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Prevalence of metabolic syndrome among Vietnamese adult employees

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Abstract *Background and aims:* Metabolic syndrome (MtS) is associated with increased risk of many health disorders, especially cardiovascular diseases. In Vietnam, study examining MtS is meager and especially lacking for the workforce. We estimated the prevalence of MtS and its associated factors among Vietnamese employees.
Methods and results: We analyzed secondary data of annual health check of employees of 300 Vietnamese companies from the Vinmec Healthcare System. We used three definitions for MtS: International Diabetes Federation (IDF), National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III), and NCEP ATP III-Asia. Of 57,997 participants evaluated, 48.5 % were males and 66.2 % were younger than 40 years old. The unadjusted MtS prevalence was 8.4 % (IDF), 10.2 % (NCEP ATP III), and 16.0 % (NCEP ATP III-Asia). The age-sex adjusted prevalence of MtS (NCEP ATP III-Asia) was 21.8 % (95 % confidence interval (CI): 21.4 %, 22.2 %). MtS prevalence increased with age, reached 49.6 % for age ≥60. The aging related increase was more remarkable in females than males (prevalence ratio (PR) (95 % CI) for age ≥60 comparing to age <30 years old in males vs. females was 4.0 (3.6, 4.3) vs. 20.1 (17.7, 22.9)). High blood triglyceride (83.4 %) and abdominal obesity (74.5 %) were the predominant contributors to MtS.
Conclusion: In this relatively young Vietnamese working population, 16 % had MtS with high triglyceride and abdominal obesity being the predominant contributors. These findings emphasize

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the need for developing effective high triglyceride and abdominal obesity prevention and control programs to curb the emerging epidemic of metabolic disorders in the workforce.

1. Introduction

Metabolic syndrome (MtS) consists of a group of conditions including high blood glucose, blood lipid disorder, high blood pressure, and high waist circumference. The biology underlying MtS includes insulin resistance, atherogenic dyslipidemia, endothelial dysfunction, and visceral adiposity [1,2]. MtS has been well known for its association with the increased risk of many diseases such as type II diabetes, cardiovascular diseases (CVDs) and also some cancers [3].

There has not been a universally agreeable definition of MtS. Although almost all definitions for MtS are based on the above four disorders, the inclusion of each disorder group and their cut-off values are different [1,4]. In the definition that the World Health Organization (WHO) first developed in 1998, insulin resistance is an absolute requirement [5]. The definition proposed by National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) in 2001 and updated by the American Heart Association and the National Heart Lung and Blood Institute in 2005 incorporates indirect criteria of insulin resistance including body weight, visceral obesity, atherogenic dyslipidemia and hypertension [3,6]. The NCEP ATP III definition adapted for Asians uses similar criteria but with different cut-off values (e.g., lower body mass index (BMI) thresholds for overweight and obesity). The definition published by the International Diabetes Foundation (IDF) requires obesity, but not necessarily insulin resistance, to be present [7].

The prevalence of MtS varies by geographical regions, ethnicity, and other population characteristics, some of which can be attributed to the definition of MtS used in the studies [8–10]. The prevalence of MtS also varies by occupation. Some studies reported higher prevalence of MtS in individuals with longer sitting duration or those with sedentary occupations such as office workers than in agriculture, forestry, and fishery (AFF) workers [11,12]. Whereas, some studies reported higher prevalence of MtS in female manual or agricultural, forestry, and fishery workers and in male equipment, machine operating, and assembling workers [13,14]. The influence of occupations on the prevalence of MtS differs among age groups, sexes, and study populations [13–15].

