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RESEARCH ARTICLE

# Prevalence of obesity and overweight in an adult population of Tehran metropolis

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## Abstract

**Purpose** Obesity is a chronic low-grade inflammatory condition with increasing global prevalence and is associated with cardiovascular diseases. In this study, we aimed to investigate the prevalence of obesity in the Tehran cohort study (TeCS) population.

**Methods** We used the data collected by systematic random sampling during the recruitment phase of TeCS. The data comprised 4215 households from all districts of the Tehran metropolis, from which 8296 adults aged ≥ 35 years participated between May 2016 and February 2019. Sociodemographic data, medical history, laboratory tests, and anthropometric measurements were gathered from the participants. Participants with missing data were excluded from the final analysis. Finally, the data was analyzed using SPSS version 23, and distribution maps were created by Stata 14.2.

**Results** A total of 8211 participants (53.9% women) with an average age of 53.7 ± 12.6 years were studied. The age-weighted prevalence of overweight and obese among women was (37.5% [95% confidence interval (CI): 34.5, 40.6] and 35.5% [95% CI: 32.6 -38.6]) compared to men (47% [95% CI: 43.6, 50.3] and 22.9% [95% CI: 20.1 -25.8]). The prevalence of substantially increased risk of metabolic complications (SIRMC) based on waist circumference (WC) and waist-to-hip ratio (WHR) was 49.2% (95% CI: 46.3 -52.2) and 75.5% (95% CI: 72.7 -78.1) respectively.

**Conclusions** The prevalence of obesity in Tehran (29.3%) was much higher than in previous reports, particularly among older people, women, and socioeconomically underdeveloped districts. After age 55, more than 80% of women had SIRMC compared to 30% of men.

**Keywords** Obesity · Overweight · Waist circumference · Waist-to-hip ratio · Epidemiology

## Introduction

General obesity is a chronic inflammatory disease that affects 13% of adults worldwide and is defined by a body mass index (BMI) of 30 kg/m [2] or more [1]. Central obesity, characterized by high waist circumference (WC) and waist-to-hip ratio (WHR), has a prevalence of 41.5% [2]. Obesity is associated with an increased risk of metabolic complications and cardiovascular death by both definitions [3, 4]. In 2021, high BMI accounted for 1.95 million cardiovascular disease deaths and 3.7 million total deaths, contributing to 1560 disability-adjusted life-years (DALYs) per 100,000 persons [5].

The increasing trends in obesity observed nationwide [6–9] and worldwide [2] can be attributed to high caloric intake and physical inactivity, which are related to

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**Key Messages**
- According to the Tehran Cohort Study, the age and sex-weighted prevalence of obesity in Tehran was 29.3%.
- Obesity prevalence was remarkably higher in older people, women, and socioeconomically underdeveloped districts of Tehran.
- After age 55, more than 80% of the women had a substantially increased risk of metabolic complications compared to 30% of the men.

Extended author information available on the last page of the article

socioeconomic status and demographic factors [10]. In the Middle East, the prevalence of obesity and overweight was estimated to be 21% and 33%, respectively [11]. Previous studies in Iran found a prevalence of 22.7% for obesity, which is almost double the global rate [12]. Nevertheless, data on the prevalence of obesity in Tehran, the capital and largest city of Iran, are insufficient. Therefore, we aimed to determine the prevalence of obesity, overweight, and central obesity and their associated factors in the Tehran Cohort Study (TeCS).

## Methods

We used the recruitment phase data of TeCS for this analysis. We designed TeCS, a multidisciplinary cohort study, to determine Tehran's cardiovascular disease (CVD) trends. The details of the TeCS have been discussed in a previously published article [13]. However, in summary, a random sample was systematically selected based on the postal codes from all districts of Tehran. Then, the telephone numbers were derived for them to contact the residing households. We finally included adult citizens of Tehran (≥ 35 years of age) living in 4215 households (8296 adults) between May 2016 and February 2019. Participants with missing BMI, WC, or WHR were excluded in the present analysis. The Ethics Committee of Tehran University of Medical Sciences approved TeCS (IR.TUMS.MEDICINE.REC.1399.074). All participants provided written informed consent at the beginning of the study.

