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Original Article

Physiology Section

Assessment of Anthropometric Variables in Type-2 Diabetes Mellitus among 4,473 Subjects in 10 Wards of Urban Belagavi District, North Karnataka, India: A Community-based Cross-sectional Study

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ABSTRACT

Introduction: Type-2 Diabetes Mellitus (T2DM) is a global epidemic and a serious risk for the younger generation. A sedentary lifestyle, urbanisation, and poor dietary choices are cornerstones of diabetes. Early detection of risk factors and prevention of their progression can go a long way in delaying the onset of the disease and reducing the economic burden due to its secondary complications.

Aim: To assess anthropometric variables of T2DM among the population in Belagavi, North Karnataka, India.

Materials and Methods: A community-based cross-sectional study was conducted among a study population of 4,473 individuals in 10 wards of urban Belagavi district from September 2021 to September 2023 by house-to-house visits. The 10 wards were selected using a random allocation method by computer-generated random sequence. The study population was divided into three groups: the diabetic group, children of the diabetic group, and a healthy non diabetic group (Group-1, Group-2, and Group-3) with population sizes of 649, 855, and 2,969, respectively. Anthropometric parameters were recorded by trained nurses using measuring tapes, stadiometers, and weighing scales. Data were analysed using Statistical Package for Social Sciences (SPSS) 24.0 software. One-way Analysis of Variance (ANOVA) test was used to compare the data between the three groups. The Pearson's correlation test was used to find the association between Body Mass Index (BMI) and Waist Hip Ratio (WHR). A p-value less than 0.05 was considered significant.

Results: There were no significant differences found in anthropometric parameters among the three groups (p>0.05). However, when comparing anthropometric parameters between different generations, a statistically significant difference was observed in Neck Circumference (NC) and WHR. Further, association between BMI and WHR among the three groups revealed that WHR is a better indicator of obesity compared to BMI, with a statistically significant p-value of 0.03. WHR detected 424 (90.4%), 463 (91.32%), and 1,220 (87%) obese cases in Group-1, Group-2, and Group-3, respectively, compared to BMI, which detected 371 (58.51%), 440 (52.25%), and 1,202 (41.91%) obese cases in Group-1, Group-2, and Group-3, respectively.

Conclusion: The NC and WHR are better indicators of anthropometric measurements. Anthropometry could be a non invasive, cost-effective predictive tool for the future risk of developing DM. The present study determined there is an impending need to conduct regular screening programs for early identification of anthropometrics other than BMI, WHR, and NC.

Keywords: Anthropometry, Hyperglycaemia, Sedentary lifestyle

INTRODUCTION

Diabetes mellitus is a group of metabolic diseases characterised by hyperglycaemia resulting from defects in insulin secretion, insulin action, or both [1]. It has been estimated that around 366 million people worldwide, or 8.3% in the age group of 20-79 years, had T2DM in 2011. This figure is expected to rise to 552 million (9.9%) by 2030 [2]. Indians characteristically have increased insulin resistance, greater abdominal adiposity (higher waist circumference despite lower BMI), and a higher prevalence of impaired glucose tolerance, which contributes to a greater risk of developing the disease at a relatively younger age. Epidemiological transition, economic growth, physical inactivity, trendy dietary patterns, and environmental factors also add to this risk [3]. An urbanised lifestyle, like changing food habits, sedentary working patterns, and stress, are the risk factors that make the population more vulnerable to diabetes mellitus [4].

Several genes like CAPN10, TCF7L2, PPARG, IRS-1 and IRS-2, KCNJ11, WFS-1, HNF1A, HNF1B, HNF4A, TCF7L2, etc., have been identified which have been associated with the various forms of diabetes [5]. Most studies focus on the genetic inheritance of the disease, but there are very few studies that focus on the anthropometric changes that have taken place over time in subsequent generations of diabetics and the epidemiological causes for such changes if any [6-8]. The lack of focus on epidemiological studies has resulted in poor preventive strategies when it comes to diabetes. Much emphasis has been placed on treating DM and associated complications, but little effort has been made towards the prevention of the same. Early detection of the risk factors and prevention of their progression can go a long way in delaying the onset of the disease and reducing the economic burden due to its secondary complications.

