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Increase in prevalence of metabolic syndrome and its determinants, and impact of lifestyle factors: a population-based cohort study among the adult Toto of West Bengal, India

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ABSTRACT

Background & objectives: Emergence of modernization coupled with sedentary lifestyle has led to increase in prevalence and incidence of metabolic syndrome (MetS) among the Asian Indians, including the indigenous peoples, in the last two decades. The objectives of the study was to find out the prevalence of MetS at present, the differences in lifestyle between persons with and without MetS, and the differences in prevalence between two cohorts - the present (2019-20) and previous (2002-19) among the Toto, a small tribal population. *Methods*: Blood samples were collected in fasting (12h) condition with written consent. Anthropometric measures, blood pressures, lipid profile, and blood glucose were assessed among 306 individuals aged $\geq$ 20 yrs. For defining MetS the criteria as suggested by National Cholesterol Education Program (NCEP) Adult Treatment Panel III (2005) were used for the present cohort and NCEP ATP III (2001) for comparing with the previous cohort. *Results*: The prevalence of MetS was 40.2 % including 34.5% males and 46.8%. Significant differences existed between individuals with and without MetS by lifestyle factors. Interaction of gender and age groups had no significant effect on any of the determinants of MetS. The determinants of MetS showed much variability between two cohorts and the prevalence of MetS itself had a significant increase (P< 0.001) in the last two decades. The odds of having MetS are five times higher in the 2019-20 cohort than in the 2002-03 cohort. *Interpretation & conclusion*: Our study indicates that rapid changes in lifestyle have had adversely affected the cardio-metabolic profile irrespective of generation even among the indigenous peoples, like the Toto. It therefore warrants serious public health attention to provide early detection, proper intervention and lifestyle modifications among the traditional societies keeping in mind the ethnic heterogeneity among people of Indian origin.

Key words: metabolic syndrome, lifestyle, tribal population, Toto, Asian Indian, cohort study

INTRODUCTION

Metabolic Syndrome (MetS) is a growing public health burden worldwide. It is a constellation of several risk factors of metabolic origin that is characterized by abdominal obesity, increased triglycerides (TG), reduced high density lipoprotein cholesterol (HDLc), hypertension, and elevated fasting blood glucose. MetS is defined when a cluster of at least three out of these five cardio-metabolic abnormalities occur concomitantly in a person.[1,2] It is estimated that around 12-37% of the Asian population and 12-26% of the European population suffer from MetS. Individuals with MetS have two-fold the risk of developing cardiovascular disease (CVD) and about five-fold the risk of type 2 diabetes mellitus (T2DM) and all-cause mortality.[3]

The prevalence of MetS has markedly increased worldwide, particularly in the last two decades. Adoption of modern lifestyle, perhaps mediated through westernized diet and physical activity along with socioeconomic rise in developing countries, are thought to be the main reasons behind this pandemic of MetS.[4] It is however reasonable to mention that in best of our knowledge, studies related to the changes in prevalence and incidence of MetS in a population over time are, few and far between[5-7] and sadly lacking in India. It is also quite uncertain whether the change in trend of MetS is also the case, keeping in mind the cultural heterogeneity, in different ethnic groups, including the Asian Indians. Hence, investigating the change in prevalence of MetS and trends of its determinants has become important. We therefore aimed to study the prevalence of MetS and its determinants, the differences in lifestyle practices between individuals with and without MetS, and effect of the interaction of gender and age groups on MetS in a population-based cohort study among the Toto of West Bengal, India. Furthermore, we compared the prevalence of MetS and its determinants between the present cohort study (2019-20) with a previous cohort study (2002-03) conducted on the same population.[8,9] Once the change in prevalence and incidence becomes clear, and by knowing the trends of MetS and its determinants in association with lifestyle practices, this would certainly give a better insight in to the efforts needed for proper intervention and prevention of MetS among the people of Indian origin.