### Data collection

We used the TeCS database for this study. Demographic data included age, tobacco use (never, former smoker, and current smoker), opium use, alcohol use, physical activity level (classified as low, moderate, and high), marital status (single, married, and other), ethnicity (Fars, Azari, and other ethnicities), and education. Metabolic complications recorded in this study were hypertension, diabetes, hyperlipidemia, and chronic kidney disease (CKD). Baseline laboratory parameters determined from fasting blood samples included high-density lipoprotein (HDL), low-density lipoprotein (LDL), total cholesterol (TCH), triglycerides (TG), fasting blood sugar (FBS), and creatinine (Cr). The anthropometric characteristics were weight, height, waist circumference (WC), hip circumference (HC), body mass index (BMI), and waist-to-hip ratio (WHR).

### Definitions

Height was measured in centimeters while participants stood straight without shoes. Weight was measured in kilograms using a standard digital scale with an accuracy of 0.5 kg while participants wore minimal clothing. A trained nurse measured WC midway between the bottom of the last palpable rib and the top of the iliac crest and (HC) at the widest part of the buttocks according to World Health Organization guidelines [3] (WHO). WC (cm) and HC (cm) were measured while subjects stood straight with arms at their sides, feet close together, and weight evenly distributed on both feet [3]. BMI was calculated by dividing weight in kilograms by the square of height in meters.

WHR was determined by dividing WC by HC. Overweight was defined as a BMI of 25 to 30 $kg/m^2$, and obesity as a BMI ≥ 30 $kg/m^2$. Central obesity with an increased risk of metabolic complications was defined as WC > 94 cm in men and > 80 cm in women [3]. In addition, central obesity with a substantially increased risk of metabolic complications (SIRMC) was defined as WC > 102 cm in men and > 88 cm in women or WHR ≥ 0.90 in men and ≥ 0.85 in women.

We adhered to the established criteria set forth by the World Health Organization and International Diabetes Federation to define type 2 diabetes mellitus and assess glycemic control [14]. Type 2 diabetes mellitus was identified through self-reporting of a previous diagnosis by healthcare providers, current use of glucose-lowering medications, or a fasting plasma glucose (FPG) of ≥ 126 mg/dl. Impaired fasting glucose (IFG) was determined by an FPG of 100 to 125 mg/dl without a previous diagnosis or current medication use. We followed the 2018 ESC/ESH guideline criteria to assign participants to different BP groups. Hypertension was diagnosed if any of these conditions were present: 1) SBP of 140 mmHg or more or DBP of 90 mmHg or more, 2) self-reported history of hypertension confirmed by healthcare providers, or 3) current use of BP-lowering medication [15]. We used self-reported data to categorize the participants into current, former, or never smokers of tobacco cigarettes, waterpipes, or pipes. Current smokers were those who smoked regularly or occasionally at the time of the interview. Former smokers were those who had a history of smoking or had quit smoking and did not smoke at the time of the interview. Never smokers were those who had never smoked any tobacco product [16]. Hyperlipidemia was determined by either a) having a history of or current diagnosis or treatment for hyperlipidemia, or b) having total cholesterol levels of ≥ 200 mg/dL, low-density-lipoprotein cholesterol levels of ≥ 130 mg/dL, or triglyceride levels of ≥ 150 mg/dL. Chronic kidney disease is characterized by either kidney damage or a persistently low estimated glomerular filtration rate (eGFR) of less than 60 ml/min/1.73 m for three months or longer, regardless of the underlying cause. The study measured opium and alcohol use by asking participants if they had consumed any products containing opium or its derivatives or any alcoholic products in the last

year. Participants' education levels are based on the school grades passed, i.e., illiterate, elementary school (1–5), high school (6–12), and diploma (> 12). Physical activity levels were assessed using a questionnaire asking participants to rate their activity on a low to high scale [13].