In Vietnam, several studies have reported the prevalence of MtS in different population groups (rural/urban areas, sex, and age groups). A systematic review and meta-analysis of 18 studies conducted in Vietnam which pooled the data of 35,421 “healthy” participants aged ≤65 years reported the prevalence of MtS in the Vietnamese adult population to be 16.1 % (95 % confidence interval (CI): 14.1%–18.1 %) with a slightly higher prevalence being observed for females (17.3 %, 95 % CI: 13.8%–20.8 %) [16–19]. However, the prevalence of MtS in work forces in Vietnam has not been evaluated. Since occupation may influence the development of MtS and the influence may differ among populations, age groups and sexes, information regarding the prevalence of MtS among Vietnamese occupational groups would be very useful. Given that Vietnam has a rapidly growing economy and MtS is associated with many major health risks which may impact not only the longevity and quality of life of workers but also economy of the country at large, we conduct a systematic evaluation on MtS prevalence and its major contributing factors using regular occupation health check data from the Vinmec Healthcare System (Vinmec). Vinmec is a chain of private general hospitals that spread across big cities in Vietnam. Vinmec performs annual health checks for employees of many companies and conglomerates in different sectors from car making industry, real estate construction, to trading, banking, education, and healthcare.

2. Methods

2.1. Study population

We extracted data of all employees who had their health check at the Vinmec Healthcare System between January 2020 and September 2022. Individuals with any missing data in the five metabolic indicators of the MtS definitions were excluded from the analysis. A small proportion of employees also registered for the health check of their parents under the name of their company, and it was not possible to identify this small number of employee’s parents from the database. Therefore, we decided to exclude all individuals aged ≥80 years from the study. In addition, we also excluded pregnant women and individuals aged <18 years old from the current study.

2.2. Description of data sources

The electronic health check data are managed by the IT department at Vinmec. Demographic and clinical data can be accessed in the ViHC platform and laboratory data can be accessed in the Labconn platform. Some clinical and laboratory test data are structured and while a large part of clinical and imaging data descriptions is stored as free text in Vietnamese. The current system allows data extraction of the health checks starting from January 2020.

2.3. Data extraction and processing

We extracted all available data of the health checks starting from January 2020 to September 2022. Half of participants (47 %) had only one health check. The first health check of each individual in our database was included in this analysis. Since individuals might have laboratory testing before or after their health check, we also included laboratory data that were available 6 months before or after a health check in the study. For free-text data, we used regular expression to search for the relevant key words (e.g., company name, fatty liver, diabetes). We classified companies into three main sectors: Trade and Services, Technology and Industry, and Social enterprises based on public profiles of the company names; records without a company name were considered to be 'unclassified'. These three main company sector categories were used following the similar company categories of the biggest conglomerate in Vietnam. The classification of companies was done and crosschecked by two data engineers. In case of disagreement, the two data engineers discussed to determine the classification that was agreeable by both. Data regarding actual occupation of individual employees was not accessible for this study.

2.4. Definition of metabolic syndrome

Three definitions for MtS were used in our study including NCEP ATP III, modified NCEP ATP III criteria for Asian (NCEP ATP III-Asia), and IDF [1,20]. All these three definitions use five metabolic indicators described in Table S1. In our in-depth analysis of MtS, we used the NCEP ATP III-Asia definition because the study population is primarily Vietnamese.

2.5. Data analysis

We calculated the prevalence of MtS overall and stratified by sex, age group, occupational group, and region. Since the distribution of age and sex in our study population is different from the general population of Vietnam and there is a potential selection bias due to data missingness, in addition to crude prevalence, we also calculated the age and sex-adjusted prevalence of MtS using direct standardization with data of the 2019 Vietnam population and housing census as the standard population.

Moreover, we evaluated the factors associated with MtS using multiple regression models, including sex, age group, occupation, and region. We applied Poisson regression models with robust variance estimation to estimate the prevalence ratio (PR) [21–23]. Two different models were fitted: a model stratified by sex, and a model adding sex and age interaction terms. Based on the models, we estimated the marginal prevalence of MtS for all sex and age groups, plotting them as a marginal plot of predicted prevalence of MtS.

All hypothesis tests were two-sided with an alpha level of 0.05. All analysis was done in Stata version 18.0 (StataCorp, College Station, TX, USA).

