3 which are identified according to best Youden indices on ROC curves. Sensitivity and specificity of different cut-off points of obesity indices for screening type 2 DM are also shown in Table 3. The cut-off for LAP is 50.5 with Sensitivity of 71.2%, Specificity of 78.3% and Youden's index 0.495.

DISCUSSION

Obesity and diabetes are emerging pandemics in the 21st century. Both are major public health problems throughout the world and are associated with significant, potentially life-threatening co-morbidities and enormous increase in costs of healthcare. There is a strong association between obesity and type 2 diabetes. The increase in the prevalence of diabetes parallels that of obesity. Some experts call this dual epidemic "*diabesity*". Although obesity is well recognized, T2 DM often goes undetected[40] until patients presents with diabetic complications. Diabetes is becoming an epidemic in Saudi Arabia. T2 DM is a major public health issue that needs to be explored in terms of aetiology, prevention and early disease detection. Therefore there is an urgent need to generate an easy, understandable and effective ways for prevention of diabetes among Saudis. Anthropometric parameters are a simple and useful tool that can be used to screen for T2 DM. Compared with more sophisticated methods such as MRI and CT, anthropometric parameters are generally easy to use, portable, and affordable and also pose no risk to patients [41]. The Diabetes Prevention Program sub study showed that visceral fat measured by CT provided no significant advantage over simple measures in predicting the development of diabetes[42]. Therefore, the use of anthropometric measures is an alternative for ill-equipped or inadequately supported rural general practitioners to assess the risks of their patients quickly, easily and inexpensively. There is some evidence that the association of anthropometric measurements with T2 DM risks varies across markers. For example, unfavorable body fat distribution has been found to be more strongly associated with T2 DM than increased body mass index (BMI) alone [43]. Anthropometric parameters above the threshold cutoff values were found to be predictors of diabetes and other cardiovascular risk factors in various populations even though it is not clear which anthropometric parameter is ideal for a particular population. Various adiposity indices have been studied to assess the risk of diabetes. However, no definite measurement tools or index for best predicting diabetes has yet been identified. The most widely studied indices are BMI. WC, WHpR, WHtR, VAI, CI and LAP [19,21].There has been much discussion and no clear consensus on which obesity measure is the most sensitive or specific for detecting diabetes. Previous studies comparing BMI, WC, WHtR and LAP for predicting the incidence of diabetes have been inconsistent [11,21,34,37,44-47] with a very few studies addressing these issues in the Saudi population. The aim of the present study is to compare the use of these anthropometric markers in Saudi individuals and determine the best obesity indicators.

The findings of the present study indicated a positive relationship between diabetes and different anthropometric parameters (LAP, WHtR, WC, BMI), as well as an inverse relationship between diabetes and educational level. This study identified LAP, WHtR and WC to be associated with T2 DM better than BMI. The odds of a diabetic individual having high LAP value was 3.91 times more as compared to a non-diabetic individual.

Analysis of ROC curves demonstrated that among men, LAP had the best discriminatory power compared with other parameters, while BMI was the weakest predictor. The AUC of LAP was the highest among the four adiposity indices. The present value for AUC of LAP is in agreement with the previous studies[25,26,34]. Studies presented more discriminatory capacity of LAP for the incidence of diabetes than BMI and similar to WC, WHpR and WHtR [24,25,26,29,34]. The results of a very recent study exhibited greater detecting power of LAP than BMI and WC[48].

The advantage of LAP over BMI is that the former can differentiate between visceral adipose tissue and subcutaneous adipose tissue. Increased Visceral adiposity is prone to more lipolysis, leading to development of insulin resistance further progressing to impaired glucose tolerance and overt diabetes mellitus [49]. Hence transition from obesity to T2 DM is not merely due to increase in body weight but it is due to increased lipid accumulation in ectopic sites[50]. Detection of ectopic lipid is difficult but increase in LAP will reflect the increase in ectopic lipid tissue which is highly lipolytic and can injure organs like pancreas, liver *etc*. Whereas increase in BMI can be due to increase in lean tissue, increase in protective subcutaneous tissue or due to fluid retention[51].

Recently, Roriz *et al*.[52], was the first one evaluating the performance of LAP for discriminating visceral fat and observed correlations over 0.70 in men and over 0.60 in women, with area under the ROC curve over 0.78 and cutoffs ranging from 26.4 to 37.4 in men and from 40.6 to 44.0 in women, showing the good accuracy of this indicator.

Some previous studies reported that the AUC for anthropometric indices were higher in females [21,35,37,46,48], which indicated that anthropometric indices of females correlated more closely to diabetes mellitus than that of males. As is well known, the bodies of males are larger and the percentages of body fat of males are lower than that of females. As a result, anthropometric indices reflected obesity and fat mass more accurately in females. We could not include females in our study. Further studies are needed, with large samples including female participants, to check better discriminatory power of LAP over other anthropometric indices. Different authors also showed that LAP had significantly higher predictability of Metabolic Syndrome in men and women than other adiposity measures [23,36,53,54]. In a recent cross-sectional study with 180 T2 DM patients and 119 controls [55], the authors speculated that novel visceral adiposity indices, such as VAI and LAP had no advantages over simple anthropometric indices or lipid parameters in prediction of T2 DM risk.