### Statistical analysis

Continuous variables were described as mean with standard deviation (SD) when normally distributed, whereas nonnormal variables were reported as median with 25th and 75th percentiles. Categorical variables were expressed as the frequency with percentage. When comparing two groups, an independent t-test or Mann–Whitney U-test was used to analyze continuous variables, and when comparing more than two groups, a one-way analysis of variance test (ANOVA) or Kruskal–Wallis test was used. The chi-square test was used to compare categorical variables between groups. The age- and sex-weighted prevalence and associated 95% confidence interval (CI) were also provided for obesity indices using the population of Tehran in the 2016 census. In addition, the prevalence of obesity indices was stratified by age and sex groups.

Finally, the association of demographic characteristics and metabolic complications with general and central obesity was demonstrated using logistic regression analysis. Adjusted odds ratios (aOR) and 95% CIs were reported for this analysis. The distribution of obesity prevalence in Tehran districts was presented using the first three digits of the participants' zip codes with the *shp2dta* and *spmap* modules of Stata software, version 14.2 (College Station, TX: Stata Corp LP.). All other analyses were performed using IBM SPSS Statistics for Windows, version 23 (Armonk, NY: IBM Corp.).

## Results

After excluding 85 participants with incomplete data, 8211 participants with an average age of $53.7 \pm 12.67$ years were studied. Women comprised 53.9% of the total participants and 65.4% of the obese population ($P < 0.001$). In addition, 339 patients were excluded from the analysis of laboratory data because they did not comply with the prescribed fasting time.

### Body mass index

Based on BMI, 3426 (41.7%) were overweight, and 2479 (30.1%) subjects were obese. Low physical activity was more common in obese than overweight and normal participants ($P < 0.001$). The frequency of illiterates was significantly higher among obese compared to overweight and normal-weight participants ($P < 0.001$). Moreover, the prevalence of hypertension, diabetes, and hyperlipidemia was significantly higher among obese participants ($P < 0.001$). Other baseline characteristics of the population based on BMI are shown in Table 1.

### Waist circumference

Based on WC, 2035 (24.7%) subjects were at an increased risk of metabolic complications, and 4243 (51.5%) had SIRMC. The average age of WC-SIRMC participants was higher when compared with normal and increased risk groups ($P < 0.001$). In addition, low levels of physical activity, illiteracy, and metabolic complications, except CKD, were significantly more prevalent in WC-SIRMC compared to WC-increased risk and normal participants. Other variables compared between normal, increased risk, and WC-SIRMC groups are displayed in Table 2.

### Waist-to-hip ratio

Analysis based on WHR showed that 6154 (76.4%) participants had SIRMC. Similar to BMI and WC-SIRMC, the mean age of WHR-SIRMC was significantly higher than the normal risk group ($P < 0.001$). Additionally, a higher frequency of metabolic complications, lower physical activity, and illiteracy were seen in WHR-SIRMC compared to normal risk participants ($P < 0.001$). Other variables and their comparison between SIRMC and normal risk are shown in Table 3.

### Age and sex-weighted prevalences

The age and sex-weighted prevalence was 42.2% (95% CI: 39%-45.4%) for overweight and 29.3% (95% CI: 26.4%-32.3%) for obesity (Table 4). In addition, 37.5% (95% CI: 34.5%-40.6%) of the women and 47% (95% CI: 43.6%-0.3%) of the men had a BMI ≥ 25. In contrast, obesity (BMI ≥ 30) was more common in women (35.5%; 95% CI: 32.6%-38.6%) than in men (22.9%; 95% CI: 20.1%-25.8%).

The age- and sex-weighted prevalence rates of WC-SIRMC and WHR-SIRMC were 49.2% (95% CI: 46.3%-52.2%) and 75.5% (95% CI: 72.7%-78.1%), respectively (Table 4). Based on WC, 67.9% (95% CI: 65.1%-70.6%) of women had SIRMC compared to 30.1% (95% CI: 27%-33.3%) of the men; however, the prevalence of men with WHR-SIRMC was higher at 80.6% (95% CI: 77.9%-83.1%) compared to women at 70.5% (95% CI: 67.7%-73.1%). Table 4 summarizes age- and sex-weighted prevalence rates.