3. Results

3.1. Participant characteristics

From January 2020 to September 2022, the Vinmec health check database had 191,523 records of 134,339 individuals who were employees of 300 companies (exclusive of participants aged <18 years or >80 years and pregnant women). Among them a total of 57,997 individuals with complete data of 5 MtS indicators were included in this analysis. The mean (standard deviation, SD) age was 37.4 (11.6) years. Males accounted for 48.5 % (n = 28,112) with the mean age (SD) of 38.9 (11.7) years old and females were slightly younger (mean age (SD) 36.1 (11.3) years old). Most study participants were young—28.9 % were younger than 30 years and 66.2 % were younger than 40 years. Nearly half of the employees worked in Trade and Services (43.8 %), and the remaining worked in Technology and Industry (10.8 %), Social enterprises (9.0 %), or other unclassified occupations (36.4 %). More than three-fourth of the population (78.4 %) came from Northern Vietnam (Table 1).

Compared to females, males were older and had higher mean weight, height, BMI, waist circumference; however, fewer of them had fatty liver than females. More men worked in Technology and Industry, while more women worked in Trade and Services and Social enterprises. Sex distribution was similar between the Northern Vietnam and Central/Southern Vietnam (Table 1, Table S6).

3.2. Prevalence of metabolic syndrome

Using three different definitions of MtS resulted in very different prevalence of crude MtS; the prevalence of MtS using the NCEP ATP III-Asia definition was highest (IDF: 8.4 %, NCEP ATP III: 10.2 %, and NCEP ATP III-Asia: 16.0 %). After standardizing for sex and age using the 2019 Vietnam standard population, the adjusted overall prevalence of MtS using the NCEP ATP III-Asia definition was 21.8 % (95 % CI: 21.4%–22.2 %). Hereafter, the results based on NCEP ATP III − Asian definition are primarily presented.

Both unadjusted and age-adjusted prevalence of MtS in males were higher than in females. The prevalence of MtS gradually increased across the age groups, patients aged ≥60 years had the highest prevalence (unadjusted prevalence using the NCEP ATP III-Asia: 49.1 %, sex-adjusted prevalence: 49.6 % (48.0%–51.2 %)) (Table 2). At younger age (<50 years), males had higher prevalence of MtS than females; however, after aged 60, the prevalence of MtS in females (54.7 %) surpassed that of males (44.3 %) (Fig. 1, Table S2 and Table S3).

The unadjusted prevalence of MtS was similar among the occupational groups (12.8–13.7 %), except the group of individuals with unclassified occupation (21.0 %). However, the adjusted prevalence showed more similar across all four groups (Table 2) owing to the differences in age-sex composition among occupational groups (Table S2).

In the multiple regression model stratified by sex, higher prevalence of MtS was associated with older age in both males and females. Compared to individuals who worked in

Table 1 Patient characteristics.

	Female (n = 29,885)	Male (n = 28,112)	Total (n = 57,997)	p-value
Age (year), mean (SD)	36.1 (11.3)	38.9 (11.7)	37.4 (11.6)	<0.0001
Age group, n (%)				<0.0001
<30	10,201 (34.1)	6532 (23.2)	16,733 (28.9)	
30–39	11,109 (37.2)	10,516 (37.4)	21,625 (37.3)	
40–49	4761 (15.9)	6002 (21.4)	10,763 (18.6)	
50–59	2076 (6.9)	3011 (10.7)	5087 (8.8)	
≥60	1738 (5.8)	2051 (7.3)	3789 (6.5)	
Weight (kg), mean (SD)	53.1 (7.2)	68.8 (10.3)	60.7 (11.8)	<0.0001
Height (cm), mean (SD)	156.3 (5.3)	168.1 (6.0)	162.1 (8.1)	<0.0001
BMI (kg/m^2), mean (SD)	21.7 (2.7)	24.3 (3.1)	23.0 (3.2)	<0.0001
BMI group, n (%)				<0.0001
Underweight (<18.5)	2485 (8.3)	599 (2.1)	3084 (5.3)	
Normal (18.5–22.9)	19,304 (64.6)	8663 (30.8)	27,967 (48.3)	
Overweight (23–24.9)	4827 (16.2)	8107 (28.9)	12,934 (22.3)	
Obese (≥25.0)	3244 (10.9)	10,724 (38.2)	13,968 (24.1)	
Waist circumference (cm), mean (SD)	74.2 (9.2)	85.4 (66.4)	79.6 (47.0)	<0.0001
Abdominal obesity, n (%)				<0.0001
<90 cm (M) or <80 cm (F)	23,241 (77.8)	20,518 (73.0)	43,759 (75.5)	
≥90 cm (M) or ≥80 cm (F)	6644 (22.2)	7594 (27.0)	14,238 (24.5)	
Occupational group, n (%)				<0.0001
Technology and Industry	2093 (7.0)	4146 (14.7)	6239 (10.8)	
Trade and Services	13,932 (46.6)	11,463 (40.8)	25,395 (43.8)	
Social enterprises	3571 (11.9)	1653 (5.9)	5224 (9.0)	
Unclassified	10,289 (34.4)	10,850 (38.6)	21,139 (36.4)	
Region, n (%)				<0.0001
Northern	23,721 (79.4)	21,765 (77.4)	45,486 (78.4)	
Central and Southern	6164 (20.6)	6347 (22.6)	12,511 (21.6)	