Considering this scenario, the literature survey revealed that there were no major studies conducted in Belagavi, India to address this problem. Hence, the present study was undertaken with the aim to assess the anthropometric factors related to T2DM among Belagavi, North Karnataka, India. The primary objectives of the study were to compare the anthropometric parameters between three groups (Group-1: Normal Control, Group-2: Healthy Children of Diabetics, and Group-3: Healthy Subjects) and to compare the anthropometric parameters of the diabetics between three generations (First, Second, and Third). The secondary objective of the study was to find an association between BMI and WHR among Group-1, 2, and 3, respectively.

MATERIALS AND METHODS

A community-based cross-sectional study was conducted among a study population of 4,473 individuals from 10 wards of urban Belagavi districts through house-to-house visits. The study period was from September 2021 to September 2023. The study was approved by the Institutional Ethical Committee via Reference: KLEU/Ethic/2012-13/D4565 dated 18/03/2013.

The 10 wards were selected using a random allocation method with a computer-generated random sequence placed in a sealed opaque envelope. The study protocol was explained to all participants, and written consent was obtained. Data collection started with a general discussion to build rapport with the subjects and establish confidence. Subjects who could not be contacted during the initial visit were contacted subsequently during weekends based on their convenience. The proforma included fields for name, age, gender, clinical history, family history, and recording of anthropometric measurements.

Sample size: According to the literature survey, assuming approximately a 13% prevalence of diabetes with a 95% Confidence Interval (CI) and a possible error of 10%, we initially screened a total of 5,150 people. However, only 4,473 individuals consented to participate in the study [9].

- **Grouping:** The study population of 4,473 individuals was categorised into three groups as follows:

  Group-1: (n=649) consisting of patients with diabetes mellitus diagnosed before screening.

  Group-2: (n=855) Healthy children of diabetic patients.

  Group-3: (n=2,969) Non diabetic individuals with no family history of diabetes.

- **Subgrouping:** Group-1 was further subdivided into first-generation known diabetics, second-generation, and third-generation diabetics.

Inclusion criteria: All study subjects aged 18-60 years, patients with a history of diabetes mellitus, children of patients with diabetes mellitus, and healthy individuals from urban wards of Belagavi, Karnataka, who were willing to participate in the study were enrolled as study participants.

Exclusion criteria: Patients with chronic disorders or diseases like collagen vascular disorders or infections like tuberculosis, which may affect their anthropometric parameters due to underlying diseases, were excluded from the study.

Study Procedure

The data was collected by trained nursing staff to gather information and record all anthropometric measurements. All instruments were standardised for anthropometric measurements. Pilot testing was initially conducted on 100 medical students and then on 100 nursing staff to determine the reliability and validity of the proforma and measurements.

Study parameters:

1. **Diagnosed cases of T2DM:** Individuals with a history of diabetes or who were receiving diabetes drug treatment.
2. **Family history of diabetes:** Subjects with one or both parents/grandparents having diabetes were considered to have a positive family history.
3. **Weight in kg:** Body weight was measured (to the nearest 0.01 kg) with the subject standing still on the electronic weighing scale, feet about 15 cm apart, and weight equally distributed on each leg. Subjects were instructed to wear minimal outerwear (as culturally appropriate) and no footwear while their weight was being measured.
4. **Height in cm:** Height was measured using a non stretchable tape (to the nearest 0.1 cm) with the subject in an erect position against a vertical surface and the head positioned so that the top of the external auditory meatus was level with the inferior margin of the bony orbit [7].
5. **Body Mass Index (BMI):** BMI was calculated using the formula: weight (kg) / height (m^2). Individuals were categorised as underweight with BMI <18.5, normal range with BMI 18.5-22.9, overweight with BMI >23-24.9, obese-1 with BMI 25-29.9, and obese-2 when BMI >30 kg/m^2 [10].

   The subjects with a BMI >23 kg/m^2 and a WHR >1.0 in males and >0.8 in females were considered in the obese category.