**Table 1** Demographic and clinical characteristics of the population based on BMI

| | Total $N=8211$ | BMI < 25 $n=2306$ | Overweight $n=3426$ | Obese $n=2479$ | $P$ value | missing |
|---|---|---|---|---|---|---|
| Demographics | | | | | | |
| Age category | | | | | **< 0.001** | 0 |
| 35–44 | 2308 (28.1%) | 772 (33.5%) | 982 (28.7%) | 554 (22.3%) | | |
| 45–54 | 2196 (26.7%) | 542 (23.5%) | 923 (26.9%) | 731 (29.5%) | | |
| 55–64 | 1955 (23.8%) | 469 (20.3%) | 833 (24.3%) | 653 (26.3%) | | |
| 65–74 | 1205 (14.7%) | 322 (14%) | 478 (14%) | 405 (16.3%) | | |
| 75 + | 547 (6.7%) | 201 (8.7%) | 210 (6.1%) | 136 (5.5%) | | |
| Age, mean (SD) | 53.7 (12.67) | 53.3 (13.89) | 53.4 (12.42) | 54.6 (11.74) | **< 0.001** | 0 |
| Gender | | | | | **< 0.001** | 0 |
| Female | 4424 (53.9%) | 1141 (49.5%) | 1661 (48.5%) | 1622 (65.4%) | | |
| Male | 3787 (46.1%) | 1165 (50.5%) | 1765 (51.5%) | 857 (34.6%) | | |
| Tobacco use | | | | | **< 0.001** | 7 |
| Never | 6286 (76.6%) | 1680 (73%) | 2608 (76.2%) | 1998 (80.6%) | | |
| Past smoker | 329 (4%) | 93 (4%) | 146 (4.3%) | 90 (3.6%) | | |
| Current smoker | 1589 (19.4%) | 529 (23%) | 670 (19.6%) | 390 (15.7%) | | |
| Opium consumption | 435 (5.3%) | 164 (7.2%) | 176 (5.2%) | 95 (3.8%) | **< 0.001** | 32 |
| Alcohol use | 739 (9%) | 236 (10.3%) | 332 (9.7%) | 171 (6.9%) | **< 0.001** | 39 |
| Physical activity level | | | | | **< 0.001** | 66 |
| Low | 1407 (17.3%) | 325 (14.2%) | 486 (14.3%) | 596 (24.2%) | | |
| Moderate | 4743 (58.2%) | 1285 (56.3%) | 2017 (59.4%) | 1441 (58.4%) | | |
| High | 1995 (24.5%) | 673 (29.5%) | 893 (26.3%) | 429 (17.4%) | | |
| Marital status | | | | | 0.203 | 3 |
| Single | 65 (0.8%) | 21 (0.9%) | 24 (0.7%) | 20 (0.8%) | | |
| Married | 7947 (96.8%) | 2214 (96.1%) | 3326 (97.1%) | 2407 (97.1%) | | |
| Other | 196 (2.4%) | 69 (3%) | 75 (2.2%) | 52 (2.1%) | | |
| Ethnicity | | | | | **0.013** | 6 |
| Fars | 3999 (48.7%) | 1142 (49.6%) | 1635 (47.8%) | 1222 (49.3%) | | |
| Azari | 2435 (29.7%) | 630 (27.3%) | 1043 (30.5%) | 762 (30.8%) | | |
| Other | 1771 (21.6%) | 532 (23.1%) | 745 (21.8%) | 494 (19.9%) | | |
| Education category | | | | | **< 0.001** | 6 |
| Illiterate | 565 (6.9%) | 136 (5.9%) | 215 (6.3%) | 214 (8.6%) | | |
| 1–5 | 835 (10.2%) | 171 (7.4%) | 323 (9.4%) | 341 (13.8%) | | |
| 6–12 | 4279 (52.2%) | 1119 (48.6%) | 1797 (52.5%) | 1363 (55%) | | |
| > 12 | 2526 (30.8%) | 876 (38.1%) | 1089 (31.8%) | 561 (22.6%) | | |
| Metabolic complications | | | | | | |
| Hypertension | 2288 (27.9%) | 399 (17.3%) | 906 (26.5%) | 983 (39.7%) | **< 0.001** | 3 |
| Diabetes status | | | | | **< 0.001** | 140 |
| Normoglycemic | 4526 (56.1%) | 1532 (67.6%) | 1886 (55.9%) | 1108 (45.6%) | | |
| IFG | 2066 (25.6%) | 459 (20.3%) | 898 (26.6%) | 709 (29.2%) | | |
| Diabetic | 1479 (18.3%) | 275 (12.1%) | 589 (17.5%) | 615 (25.3%) | | |
| Hyperlipidemia | 2670 (32.5%) | 553 (24%) | 1139 (33.3%) | 978 (39.5%) | **< 0.001** | 4 |
| CKD | 66 (0.8%) | 16 (0.7%) | 24 (0.7%) | 26 (1%) | **< 0.001** | 0 |
| Lab data | | | | | | |
| HDL | 44.8 (12.44) | 47.4 (13.34) | 43.7 (12.11) | 43.8 (11.67) | **< 0.001** | 339† |
| LDL | 113.2 (33.95) | 110.1 (32.77) | 114.2 (34.48) | 114.8 (34.1) | **< 0.001** | 339 |
| TCH | 172.5 (40.12) | 168.5 (38.2) | 173.3 (40.95) | 175.1 (40.43) | **< 0.001** | 339 |
| TG | 124 (88, 175) | 99 (72, 145) | 130 (92, 181) | 141 (101, 193) | **< 0.001** | 339 |
| FBS | 97 (90, 107) | 94 (88, 102) | 97 (91, 107) | 100 (93, 113) | **< 0.001** | 339 |
| Creatinine | 0.8 (0.7, 0.94) | 0.8 (0.69, 0.93) | 0.81 (0.7, 0.96) | 0.8 (0.7, 0.93) | **< 0.001** | 18 |