BMI, body mass index; SD, standard deviation. BMI classification was based on the criteria for Asian populations.

Table 2 Prevalence of Metabolic syndrome by different definitions, unadjusted and adjusted using the 2019 Vietnam population.

Prevalence (%)	Unadjusted			Adjusted
	IDF	NCEP ATP III	NCEP ATP III-Asia	NCEP ATP III-Asia
Overall	8.4	10.2	16.0	21.8 (21.4, 22.2)
Sex*				
Female	8.3	6.0	9.8	17.8 (17.2, 18.3)
Male	8.5	14.6	22.5	25.5 (24.9, 26.0)
Age group*				
<30	3.0	3.3	5.8	6.6 (6.2, 7.0)
30–39	5.3	6.7	11.2	11.2 (10.8, 11.6)
40–49	9.8	13.3	20.9	19.6 (18.9, 20.3)
50–59	19.2	21.9	34.6	34.1 (32.8, 35.4)
≥60	31.5	36.0	49.1	49.6 (48.0, 51.2)
Occupational group				
Technology and Industry	5.8	8.9	13.7	20.7 (19.0, 22.4)
Trade and Services	6.5	7.8	12.8	20.9 (20.1, 21.7)
Social enterprises	7.3	8.3	13.7	20.8 (19.4, 22.2)
Unclassified	11.8	13.8	21.0	23.1 (22.5, 23.6)
Region				
Northern	7.4	9.6	14.9	21.1 (20.7, 21.6)
Central and Southern	12.0	12.3	19.9	24.0 (23.2, 24.9)

Crude prevalence of MtS (using three definitions of MtS) was calculated overall and stratified by sex, age, occupational group, and region. Prevalence of MtS (NCEP ATP III-Asia definition) was adjusted by sex and age using the 2019 Vietnam population and housing census as the standard population; 95%CI was also calculated for adjusted prevalence. *: The adjusted prevalence of MtS by sex was age-standardized and the adjusted prevalence of MtS by age group was sex-standardized.

Technology and Industry, those who worked in other occupational groups had a modest increase in MtS prevalence. Individuals in Central and Southern Vietnam also had higher prevalence than those in Northern Vietnam (Table 3). In a regression model that included sex-age group interactions, the increasing trend of MtS prevalence across age groups was confirmed, but the trend was different between males and females with more dramatic increasing trend in females after 50 years old (Table S4). A marginal plot calculating the adjusted prevalence of MtS (Figure S1)

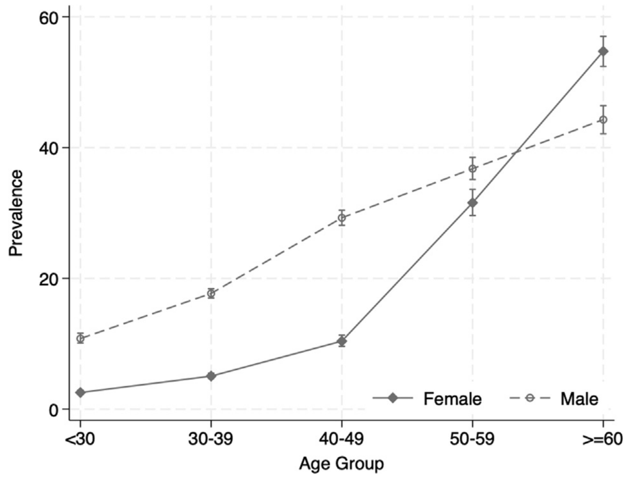

Figure 1 Unadjusted prevalence of MtS by sex and age group using the NCEP ATP III-Asia definition. The plot shows that compared to males, females had a more dramatic increase in the prevalence of MtS at older age despite the lower prevalence at younger age.

showed a similar trend to the observed crude prevalence in Fig. 1.