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MATERIAL & METHODS

Prior ethical clearance to conduct the research was obtained from the Institutional Ethics Committee, West Bengal State University, Barasat. Informed written consent was obtained from each participant prior to the actual commencement of the study. The present population based cohort study (2019-20) was conducted among the Toto (a particularly vulnerable tribal group), living in the state of West Bengal, India. The Toto are a demographically small population and geographically localized in a single village (named Totopara) of the district of Alipurduar (*erstwhile*, Jalpaiguri), West Bengal bordering Bhutan. At present the total population of the Toto is 1648 which includes 852 males and 796 females. During the previous cohort study (2002-03) their population was 1206 (637 males and 569 females). [9] Toto possess Mongoloid morphological features and speak dialects that belong to the Tibeto-Burman linguistic family. The previous cohort study was comprised of 283 participants (133 males and 150 females).[9] The present cohort study comprised of 306 participants (165 males and 141 females). Individuals with known illness, growth and developmental disorders, severe health issues in the past year, existence of any secondary cause of hypertension, and pregnant women were not included in the study. Anthropometric measures namely height (cm), weight (kg), and circumferences of waist (WC) and hip (cm) were obtained using standard techniques.[10] Height and weight (in light clothing) was measured to the nearest 0.1 cm and 0.5 kg, respectively. Waist circumference was measured to the nearest 0.1 cm using an inelastic tape. The minimum WC was measured at the level of natural waist, which was the narrowest part of the torso. The body mass index (BMI in kg/m2) was subsequently computed. Individuals were classified in to Normal, overweight, and obese as per WHO classification of BMI.[11]

A 12 h fasting blood sample ~2ml was collected from each individual by finger prick with the help of single-use micro lancet. Clinical biochemistry analyses were performed, and levels of the following parameters were determined: fasting blood glucose (FBG), total cholesterol (TC), high-density lipoprotein cholesterol (HDLC), low-density lipoprotein cholesterol (LDLC), very low-density lipoprotein cholesterol (VLDLC) and triglycerides (TG). FBG was measured using code free blood glucose strip and lipid levels were measured using Lipid Profile test strip with the help of Standard SD Biosensor (Korea) analyser. For classifying MetS and its determinants the NCEP ATP III (2005)[12] criteria was followed for the present study cohort (2019-20). NCEP ATP III (2001) [13] criteria for determining MetS was followed to compare the prevalence of MetS between the two cohorts (2002-03 vs. 2019-20) since the previous cohort was studied following 2001 definition.[9] Lifestyle factors were recorded and classified by using a pre-designed schedule. For physical activity level (PAL) the study participants were categorized into high, moderate, and low PAL following the criterion laid down in determining Indian Diabetes Risk Score.[14] Individuals who had physically demanding occupation and performed regular exercise/rigorous household activities were grouped under High PAL. Individuals who either had physically demanding occupation or did perform regular exercise were grouped under moderate PAL. Whereas, individuals who neither had physically demanding occupation nor did regular exercise were grouped under Low PAL. Physically demanding occupation includes works like day labour, industrial labour, agricultural labour etc., which requires high physical activity. Leisure time activity (LTA) was also ascertained by knowing how much time they spend for LTA under sedentary mode and classified in to two groups i) LTA up to 1 hour and ii) LTA more than one hour. Frequency of intake of junk/fast food was also recorded by knowing the frequency of consumption and classified as i) regular, ii) occasional, and iii) no.

Prevalence (%) of MetS and its determinants were ascertained among the present cohort using NCEP ATP III (2005) criteria both by gender and by age groups. The participants were divided in to four age groups viz., 20-09 yrs; 30-39 yrs; 40-49 yrs; and 50-59 yrs. Differences in lifestyle factors and BMI between participants with and without MetS was analysed by contingency chi-square test. Interaction of gender and age groups on determinants of MetS was performed by two-way analysis of variance (ANOVA) with post hoc (Tukey HSD test) for comparison between the determinants of MetS within the age groups. To compare the mean differences in SBP, DBP, TG, HDLc, and FBG between the two cohorts (2002-03 vs. 2019-20) independent t-test was performed. The difference in prevalence of MetS between the two cohorts was calculated using NCEP ATP III (2001) criteria. The odds ratio (OR) with 95% CI was also computed to find out the odds of the outcome of the MetS in the present (2019-20) cohort than the previous (2002-03) cohort. All statistical analyses were performed using SPSS (PC + version 14.0). Graphical presentation was performed with the help of GraphPad Prism8. A statistical significance (two tailed) was set at $p < 0.05$.