   The subjects with a BMI <23 kg/m^2, and WHR <1.0 in males and <0.8 in females were categorised in the non obese category.
6. **Waist circumference in cm:** Waist circumference (to the nearest 0.1 cm) was measured using a tailor's tape at a point midway between the tip of the iliac crest and the last costal margin in the back and at the umbilicus in the front. The International Diabetes Federation (IDF) standard cut-offs of ≥88 cm and ≥90 cm were used for women and men, respectively. This measurement is an indicator of abdominal obesity [11].
7. **Hip circumference in cm:** Hip circumference was measured at the widest portion of the hip (at the level of the greater trochanters) to the nearest 0.1 cm with a measuring tape, while the subject was standing with the arms by the side and feet together [11].
8. **Neck Circumference in cm (NC):** Neck circumference was obtained with the subject sitting with the head in a horizontal plane position. A measuring tape was applied around the neck below the laryngeal prominence and perpendicular to the long axis of the neck. The minimal circumference was measured and recorded to the nearest 0.1 cm [12].
9. **Waist/Hip Ratio (WHR):** The WHR was calculated as the ratio of waist circumference to hip circumference [11]. A WHR of >0.9 for males and >0.8 for females was defined as truncal obesity.

STATISTICAL ANALYSIS

The data were analysed using International Business Machines (IBM) Corp. Released in 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp. A one-way ANOVA test was used to compare the data among the three groups. An independent t-test was used to compare anthropometric parameters between the groups. A p-value less than 0.05 was considered significant. The association between BMI and WHR among the three groups of the study population was assessed using the Chi-square test.

RESULTS

The three groups were analysed for anthropometric comparison by ANOVA Test. No significant difference was found in the anthropometric parameters among the three groups (p>0.05) [Table/Fig-1].

The results of the comparison of anthropometric parameters between the 1st, 2nd, and 3rd generations of diabetics in the study population were analysed by ANOVA test and showed a significant difference in WHR (p=0.06) and NC (p=0.032) [Table/Fig-2]. The weight also increased across three generations but was statistically insignificant (p=0.703). This indicates that as the generation progresses, individuals are becoming metabolically obese compared to their previous generations.

The comparison of anthropometric parameters between two generations showed an increased weight, waist, hip, and WHR from the 1st to the 2nd and 3rd generations. Waist hip circumference was significantly increased from the 1st to the 3rd generation (p=0.029)

Anthropometric parameters	Group-1- Study subjects diagnosed with DM	Group-2-Healthy children's of DM diagnosed subjects	Group-3-Healthy subjects with no history of DM	p-value
Height (cm)	154.15±10.93	154.18±10.97	153.06±11.20	0.11
Weight (kg)	69.60±10.39	69.15±10.60	68.40±10.45	0.125
Waist circumference (cm)	100.21±9.41	98.48±9.73	90.77±9.56	0.661
Hip circumference (cm)	97.58±5.45	98.04±5.39	96.84±5.41	0.319
WHR	1.02	1.0	0.94	0.51
Neck circumference (NC) (cm)	34.82±1.74	34.61±1.76	34.46±1.73	0.274
BMI (kg/m²)	29.6±5.6	28.7±5.9	27.9±6.1	0.26

[Table/Fig-1]: Comparison of anthropometric parameters between three groups.
WHR: Waist hip ratio; BMI: Body mass index

Anthropometric parameters	Generations of DM study population			F-value	p-value
	1st Gen	2nd Gen	3rd Gen		
Height (cm)	154.21± 11.16	154.22± 10.70	154.24± 11.06	0.081	0.922
Weight (kg)	68.54± 10.28	68.58± 10.54	69.59± 10.27	0.353	0.703
Waist circumference (cm)	98.71± 9.30	99.75± 9.37	101.14± 9.34	2.826	**0.060**
Hip circumference (cm)	98.04± 5.49	98.57± 5.41	99.63± 5.52	1.700	0.183
WHR	1.01	1.01	1.02	0.22	0.09
Neck circumference (NC) (cm)	34.03± 1.71.74	34.21± 1.72	34.54± 1.7	3.445	**0.032**
BMI (kg/m²)	29.2±6.28	29.21± 6.09	29.4± 5.9	0.52	0.52

[Table/Fig-2]: Comparison of anthropometric parameters between different generations by ANOVA test.
WHR: Waist hip ratio; BMI: Body mass index

and from the 2nd to the 3rd generation (p=0.018). Similarly, there was a significant increase in NC from the 1st to the 3rd generation (p=0.023), and also from the 2nd to the 3rd generation (p=0.009). WHR was significantly increased from the 2nd to the 3rd generation (p=0.023). It was also observed that the BMI remained more or less the same, whereas WHR, weight, waist, and NC showed an increase across the generations [Table/Fig-3].