**Table 1** (continued)

| | Total $N=8211$ | BMI < 25 $n=2306$ | Overweight $n=3426$ | Obese $n=2479$ | $P$ value | missing |
|---|---|---|---|---|---|---|
| Anthropometric | | | | | | |
| WHR | 0.9 (0.07) | 0.9 (0.07) | 0.9 (0.07) | 0.9 (0.07) | **< 0.001** | 198 |
| WC | 96.3 (11.71) | 85.9 (8.69) | 95.9 (7.87) | 106.4 (9.88) | **< 0.001** | 28 |
| HC | 105.2 (9.84) | 96.6 (6.26) | 104.1 (5.75) | 114.5 (9.03) | **< 0.001** | 184 |

*CKD*: chronic kidney disease; *WHR*: waist-to-hip ratio; *WC*: waist circumference; *HC*: hip circumference; *HDL*: high-density lipoprotein; *LDL*; low-density lipoprotein; *TCH*: total cholesterol; *TG*: triglyceride; *FBS*: fasting blood sugar; *IFG*: impaired fasting glucose. Categorial variables are displayed as *n* (%), and continuous variables as mean (SD)

† Patients who did not fast for at least 8 h before the blood tests were excluded

$P < 0.05$ was considered as significant and *P*-value for these variables are shown in bold

### Age and sex stratification

Overweight prevalence in both sexes decreased as the age of the population increased, whereas obesity prevalence increased in women, peaking in the 65–74 age group (Fig. 1 and Table S1). Similarly, the prevalence of WHR-SIRMC increased in both sexes with older age (Fig. 1 and Table S1). The WC-SIRMC in women showed a similar trend, peaking after 55 years, while WC-SIRMC in men fluctuated slightly, with around 30% prevalence in all age groups.

### Distribution maps

Overweight prevalence showed a mixed pattern in different regions of the Tehran metropolis, with Western districts (Range: 35.6%-43%) generally showing a lower prevalence than the rest (35.6%-50.5%). In contrast, obesity was less prevalent in the Northern areas (17.2%-28.1%, Fig. 2). Tehran's Northwest districts also had the lowest prevalence of WHR-SIRMC (71.9%-77%) vs (71.9%-87.5%) in other areas. The prevalence of WC-SIRMC was higher in Tehran's central districts than in other regions (47.4%-59.3%, Fig. 2).

### Adjusted association

In the adjusted model, male sex was associated with a lower prevalence of general obesity and central obesity based on WC-SIRMC. On the other hand, in the WHR-SIRMC analysis, male sex was linked with a higher rate of central obesity (Table S2). Moreover, higher levels of physical activity and higher education were associated with lower rates of general and central obesity. Finally, metabolic complications, like hypertension and diabetes, were seen with a higher frequency in obese participants.