RESULTS

The prevalence of MetS among the adult Toto was found to be 40.2% including 34.5% males and 46.8% females as shown in Table I along with its determinants. Figures 1 illustrate the age group-wise distribution of prevalence of MetS. It showed that among younger generation i.e., age groups of 20-29 yrs and 30-39 yrs the prevalence was 21.3% and 41% respectively. Whereas, the prevalence among the older generations which include age group 40-49yrs and $\geq$ 50 yrs was 68.4% and 65.7% respectively. Both Toto males and females of age group 40-49 yrs showed

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higher prevalence of MetS as compare to any other groups. WC – waist circumference; TG – triglycerides; HDLc – high density lipoprotein cholesterol; SBP – systolic blood pressure ; DBP – diastolic blood pressure; FBG – fasting blood glucose. NCEP ATP-III – National Cholesterol Education Program Adult Treatment Panel III; MetS – metabolic syndrome. Table II showed the differences in lifestyle practices and body mass between participants with and without MetS. It was found that participants with MetS had significantly higher tendency of practicing low physical activity (P=0.030), more leisure time activity (P= 0.003), and more frequent intake of junk food (P< 0.001) as compare to participants without MetS. Participants with MetS had significantly higher obesity (P< 0.001) than their counterpart. However among the participants with MetS, 55% were non-obese MetS which also include 30% normal (neither obese nor overweight) MetS i.e., lean MetS. Interaction between gender and age groups are shown in Table III by means of two-way ANOVA. It was found that gender had significant effect on WC (P=0.033), TG (P=0.006), and FBG (0.010). Age group was found to have significant effect (p< 0.001) on WC, SBP, DBP as well as FBG. However no significant effect of the gender and age group interaction was noticed on any of the known determinants of MetS. Table IV shows the post hoc (Tukey's HSD) test for comparison of differences between age group MetS determinants. Differences between age group were mostly significant for WC, SBP, DBP, and FBG. No significant difference was noticed for TG and HDLc across different age groups.

The mean differences between the present cohort study (2019-20) and previous cohort (2002-03) of MetS determinants are illustrated in Figure 2. For SBP it was found that there was a significant difference in mean SBP across all age groups in males as well as in females except for 20-29 yrs of age group. For DBP, except for 20-29 yrs all other age groups showed significant increase in mean DBP irrespective of gender. No significant difference in mean TG was noticed among any of the age groups in males as well as in females except for 30-39 yrs of age group. Significant differences in mean HDLc were noticed only among 20-29 yrs in males and among 20-29 yrs, and 30-39 yrs among females. Significant differences in mean FBG were noticed in both males and females in all the age groups. Differences in prevalence of the determinants of MetS between the two cohorts are illustrated in Figure 3. It was found that the present cohort (2019-20) had much higher frequency of high SBP, High DBP, and High FBG than the previous cohort (2002-03). Figure 4 illustrates the differences in prevalence of MetS between the two cohorts. It was found that the odds ratio of MetS is 5.3 (95% CI 3.0862-9.1017; P< 0.001).

DISCUSSION

We found 40% of the adult Toto had MetS (including one-third of males and almost half of the females) based on NCEP ATP-III (2005) criterion. It clearly shows that prevalence is quite high even among the indigenous peoples. In India, the prevalence ranges from 9.2% to 43.2% as reported in several studies both in rural and urban areas.[15,16] Reported rates of MetS using different definitions ranged from 6.5% to 46.5% in developing countries.[17] It ranges from as low as 11.9% in the Philippines to as high as 49% in urban Pakistan.[17] In the present study the frequency of MetS was found to be inversely related to PAL and directly related to leisure time activity, and intake of junk food. Cross-sectional studies had reported an inverse association between PAL and MetS.[18,19] The Toto are rural inhabitants, and were predominantly engaged in agri-horticultural activities and also worked as agricultural labourers, and therefore underwent a lot of physical exercise, especially because of the lack of flat agricultural terrain as notice in the previous study[9]. However, in the present cohort, we found a lot of change in their occupational and lifestyle practices, particularly in physical activity level and change in dietary habits. The change was noticed more among the young adults (< 40yrs) than the older adults ($\geq$ 40yrs). Most of the older adults still perform their age-old traditional practices unlike their younger counterpart. The adverse effect of physical inactivity or low PAL on MetS is thought to be due to reduced energy expenditure resulting in increased energy intake. The nutritional shift from "traditional" dietary habits to "western" dietary pattern characterized by high intake of refined grains, red meat, high fat etc. had significantly affected the populations across continents, including the indigenous peoples. The study clearly indicates that rapid change in lifestyle in recent years had led to an increase prevalence of MetS even in traditional societies, like the Toto.