Anthropometric parameters	Genera-tions	p-value	Genera-tions	p-value	Genera-tions	p-value
Height (cm)	1st	0.740	1st	0.763	2nd	0.893
	2nd		3rd		3rd	
Weight (kg)	1st	0.954	1st	0.422	2nd	0.408
	2nd		3rd		3rd	
Waist circumference (cm)	1st	0.747	1st	**0.029**	2nd	**0.018**
	2nd		3rd		3rd	
Hip circumference (cm)	1st	0.074	1st	0.983	2nd	0.360
	2nd		3rd		3rd	
Neck circumference (NC) (cm)	1st	0.525	1st	**0.023**	2nd	**0.009**
	2nd		3rd		3rd	
WHR	1st	0.069	1st	0.206	2nd	**0.023**
	2nd		3rd		3rd	
BMI (kg/mt²)	1st	0.648	1st	0.858	2nd	0.652
	2nd		3rd		3rd	

[Table/Fig-3]: Comparison of anthropometric parameters in-between different generations.
WHR: Waist hip ratio; BMI: Body mass index; independent t-test

Obesity, as defined by BMI, was compared with that defined by WHR among DM patients of Group-1, and both were found to be significantly different (p=0.03). Among the DM population, as per WHR classification, 424 (90.4%) were found to be obese, however, BMI could detect only 371 (58.51%) (Obese I+Obese II). For Group-2, As per WHR, 463 (91.32%) were obese compared to 440 (52.25%) by BMI Classification. Similar observations were made in Group-3, where 1220 (87.64%) were diagnosed as obese according to WHR classification, compared to 1202 (41.91%) using BMI classification [Table/Fig-4]. This shows that WHR is a better indicator of obesity compared to BMI.

Variables	BMI	WHR	p-value
Group-1			
Obese	371 (58.51%)	424 (90.40%)	0.03*
Non obese	263 (41.48%)	45 (9.59%)	
Group-2			
Obese	440 (52.25%)	463 (91.32%)	0.54
Non obese	402 (47.71%)	44 (8.67%)	
Group-3			
Obese	1202 (41.91%)	1220 (87.64%)	0.90
Non obese	1666 (58.08%)	172 (12.3%)	

[Table/Fig-4]: Association between BMI and WHR among three groups of the study population.
BMI: Body mass index; WHR: Waist hip ratio; Chi-square test

DISCUSSION

The present study identified increased NC and WHR to be associated with T2DM. The risk of T2DM is determined by the interplay of genetic and metabolic factors. Being overweight and obese, along with physical inactivity, is estimated to cause a large proportion of the global diabetes burden [12]. A meta-analysis on predicting the incidence of diabetes has reported that higher waist circumference and higher BMI are associated with an increased risk of T2DM, although the relationship may vary in different populations [13,14]. In the present study, it has been observed that BMI alone is not a robust marker for T2DM, and other anthropometric factors, especially WHR, may prove to be stronger predictors of the disease. Generations of diabetics have distinctive characteristics that can prove to be good indicators of an individual's predisposition to develop T2DM, apart from family history. As generations progress, the anthropometric measurements appear to be more diabetogenic, thus explaining the importance of the study.

According to a study by Alzeidan R et al., NC stands out as an independent predictor of obesity, metabolic syndromes, and diabetes mellitus. The present study also has similar findings, indicating that across generations, BMI may not be a good marker of obesity [15].

Generation-wise analysis of NC in Group-1 showed a statistically significant difference between the generations. It was found to increase from the 1st to the 3rd generation (p=0.023) and from the 2nd to the 3rd generation (p=0.009). This is supported by a study by Cho NH et al., who studied NC in an Asian population and found that NC in DM patients was significantly larger compared to non diabetics [16]. In the present study, NC was highest in the 3rd generation, which can be attributed to changes in lifestyle from generation to generation. Various studies have reported that as diabetics progress through generations, there is an increase in the incidence of diabetes, and there is often fall short of surrogates for the detection of this possible marker for propensity to develop diabetes. Increased fat deposition around the neck could be a potential marker for insulin resistance and an increase in the chance to develop diabetes [17,18].