## Discussion

In the current study, we determined the prevalence of overweight (42.2%) and obesity (29.3%) and its associated metabolic complications in Tehran using data from TeCS. The analysis showed that the WC-SIRMC and WHR-SIRMC were 49.2% and 75.5% respectively. A previous cross-sectional study on Iranian adults ≥ 18 years old in 2016 estimated the prevalence of obesity at 22.7% (95% CI: 22.2%–23.2%) and overweight/obesity at 59.3% (58.7%–59.9%) [12]. In another cross-sectional study performed in the Tehran metropolis in 2011 (HEART-2 study), the prevalence of overweight and obesity was 34.6% and 13.1%, respectively [17]. The population in the mentioned studies comprised adults ≥ 18 years old, whereas we included adults ≥ 35 years old. These investigations showed that participants under 35 generally have a lower BMI [12, 17]. Nevertheless, in age groups older than 35, the prevalence of obesity was still higher in the current investigation compared to the HEART-2 study. The data for the current cohort was collected after 2016, and the prevalence of obesity has been on an upward trend in recent decades, confirmed in regional and global studies [8, 18, 19]. This trend may have contributed to the higher obesity prevalence in our study. On the other hand, the prevalence of overweight was approximately similar between the two studies.

Obesity prevalence was almost twice in women compared to men in all age groups, except 35 to 44 years, in which the prevalence was roughly identical. In contrast, being overweight was slightly more common in men compared to women in all age groups. These findings align with previous studies, which reported women may have a greater risk of obesity than men [17, 18, 20]. Differences in cultural roles, fat storage distribution, ability to mobilize stored fat, and insulin sensitivity may explain the discrepancy between the