The prevalence of MetS in younger generation (below 40 yrs) may apparently look less than their older counterparts (above 40 yrs) in the present study. However, they are experiencing the risk at a much earlier age than their older generation. It is therefore reasonable to argue that the millennial are no safer to chronic diseases and experiencing the co-morbidities at a much earlier age resulting in to a serious public health threat. In U.S. between 2011 and 2016, about 20% of the adults under the age of 40 yrs had MetS.[20] It has been reported that the health of millennial is deteriorating faster than older generations across the globe. It is further stated that if the trend continues, millennial could have shorter life expectancy than their parental generation.[21] Previously T2DM and CVD were considered predominantly a disease of middle-aged and older people. However, in recent years, the age of onset has decreased and the co-morbidities have been reported in adolescents and children worldwide, particularly in high prevalence populations. Japan, for instance, has seen a fourfold rise in incidence of T2DM in 6-15 yrs old. In the U.S. between 8% and 45% of newly presenting children and adolescents had reported T2DM. The problem is particularly noticeable in indigenous peoples.[22] Population-based data, however, are sparse and indeed absent in most countries. The present study therefore, puts a serious attempt to highlight the vulnerability of MetS facing by the younger generation. It was found that the interaction of gender and age group did not show any significant effect on any of the determinants of MetS. It indicates that millennial are equally at risk like their older counterparts. It was also found that among the participants with MetS, 55.3% were non-obese (BMI < 25kg/m^2) which include 30% lean (BMI < 23 kg/m^2). It indicates more than half of the people with MetS were "non- obese MetS" and 30% "lean MetS". The Asian Indians does have excess cardiovascular risk at given BMI and WC considered as 'normal' and more often experience the co-morbidities at a much lesser BMI and WC as compare to Europeans.[11] Lean MetS should therefore need serious public health attention and must be considered a reality among the Asian Indians, and not just a concept. A study in rural Bengal revealed that there exist significant numbers of persons with non-obese/lean MetS.[23] The presence of large number of people with lean MetS could have a huge impact in the society, hence factors other than nutritional affluence was suggested to have an impact on the aetiology of MetS.[23] Similar trends have also been observed in studies from Taiwan[24] and Malaysia[25]. Individuals in the upper normal weight and slightly overweight BMI range have relatively high prevalence and increased risk of having MetS.

From 2002-03 to 2019-20, overall prevalence of MetS increased from 6.5% to 26.5% following NCEP ATP – III 2001 criterion, with an odds ratio of 5.3 (95% CI 3.086 to 9.102). It indicates that the odd of having MetS is five times higher among the 2019-20 cohort than 2002-03 cohort. The present study, to find out the trends of MetS within a population over a time period is, in best of our knowledge, is first of its kind from India. Only three such studies (two from U.S. and one from Korea) have been found which has shown the change in prevalence and incidence of MetS in a population over a period. In a study from U.S. from 2003-2004 to 2011-2012, overall prevalence of the metabolic syndrome increased from 32.9% in 2003-2004 to 34.7% in 2011-2012. Increasing metabolic syndrome prevalence was seen with increasing age in all groups. Nearly 35% of all adults and 50% of those aged 60 years or older were estimated to have the metabolic syndrome, a concerning observation given the aging US population.[5] In an another study from U.S. the patterns of MetS across six waves of NHANES between 1999 and 2010 were examined and showed that although the prevalence of MetS (as it is currently defined) has declined slightly over time, there have been population level changes in its determinants. Most striking is the upward trend in abdominal obesity across the entire U.S. population since the first survey wave in 1999 and 2000. Insulin resistance also appears to be on the rise. However, there is a downward trend in elevated triglycerides with a current overall prevalence near 25% likely corresponding with increased use of statins and other lipid-modifying agents.[6] The prevalence of metabolic syndrome and its components was estimated in adults aged ≥30 years from the Korean National Health Insurance Service data from 2009 to 2013. The revised NCEP criteria were used to define metabolic syndrome. The prevalence of metabolic syndrome increased from 28.84% to 30.52%, and the increasing trend was more prominent in men. Prevalence of hypertriglyceridemia, low HDL-cholesterol, and impaired fasting plasma glucose significantly increased. However, the prevalence of hypertension decreased in both genders. The prevalence of abdominal obesity decreased in women over 50 years-of-age but significantly increased in young women and men below 50 years-of-age.[7] In our study we found an increasing trend of abdominal obesity along with elevated blood pressures, and fasting blood glucose among the present cohort as compare to the earlier cohort.

One of the main limitations of this study was that it was conducted on a small sample size. Relatively larger sample size along with data of tribal groups of other states would give better insight about the ethnic heterogeneity in prevalence of MetS among the People of Indian origin. The comparison between two cohorts was restricted to the definition based on NCEP ATP III 2001 since the previous study was conducted on 2001 criteria.[9] Variation in definition of MetS also causes much difference in the ultimate prevalence of MetS. Differences in techniques for evaluating the metabolic profiles between the two study periods further limit the outcome of the findings.