3.3. Contributing factors to metabolic syndrome

The metabolic profile between patients with and without MtS using the three definitions are presented in Table S5. Individuals with MtS using IDF definition had a bit higher waist circumference BMI as compared to those with MtS using NCEP ATP III and NCEP ATP III-Asia definition. All individuals with MtS using IDF definition had abdominal obesity (waist circumference≥90 cm (male) or≥80 cm (female)) while 59.9 % and 74.5 % of those with MtS using NCEP ATP III and NCEP ATP III-Asia definition respectively had abdominal obesity.

High triglyceride and abdominal obesity were the most common contributors to MtS (83.4 % and 74.5 %, respectively), followed by high HDL-cholesterol (62.5 %), hypertension (60.5 %), and diabetes (38.9 %) (Table 4). Among individuals without MtS, approximate 25 % had low HDL-cholesterol and about 20 % had high triglyceride. Patients with MtS also had higher prevalence of severe fatty liver (1.2 %) compared to patients without MtS (0.1 %). In a multiple regression model that adjusted for sex, age group, occupational group, and region, MtS with associated with a 7.8-fold increase in the prevalence of severe fatty liver (prevalence ratio 7.8, 95%CI 5.3, 11.4) (Table S6).

4. Discussion

To our knowledge, this study is the largest and also the first employee health examination-based study conducted in Vietnam describing MtS prevalence in workforce. The study population is relatively representative for the

Table 3 Factors associated with MtS using the NCEP ATP III-Asia definition.

	Male		Female	
	MtS/No MtS	PR (95%CI)	MtS/No MtS	PR (95%CI)
Age group				
<30	705/5827	REF	259/9942	REF
30–39	1860/8656	**1.6 (1.5, 1.8)**	561/10,548	**2.0 (1.7, 2.3)**
40–49	1756/4246	**2.7 (2.5, 2.9)**	495/4266	**4.0 (3.4, 4.6)**
50–59	1107/1904	**3.3 (3.0, 3.6)**	655/1421	**11.6 (10.2, 13.4)**
≥60	908/1143	**4.0 (3.6, 4.3)**	951/787	**20.1 (17.7, 22.9)**
Occupational group				
Technology and Industry	709/3437	REF	144/1949	REF
Trade and Services	2338/9125	**1.1 (1.0, 1.1)**	920/13,012	1.1 (0.9, 1.3)
Social enterprises	463/1190	**1.2 (1.0, 1.3)**	254/3317	1.1 (0.9, 1.3)
Unclassified	2826/8024	**1.2 (1.1, 1.2)**	1603/8686	**1.2 (1.1, 1.5)**
Region				
Northern	4628/17,137	REF	2141/21,580	REF
Central and Southern	1708/4639	**1.2 (1.1, 1.3)**	780/5384	**1.1 (1.1, 1.2)**

PR, prevalence ratio; REF, reference group. MtS was defined using the NCEP ATP III-Asia definition. A Poisson regression model with robust variance estimation was performed for males and females separately, directly approximating the prevalence ratios (95%CI) of MtS associated factors.

Table 4 Prevalence of metabolic conditions by NCEP ATP III-Asia MtS status.

Metabolic conditions	MtS individuals	None MtS individuals
Abdominal obesity (≥90 cm (M) or ≥80 cm (F))	74.5	15.1
Hypertension (SBP >130 or DBP >85 mmHg)	60.5	10.3
High triglyceride (≥150 mg/dL)	83.4	19.1
Low HDL-cholesterol (<40 mg/dL (M) or <50 mg/dL (F))	62.5	24.6
Diabetes (Self-reported and/or blood glucose >5.9 mmol/L)	38.9	5.0

DBP, diastolic blood pressure; HDL, high-density lipoprotein; SBP, systolic blood pressure.

workforce in Vietnam. The fact that both crude and age-sex adjusted MtS prevalence were reported helps dissect the influence of age-sex structure and other factors on the prevalence of MtS. Existing health examination database provides a cost-efficient approach to study MtS and other health conditions.