**Table 2** Demographic and clinical characteristics of the population based on WC

| | Total $N=8225$ | Normal $n=1947$ | Increased risk[a] $n=2035$ | Substantially increased risk[b] $n=4243$ | $P$ value | missing |
|---|---|---|---|---|---|---|
| Demographics | | | | | | |
| Age category | | | | | **< 0.001** | 0 |
| 35–44 | 2315 (28.1%) | 703 (36.1%) | 641 (31.5%) | 971 (22.9%) | | |
| 45–54 | 2193 (26.7%) | 490 (25.2%) | 577 (28.4%) | 1126 (26.5%) | | |
| 55–64 | 1957 (23.8%) | 389 (20%) | 406 (20%) | 1162 (27.4%) | | |
| 65–74 | 1210 (14.7%) | 236 (12.1%) | 274 (13.5%) | 700 (16.5%) | | |
| 75 + | 550 (6.7%) | 129 (6.6%) | 137 (6.7%) | 284 (6.7%) | | |
| Age, mean (SD) | 53.7 (12.67) | 51.9 (13.25) | 52.7 (12.74) | 55 (12.21) | **< 0.001** | 14 |
| Gender | | | | | **< 0.001** | 0 |
| Female | 4433 (53.9%) | 549 (28.2%) | 800 (39.3%) | 3084 (72.7%) | | |
| Male | 3792 (46.1%) | 1398 (71.8%) | 1235 (60.7%) | 1159 (27.3%) | | |
| Tobacco use | | | | | **< 0.001** | 7 |
| Never | 6295 (76.6%) | 1285 (66.1%) | 1466 (72.1%) | 3544 (83.5%) | | |
| Past smoker | 329 (4%) | 91 (4.7%) | 105 (5.2%) | 133 (3.1%) | | |
| Current smoker | 1594 (19.4%) | 567 (29.2%) | 462 (22.7%) | 565 (13.3%) | | |
| Opium consumption | 437 (5.3%) | 178 (9.2%) | 125 (6.2%) | 134 (3.2%) | **< 0.001** | 32 |
| Alcohol use | 738 (9%) | 266 (13.7%) | 211 (10.4%) | 261 (6.2%) | **< 0.001** | 36 |
| Physical activity level | | | | | **< 0.001** | 65 |
| Low | 1416 (17.4%) | 225 (11.7%) | 254 (12.6%) | 937 (22.2%) | | |
| Moderate | 4746 (58.2%) | 1054 (54.7%) | 1181 (58.5%) | 2511 (59.6%) | | |
| High | 1998 (24.5%) | 649 (33.7%) | 583 (28.9%) | 766 (18.2%) | | |
| Marital status | | | | | 0.734 | 3 |
| Single | 63 (0.8%) | 16 (0.8%) | 13 (0.6%) | 34 (0.8%) | | |
| Married | 7961 (96.8%) | 1878 (96.5%) | 1969 (96.8%) | 4114 (97%) | | |
| Divorced | 198 (2.4%) | 52 (2.7%) | 52 (2.6%) | 94 (2.2%) | | |
| Ethnicity | | | | | 0.092 | 6 |
| Fars | 4001 (48.7%) | 951 (48.9%) | 987 (48.5%) | 2063 (48.6%) | | |
| Azari | 2444 (29.7%) | 556 (28.6%) | 581 (28.6%) | 1307 (30.8%) | | |
| Other | 1774 (21.6%) | 438 (22.5%) | 465 (22.9%) | 871 (20.5%) | | |
| Education category | | | | | **< 0.001** | 6 |
| Illiterate | 569 (6.9%) | 66 (3.4%) | 93 (4.6%) | 410 (9.7%) | | |
| 1–5 | 831 (10.1%) | 130 (6.7%) | 155 (7.6%) | 546 (12.9%) | | |
| 6–12 | 4288 (52.2%) | 982 (50.5%) | 1035 (50.9%) | 2271 (53.5%) | | |
| > 12 | 2531 (30.8%) | 767 (39.4%) | 749 (36.9%) | 1015 (23.9%) | | |
| Metabolic complications | | | | | | |
| Hypertension | 2301 (28%) | 323 (16.6%) | 460 (22.6%) | 1518 (35.8%) | **< 0.001** | 3 |
| Diabetes status | | | | | **< 0.001** | 140 |
| Normoglycemic | 4529 (56%) | 1297 (67.7%) | 1178 (59%) | 2054 (49.2%) | | |
| IFG | 2071 (25.6%) | 410 (21.4%) | 515 (25.8%) | 1146 (27.5%) | | |
| Diabetic | 1485 (18.4%) | 208 (10.9%) | 303 (15.2%) | 974 (23.3%) | | |
| Hyperlipidemia | 2678 (32.6%) | 427 (22%) | 596 (29.3%) | 1655 (39%) | **< 0.001** | 4 |
| CKD | 67 (0.8%) | 14 (0.7%) | 15 (0.7%) | 38 (0.9%) | 0.699 | 0 |
| Lab data | | | | | | |
| HDL | 44.8 (12.45) | 45.1 (12.59) | 43.5 (12.42) | 45.3 (12.36) | **< 0.001** | 353 |
| LDL | 113.2 (33.97) | 108.6 (32.09) | 113 (34.55) | 115.5 (34.31) | **< 0.001** | 353 |
| TCH | 172.5 (40.17) | 165.4 (37.69) | 171.3 (40.61) | 176.3 (40.59) | **< 0.001** | 353 |
| TG | 124 (88, 175) | 101 (72, 151) | 123 (88, 175) | 135 (97, 184) | **< 0.001** | 353 |
| FBS | 97 (90, 107) | 95 (89, 102) | 97 (90, 106) | 99 (92, 112) | **< 0.001** | 353 |

**Table 2** (continued)

| | Total $N=8225$ | Normal $n=1947$ | Increased risk[a] $n=2035$ | Substantially increased risk[b] $n=4243$ | $P$ value | missing |
|---|---|---|---|---|---|---|
| Creatinine | 0.8 (0.70, 0.94) | 0.86 (0.74, 0.97) | 0.84 (0.72, 0.98) | 0.77 (0.68, 0.9) | **< 0.001** | 32 |
| Anthropometric | | | | | | |
| WHR | 0.9 (0.07) | 0.9 (0.08) | 0.9 (0.07) | 0.9 (0.06) | **< 0.001** | 212 |
| BMI | 28 (4.82) | 23.7 (2.96) | 26.4 (2.76) | 30.7 (4.52) | **< 0.001** | 14 |
| Weight | 76.1 (14.65) | 67 (11.17) | 74.2 (11.83) | 81.1 (15.05) | **< 0.001** | 14 |
| Height | 164.7 (10.43) | 167.8 (9.22) | 167.1 (10.35) | 162.2 (10.36) | **< 0.001** | 14 |