In spite of it the present study is an attempt showing the changes in prevalence and incidence of MetS including its determinants in a population with in a span of two decades from India. Within this period the prevalence of MetS increased by over five times. Rapid changes in lifestyle had adversely affected the cardio-metabolic profile irrespective of generation even among the indigenous peoples. Understanding the current trends in MetS prevalence among the Asian Indians would help to identify the peoples who would benefit from screening and optimization of cardio-metabolic risk profiles. No single remedy could be prescribed for prevention or even curtailment of the rising prevalence of MetS. Promotion of healthy lifestyle from early childhood seems necessary to curb this epidemic because millennial are becoming more vulnerable to such co-morbidities. Rewinding to age-old healthier lifestyle, promoting traditional practice of diet over junk food, and enhanced physical activity are among some of the steps that could be considered suitable for the indigenous peoples across the world irrespective of age, gender, ethnicity, and state.

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Table I. Prevalence (%) of MetS and determinants among the adult Toto (2019-20) based on NCEP ATP-III (2005) criteria.

MetS Criteria	Male (n=165)	Female (n=141)	Total (n=306)
High WC	18.8	40.4	28.8
High TG	32.7	46.8	39.2
Low HDLc	50.3	55.3	52.6
High SBP	52.7	41.8	47.7
High DBP	35.8	33.3	34.6
High FBG	49.7	61.7	55.2
MetS	34.5	46.8	40.2

Figure 1. Prevalence (%) of MetS of the adult Toto (2019-20) by age groups.

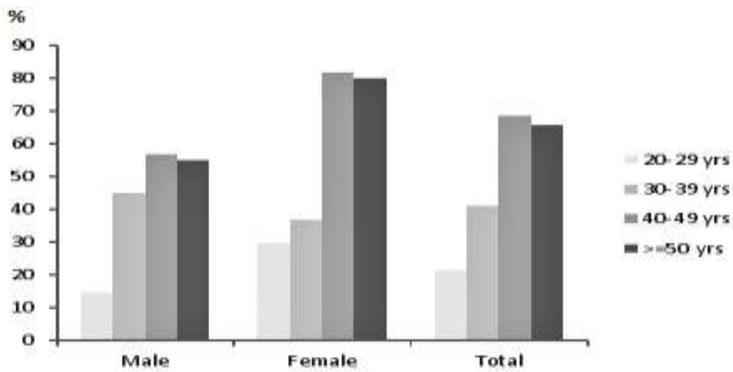

Table II. Differences in lifestyle factors and BMI between the adult Toto (2019-20) with and without MetS.

Lifestyle factors	Category	Non MetS (n=183)	MetS (n=123)	Test of Significance
Physical Activity Level	High (n=148)	98	50	χ^2 = 6.998, df=2; P = 0.030
	Moderate (n=68)	41	27	
	Low (n=90)	44	46	
Leisure Time Activity	≤ 1 hour (n=143)	98	45	χ^2 = 8.506, df=1; P = 0.003
	> 1 Hour (n=163)	85	78	
Junk/Fast Food Intake	Regular (n=62)	23	39	χ^2 = 16.755, df=2; P < 0.001

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	Occasional (n=116)	75	41	
	No (n=128)	85	43	
BMI (kg/m^2)	CED[#] (n=17)	17	0	
	Normal (n=133)	96	37	χ^2 = 16.755, df=2; P < 0.001
	Overweight (n=116)	46	31	
	Obese (n=79)	24	55	

χ^2- Chi-square test; df – degree of freedom; P – probability value; [#]CED was absent among the MetS group hence excluded in the test therefore it was a 3x2 chi-square test; Non MetS – without metabolic syndrome; MetS – with Metabolic syndrome; BMI – body mass index.

Table III. Interaction between gender and age groups on determinants of MetS - two-way analysis of variance (*ANOVA*).

		WC	TG	HDLc	SBP	DBP	FBG
Gender	SS	432.34	56801.43	304.82	255.13	169.84	2497.36
	F	4.58	7.750	1.39	0.851	1.401	6.68
	P	0.033	0.006	0.240	0.357	0.238	0.010
Age Groups	SS	4311.83	13999.78	241.72	13517.49	8902.76	16365.85
	F	15.226	0.637	0.366	15.04	24.48	14.58
	P	< 0.001	0.592	0.777	< 0.001	< 0.001	< 0.001
Interaction	SS	372.73	17560.76	282.36	1384.27	33.78	21.26.16
	F	1.32	0.799	0.428	1.540	0.093	1.895
	P	0.270	0.495	0.733	0.204	0.964	0.130