Using NCEP/ATP III – Asian definition, the unadjusted overall prevalence of MtS (16 %) found in our study population is similar to that of previously published studies in Vietnamese adults. The meta-analysis of 18 studies in Vietnam showed a pooled unadjusted prevalence of 16.1 % (95 % CI: 14.12 %, 18.08 %) [18]. The age and sex adjusted prevalence using the 2019 Vietnam population and housing census as standard population rose to 21.8 % which is a bit higher than the prevalence reported by those previous studies in Vietnam. This difference may be attributable to that our study only includes urban work forces which employees might have adapted more westernized lifestyle. Increasing of MtS prevalence rate over the years could be another explanation. Noteworthy that the age-sex adjusted prevalence of MtS in our study sample is close to that reported from Asia, and Europe, and lower than that of US. The estimates of many studies using either NCEP/ATP III, NCEP/ATP III – Asian or IDF criteria across Asia Pacific ranged from 11.9 % to 49 % [24], South Asia ranged from 26.1 % to 32.5 % [25], the pooled estimate for adults of many studies in Middle East was 25 % [8], the pooled estimate for adults across Europe was 24.3 % [26], and the pooled estimate for adults in the US was ∼35 % [27–29]. The differences in MtS prevalence might be due to true differences in the prevalence of metabolic disorders but could also be caused by selection bias and difference in MtS definition used in the studies as demonstrated in our study.

The prevalence of MtS using NCEP/ATP III – Asian criteria in males is significantly higher than females after adjusting for age. However, using IDF definition, the prevalence between genders is quite similar. A possible explanation is that the IDF definition requires visceral obesity and two out of four criteria regarding insulin resistance, atherogenic dyslipidemia (Triglyceride and HDL separately) and hypertension. Whereas NCEP ATP III (2005 revisions) or NCEP ATP III – Asian definitions require any three out of five criteria regarding insulin resistance, visceral obesity, atherogenic dyslipidemia (Triglyceride and HDL separately) and hypertension. Also, the cut-off values for waist circumference differs between IDF and the other two definitions. As such, the fact that all individuals must have abdominal obesity to satisfy IDF definition for having MtS syndrome may lead to equal chance for males and females to be classified as having MtS. A study on South Asian adults reported that the odds of central obesity in females is more than two-fold higher than that in males [30]. Males may be more likely to satisfy other criteria rather than abdominal obesity for having MtS than females and this may lead to higher prevalence of MtS in males vs. females if using NCEP ATP III (2005 revisions) or NCEP ATP III – Asian definitions. These data show that the prevalence of MtS, especially in males, may vary remarkably depending on which MtS definition used. In studies reporting MtS in South Asia and Asia Pacific, the prevalence of MtS is higher in females than males in most of the countries [24,25]. The prevalence of MtS is also reported slightly higher in females than males in many studies in Europe [26]. This indicates that the prevalence of MtS between genders of this study with higher MtS prevalence for men is not consistent with those of other studies in Asia and Europe. Therefore, further studies investigating diet and lifestyle difference between working men and working women in Vietnam may provide some insights.

The prevalence of MtS increases dramatically with older age, especially in those ≥60 years old. consistent to several reports from the US and elsewhere [24,25,27–29]. We found that increase of MtS prevalence after 60 years old is more remarkable in females than males in our study population. As such, free annual health check including MtS screening is beneficial for employees especially female workers. Although annual health check is mandatory for all officially employed full-time workers in Vietnam, not all have blood lipid screening. Therefore, including blood lipid screening in annual health check package should be recommended for middle age and elder employees of all companies, especially for female workers.