Experts generally agreed that the basis for effective use of obesity cutoff points in clinical and public health related to health outcomes rather than percent body fat. These health outcomes included myocardial infarction, stroke, dyslipidemia, and T2 DM. T2 DM was identified as the health outcome to choose cutoff points of adiposity indices in this study. Methods of deciding optimal cutoff points through ROC were reviewed by Hajian-Tilaki [37], one of which we used here was named Youden's Index. Sensitivity and specificity were regarded as equally important in this method. A similar method had been used by different authors [32,34,35,36,46]. Our data indicated that optimal cutoff points of obesity for BMI, WC, WHtR and

LAP were 25.6, 94.3, 0.52 and 50.5 in males. It is interesting to note that the optimal cutoff point of LAP for males in this study [50.5 with Sensitivity of 0.712, Specificity of 0.783 & Youden's index 0.495] is in line with published value of Dev *et al*. [34]. However, the present value is higher than the values reported by other investigators[25,48,52]. Previous studies reported that optimal cutoff points of obesity indices were higher in males than compared to that in females[21,25,35,37,48]. We strongly suggest additional studies including female participants.

Many studies have suggested the use of ethnic-specific cutoff points for assessing diabetes risk[19,21,25,30,32,37,46,52,53]. As for the population-specific anthropometric cutoff points, data from Asian populations have revealed that lower values of general and central obesity measures might be meaningful for the identification of individuals at risk of diabetes [19,30,46]. One study recommended for the Arab populations to have their own anthropometric cutoff points to illustrate their ethnic variations, a matter that requires further studies using representative large sample size[32]. However, there is insufficient evidence for specific cutoffs for the identification of type 2 diabetes in Saudi population. Therefore, further studies are needed to elucidate whether the cutoff value for a high LAP proposed in this study are applicable to people of other races and ethnicities in Saudi Arabia.

The prevalence of diabetes appears to vary between racial and ethnic groups. A racial difference has been shown in the relationship between insulin resistance and the ratio of triglycerides to HDL-c, another good lipid-related index [25]. Therefore, further studies are needed to elucidate whether the high cutoff value for LAP obtained in this study are applicable to people of other races and ethnicities. There is information about the LAP cutoffs to detect other events, among them, a study with Spanish adults [56] identified the LAP value above 48.9 in men and 31.7 in women to detect metabolic syndrome. Also, previous studies reported that LAP better than other variables (*e.g*., BMI, WC and WHtR) predicted metabolic syndrome (MS), T2 DM and CVD [24,26,27,34,36,48,53, 54,57,58].

Type 2 diabetes is a major, and largely reversible, cardiovascular risk factor. About one third of patients will have the classic diabetic dyslipidemia consisting of raised plasma TG, low HDL-c and only moderately, if at all, raised LDL-c. It is important to note that the patients who used hypolipemics, used stains. Different studies showed an increased risk of T2 DM with stains usage [55,59,60]. Cederberg *et al.*[59] in a large study comprise of about 9,000 non-diabetic participants, during a 6-year follow-up showed that stain treatment increased the risk of T2 DM by 46%, mainly due to decrease in insulin sensitivity (by 24%), and insulin secretion (by 12%), compared with individuals without stain treatment.

Although this study has cross-sectional design which precludes causal inferences, we speculate that novel visceral adiposity index, such as LAP, may be the most sensitive marker for T2 DM. Large longitudinal studies are needed to further examine the potential benefits for discriminating ability of LAP for T2 DM specific for the Saudi population.

It is estimated that nearly half of T2 DM cases are not even diagnosed, and thus remains untreated[61]. Early screening of T2 DM in a high risk population and dietary and lifestyle intervention play an important role in reducing the incidence of T2 DM and improving the quality of life. LAP is cost effective, reliable, having better discriminating performance and easily measureable obesity index which can be utilized by clinicians as an appropriate discriminative tool for identification of diabetes either in hospital or community settings.

Overweight, obesity and T2 DM are largely preventable with change in life style and avoidance of sedentary habits and over-consumption of energy. Observational and interventional studies have clearly shown that type 2 diabetes can be prevented by lifestyle measures, including reduced energy intake to induce a modest but sustained weight reduction, together with changes in diet composition[62]. Current clinical guidelines acknowledge the therapeutic strength of exercise intervention for prevention and treatment of diabetes. Healthy lifestyle, with combination of physical exercise and a balanced diet, has a positive impact on body weight control, and hence should be strongly promoted, particularly among populations that experience socio-economic transitions. The cornerstones for a weight reduction program for obese patients with diabetes include a moderately hypocaloric diet, an increase in physical activity and behavior modifications. Even though evidence suggests that patients are considerably more likely to lose weight when they are advised to do so by their primary care physicians (PCP), most patients who are clinically obese do not receive weight-loss counseling in primary care. Studies have provided evidence that PCP can deliver safe and effective weight loss interventions [63,64]. All obese people should be screened for depression and anxiety and specifically for eating disorders because all these conditions can impair the patient's quality of life and can also interfere with successful management[65]. Before starting the treatment the assessment of patient's motivation and readiness for change is crucial for the outcome of the obesity management. This can be done by using the American NHLBI clinical guidelines[66,67]. After this comprehensive assessment of the patient we can plan the suitability of the patient to the various modalities of obesity management taking into consideration Severity of Obesity, the status of Diabetes control and complications, Co-morbid conditions and their control, present lifestyle, motivation levels and the current stage of change [68]. CVD is a major complication and the leading cause of early death among people with T2 DM. Health promotion and patient education should be given priority to combat CV complications in T2 DM patients. A multidisciplinary approach involving patients, health professionals, and researchers should be undertaken to reduce the incidence and prevalence of T2 DM and CVD, and improve the quality of life and well-being of patients.

CONCLUSION

Among the various adiposity indices tested, LAP was found to have the best discriminatory power. LAP is cost effective, easily measureable obesity index can be utilized by clinicians as a tool to discriminate diabetes in obese subjects.

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