SS – sum of squares, F – value of the F-statistics, p – probability value

Table IV. A Post Hoc Tukey HSD Test - Comparison of differences between age groups by determinants of MetS

Age Groups		WC	TG	HDLc	SBP	DBP	FBG
20-29 years	30-39 years	-7.487***	7.54	1.30	-5.87	-6.76***	-10.56***
	40-49 years	-10.256***	-13.98	0.80	-12.89***	-11.57***	-16.79***
	≥ 50 years	-8.185**	-3.31	-1.90	-18.09***	-14.14***	-1630***
30-39 years	20-29 years	7.489***	-7.54	-1.30	5.87	6.76***	10.56***
	40-49 years	-2.769	-21.52	0.50	-7.02	-4.81	-6.22
	≥ 50 years	-0.397	-10.85	-3.20	-12.23**	-7.38**	-5.74
40-49 years	20-29 years	10.256***	13.98	-0.80	12.89***	11.57***	16.79***
	30-39 years	2.769	21.52	0.50	7.02	4.81	6.22
	≥ 50 years	2.071	10.67	-2.70	-5.20	-2.57	0.48
≥ 50 years	20-29 years	8.185**	3.31	1.90	18.09***	14.14***	16.30***
	30-39 years	0.697	10.85	3.20	12.23**	7.38**	5.74
	40-49 years	-2.071	-10.67	2.70	5.20	2.57	-0.48

* $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$

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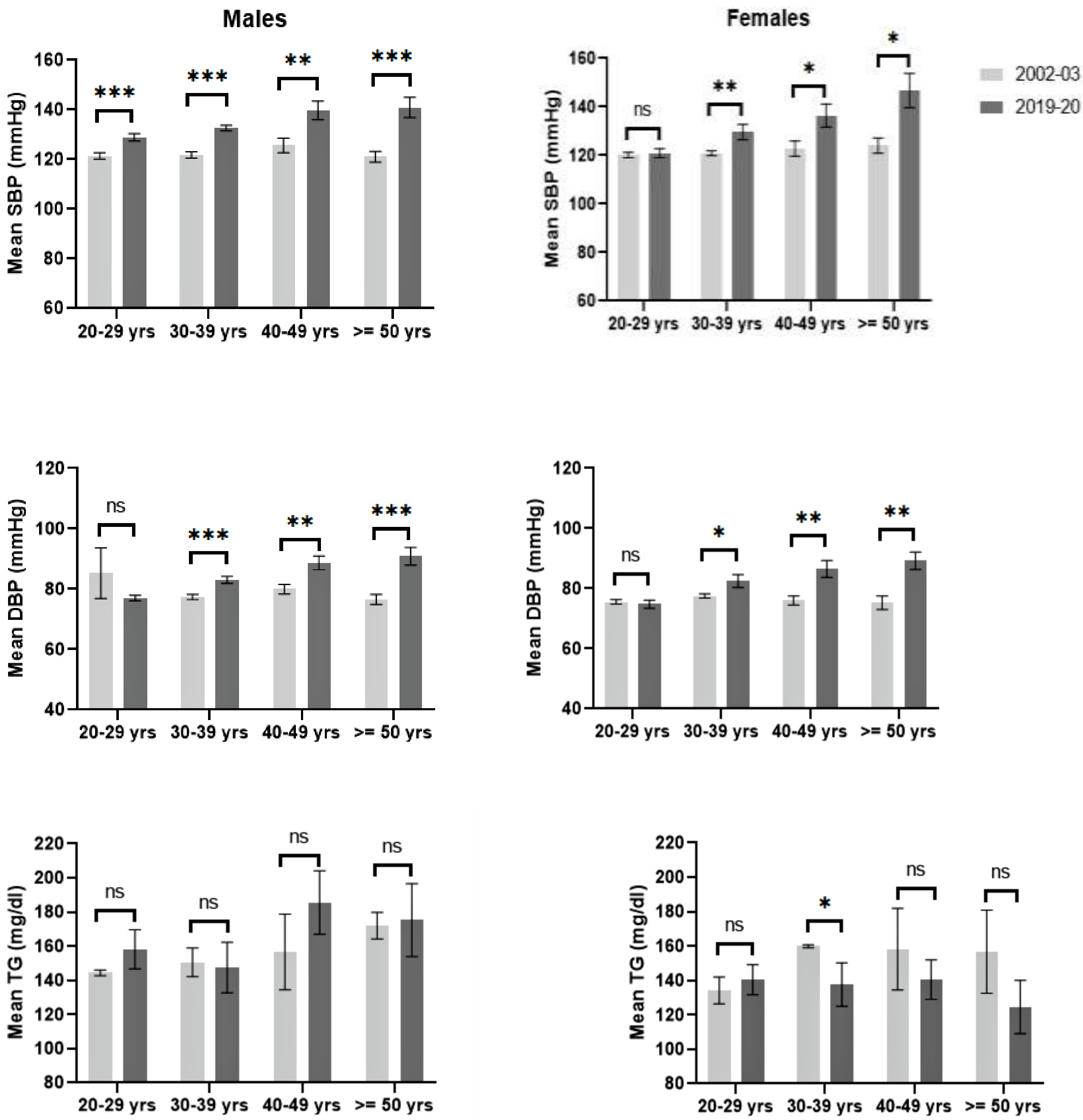
Figure 2. Mean differences in the determinants of MetS between two cohorts by gender and age - groups.