The age and sex adjusted overall prevalence of MtS did not vary significantly among employees working in different sectors although unadjusted rate differed a little. It was a limitation of our study that there was a lack of data for more proper occupational classification. Individuals were classified by their company sector, not by their actual occupation. For example, some individuals who work for construction companies may be office workers while some individuals who work for trading companies may be manual workers e.g., housekeepers. As such, it was not possible to have a good comparison of MtS prevalence among common major groups of occupations. Males working for Trade and Services and Social enterprises have borderline higher prevalence of MtS than males working for Technology and Industry sectors. This is consistent with some published studies which reported higher prevalence of MtS in those with sedentary occupations than those with more physical work [11,12]. However, the association was not significant for females. One of the reasons may be that females more likely do office work regardless of the sectors of their companies. This may also reflect the heterogeneity in occupational effect on MtS prevalence between genders. Another limitation of our study is that there was a lack of data regarding social economic status among employees, an important factor that may affect lifestyle and diet which in turn affect the prevalence of MtS. Further investigation should be done to explain the higher prevalence of MtS even after adjusting for sex and age in individuals in sector “unclassified”.

The age and sex adjusted prevalence of MtS is higher in those residing in the Middle and South of Vietnam than that of those residing in the North of Vietnam. Diet and lifestyle are quite different between the North and the South of Vietnam. Therefore, further studies are warranted to investigate the contributing factors including diet and lifestyle in the regional difference of MtS prevalence.

Based on the NCEP ATP III – Asian definition, we found that major contributing factor for MtS in our study population were high blood triglyceride (83.4 %) and abdominal obesity (74.5 %), followed by high HDL-cholesterol (62.5 %), and hypertension (60.5 %), whereas diabetes (38.9 %) contributed the least. These findings highlight the importance of controlling for high blood triglyceride and abdominal obesity, call for more research on their risk factors and prevention. Combined Exercise and Low Carbohydrate Ketogenic Diet (CELCKD) Interventions has been reported to have good effect on waist circumference and triglycerides reduction in overweight and obese individuals [31]. Physical activity with prolonged duration of moderate intensity is recommended as the most effective for abdominal obesity prevention and treatment [32]. Statin therapy is also beneficial for primary or secondary prevention of high blood triglyceride and its consequences [33]. As such, public health strategies to promote physical activity and healthy diet as well as statin therapy for those with high blood triglyceride should be implemented for the prevention and treatment of MtS.

Our data showed that MtS was associated with a large increase in the prevalence of severe fatty liver. This is consistent with published reports that fatty liver is highly prevalent in individuals with MtS and that fatty liver may be a possible component in the cluster of MtS [34–37]. However, data regarding fatty liver diagnosed by ultrasound in our study need more comprehensive evaluation regarding validity and reliability. In addition, the preliminary findings regarding the association between MtS and fatty liver in our cross-sectional data need to be further investigated with longitudinal data for causal inference.

There are some limitations of this study. First, it is based on an available routine health check data with varied check-up packages. As such, individuals who have available data for all 5 indicators required for the MtS definition and been included in this report may differ from all employees in the workforce. This may result in selection bias and impact the generalizability of our study findings. We are in the process to implement a standardized data collection protocol to collect essential information that will allow us to assess the selection bias in the future. Second, our study only provides a cross-sectional snapshot of the prevalence of MtS in Vietnamese workforce. This will be improved by longitudinal data built up with annual health check of the years afterward.

In summary, in this largest occupation-based health examination-based study conducted in Vietnam, we found that MtS affected 16 % of the relatively young Vietnamese workforce. The MtS prevalence was higher among males than females, and higher in those residing in the Middle and South of Vietnam than those residing in the North of Vietnam. The prevalence of MtS increased with age, particularly among women. High blood triglyceride (83.4 %) and abdominal obesity (74.5 %) were the most common contributors of MtS. Our study emphasizes the need of developing effective high triglyceride and abdominal obesity prevention and management programs to curb the emerging epidemic of metabolic disorders in Vietnamese workforce.

Contributor statements

NTH, LCL initiated the study, obtained approvals and fundings for the study. All authors participated in the conceptualization of the study. MTT, LBH, and TTP performed the analysis. HTN and XS planed the analysis and wrote the original draft of the manuscript. CTDT, QVN contributed to data availability. CTDT, MT, LV, JD paticipated in data analysis plan and review. LCL oversaw the study. All authors reviewed and approved the final manuscript.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.numecd.2023.10.002.

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