Waist size was found to increase significantly from the 1st to the 3rd generation (p=0.029). Waist (p=0.018), NC, and WHR (p=0.023) were observed to be significantly higher in the 3rd generation compared to the 2nd generation. These observations prove that the altered lifestyle in the newer generation increases the propensity towards lifestyle-related diseases, a common risk factor among younger generations, and may lead to an early incidence of DM in individuals. It is possible that over generations, we have evolved into a more atherogenic and insulin-resistant phenotype [19,20].

Previous studies have reported that dietary practices are linked to unhealthy body weight and/or a higher risk of type-2 diabetes, including a high intake of saturated fatty acids, high total fat intake, and inadequate consumption of dietary fibre [21,22]. High intake of sugar-sweetened beverages, which contain considerable amounts of free sugars, increases the likelihood of being overweight or obese, particularly among children. Recent evidence further suggests an association between high consumption of sugar-sweetened beverages and an increased risk of T2DM [23,24].

It was observed that instead of BMI, WHR was a more accurate indicator of obesity, as there was a statistically significant difference ($p<0.05$) among the number of obese DM patients (Group-1) based on BMI and WHR. This may be attributed to the fact that the occurrence of diabetes is more associated with abdominal obesity rather than overall obesity status [23]. The findings in the present study also substantiate the fact that the risk of diabetes is higher among those with a high waist circumference. Studies have reported that despite having a normal BMI, an adult Indian has more chance of having abdominal obesity [25,26]. Thus, if Western parameters for obesity are used from an Indian perspective, it is likely to miss out on a significant chunk of the population at risk of developing diabetes.

In other studies, it has been seen that insulin resistance in non obese Asians is due to the high percentage of visceral fat [25,26]. Populations in South-east Asia develop diabetes at a lower level of BMI than populations of European origin [27]. These findings have been further supported by several other studies from India and other countries [28-34]. However, there have been other studies where no association between BMI and diabetes mellitus could be established [35,36]. It is also known that many Asians have pear-shaped bodies (with more weight around the hips). If we consider only BMI, we might miss pear-shaped individuals in the detection of obesity.

In the present study, WHR in male obese study subjects was significantly ($p<0.05$) distributed among all the groups, namely DM subjects, healthy children of DM diagnosed, and healthy subjects, as compared to the female study population. These findings were consistent with studies conducted by various other researchers [34-37].

The present study also reported that WHR, rather than BMI, is a better indicator of DM. It was observed that there was a significant difference between BMI and WHR among healthy children of diabetic patients (Group-2) and subjects in the healthy group (Group-3). Children of diabetic parents have a higher risk of developing diabetes if anthropometrics are considered.

Based on the current evidence, the present study can propose that factors like NC and WHR can be better predictors of obesity than BMI alone. Since T2DM is directly linked with obesity, these anthropometric factors can serve as good non invasive and cost-effective indicators of a person's tendency to develop diabetes. Using only BMI in the anthropometric determination of obesity may underestimate the extent of the burden of obesity in society. This hypothesis also supports the Y-Y paradox, which proves that although two people have the same BMI, they may differ in body fat percentage, which can be reflected in NC or WHR [38]. Mohan V et al., showed a higher prevalence of diabetes mellitus among subjects with both diabetic parents (55%) compared to those with one diabetic parent (22%) [35]. This aspect can be considered when studying T2DM prevalence across communities due to its significant association with T2DM. Cohort studies with a larger sample size would, however, be necessary to determine the optimal range for the various anthropometric measurements specific to the Indian population.

Limitation(s)

The sample taken from one town may not be representative of the entire picture; multicentric trials are needed.

CONCLUSION(S)

In conclusion, NC and WHR are better indicators of anthropometric measurements. Anthropometry could be a non invasive, cost-effective predictive tool for the future risk of DM development. There is an impending need to conduct regular screening programs for the early identification of anthropometric causes of diabetes mellitus, and intensive health education programs focusing on these risk factors are recommended to be carried out among different populations to control T2DM. WHR should be routinely measured in clinical practice, as the method is robust, non invasive, and can also help for better patient management. Accordingly, the inclusion of WHR and NC measurement in routine practice, especially in high population/DM patient settings, will help in the early management of patients, and the technique is also helpful in low economic settings. Anthropometry could be a cost-effective substitute available in high-population and limited resource-setting countries like India.

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