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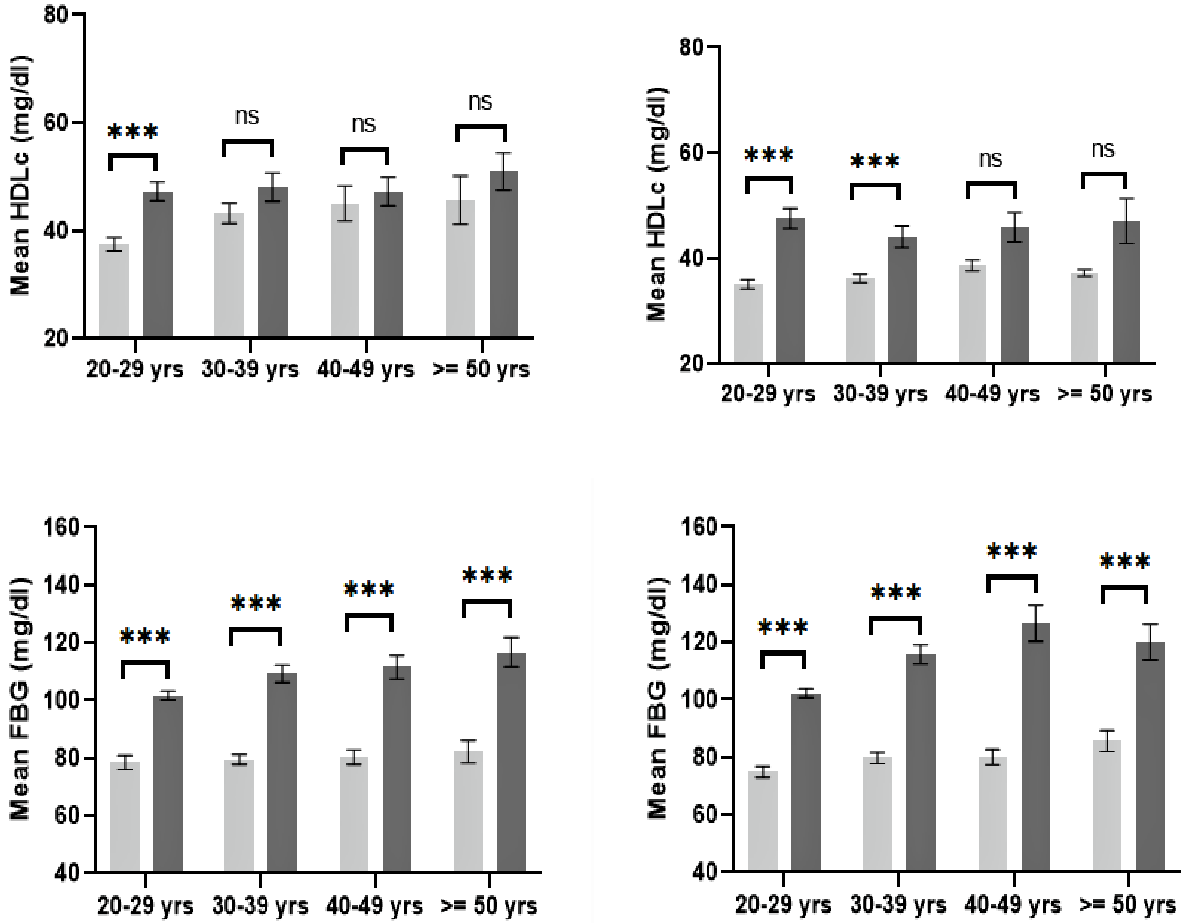
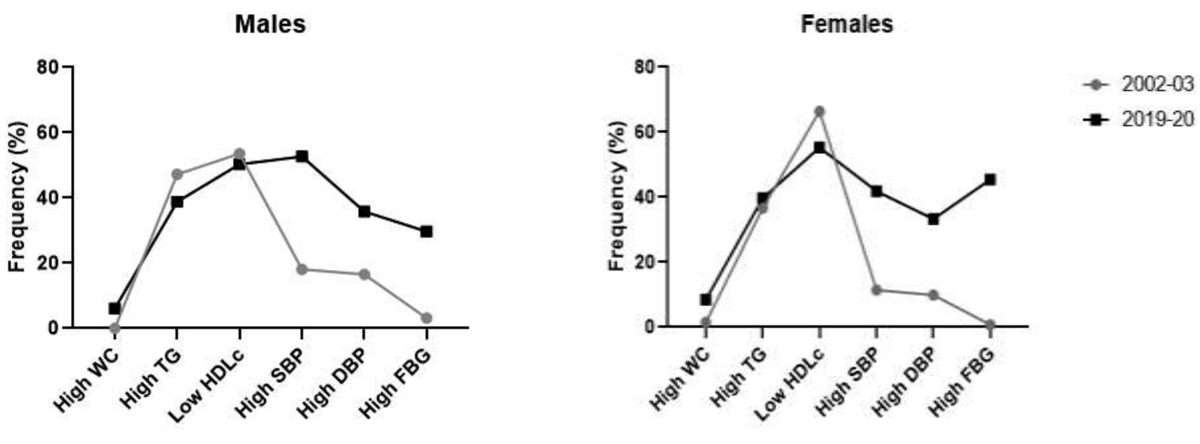


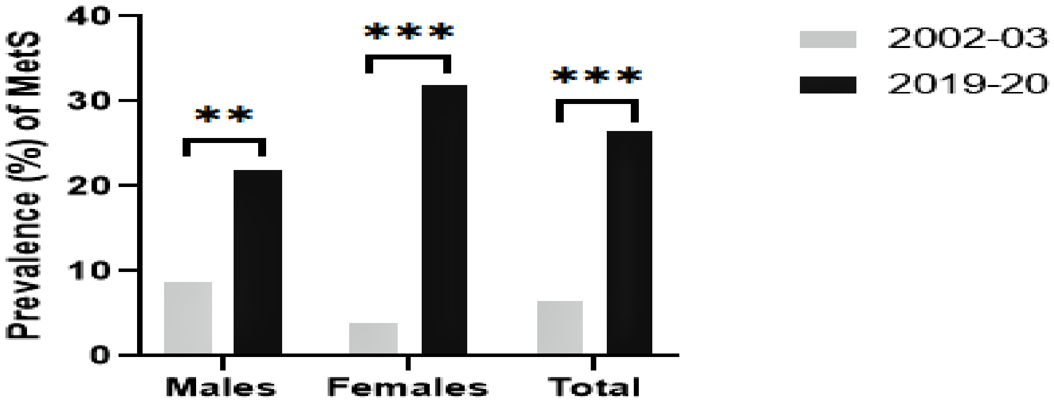
* P ≤ 0.05; ** P ≤ 0.01; *** P ≤ 0.001; ns – not significant; yrs – years.
Mean difference was analysed by independent t- test. MetS was identified following NCEP ATP III (2001) criteria. Mean of the 2002-03 cohort was adapted from previous study[9].

Figure 3. Difference in prevalence (%) of the determinants of MetS# between two cohorts by gender.



#MetS was identified following NCEP ATP III (2001) criteria. Frequency of the 2002-03 cohort was adapted from previous study[9].

Figure 4. Difference in prevalence (%) of MetS between two cohorts.



** P ≤ 0.01; *** P ≤ 0.001; prevalence of the 2002-03 cohort was adapted from previous study[9]. Males: Odds Ratio = 2.814; 95% CI = 1.399 – 5.660. Females: Odds Ratio = 11.250; 95% CI = 4.619 – 27.398
Total: Odds Ratio = **5.300**; 95% CI = 3.086 – 9.102

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ETHICAL CLEARANCE

Institutional Ethics Committee of West Bengal State University had approved the study vide ref # WBSU/IEC/18/01 dated 29/03/2019 as per the guidelines laid down by the Indian Council of Medical Research, New Delhi and in accordance with the Declaration of Helsinki.

CONFLICTS OF INTEREST

Authors declare that they do not have any conflict of interest.

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