*CKD*: chronic kidney disease; *WHR*: waist-to-hip ratio; *HDL*: high-density lipoprotein; *LDL*: low-density lipoprotein; *TCH*: total cholesterol; *TG*: triglyceride; *FBS*: fasting blood sugar; *IFG*: impaired fasting glucose. Categorial variables are displayed as *n* (%), and continuous variables as mean (SD). a. Central obesity based on WC-increased risk of metabolic complications; b. Central obesity based on WC-SIRMC

$P<0.05$ was considered as significant and *P*-value for these variables are shown in bold

sexes regarding obesity [21]. According to a comprehensive systematic review of the Iranian population, the upward trends in prevalence rates of obesity and BMI since 1990 are concerning and need an immediate call for action in terms of adult population weight-reducing strategies [22].

The prevalence of WC-SIRMC was much higher in women than in men. After 55 years, more than 80% of the women belonged to the WC-SIRMC group compared to 30% of the men. On the contrary, the WHR analysis suggested that central obesity was more prevalent in men than women (81% vs. 71%). This discrepancy was also apparent in the adjusted model. The male sex showed aORs of 1.93, 0.54, and 0.25 for WHR-SIRMC, BMI ≥ 30 and WC-SIRMC, respectively. The difference between the results of WC and WHR can be explained by the tendency of WC measurement to underestimate central obesity prevalence in men and overestimate it in women [23]. WHR may also incorrectly be in the normal range in obese women because of high hip circumference [24]. Regardless of the measurement method used, the prevalence of central obesity was higher in Tehran's adult population compared to other areas of the world [25, 26]. A 2020 meta-analysis estimated the global prevalence of central obesity at 41.5% (95% CI: 39.9%–43.2%), much lower than our estimate [2]. In this meta-analysis, central obesity prevalence was higher in older adults and women, similar to our findings [2].

Low education level was associated with a higher frequency of all obesity indices in the current study. This is consistent with the previous findings on Tehran's adult residents, in which no formal education and only primary school education were shown to be associated with a higher prevalence of obesity compared to high school education or associate degree [17]. Similarly, a meta-analysis in Iran showed that low educational and socioeconomic levels are associated with a higher prevalence of obesity [27]. Another systematic review by Cohen et al. suggested that the association between education level and obesity depends on the country's level of development [28]. Inverse associations are usually observed in more developed countries, whereas positive associations are more common in less developed countries [28].

Low physical activity was another factor linked with higher general and central obesity rates in our study. This association demonstrated a dose–response relationship in the adjusted model, with high physical activity showing lower aORs than moderate physical activity. This finding is alarming as physical inactivity prevalence is high among Iranians. In 2016, it was estimated that 54.7% of the Iranian adult population had insufficient physical activity (IPA), an increase from the 39.1% reported prevalence in 2011 [29]. Iran had the highest IPA after Colombia compared to other middle-income countries [30].

As expected, metabolic complications such as diabetes, hyperlipidemia, and hypertension were more common in the overweight/obese population. Moreover, the association between hypertension and diabetes with general and central obesity was independent of other possible confounders, such as age and sex. Previous reviews have shown that obesity is a major risk factor for cardiovascular diseases [31–33]. Several studies found that higher waist circumference is an independent predictor of higher diastolic and systolic blood pressures [34–36]. Moreover, some studies have even suggested that anthropometric measures in obese patients can be used to predict the risk of hypertension or diabetes [37, 38]. Similarly, general and central obesity have been associated with a higher risk of hypercholesteremia [39] and obstructive sleep apnea [40]. Therefore, focusing on strategies to combat obesity, especially central obesity in the Tehran metropolis, can also aid in reducing cardiovascular diseases and their complications.

The geographical analysis of obesity prevalence in Tehran showed that southern and central districts had a higher prevalence of all obesity indices than other areas. It has been demonstrated that Tehran's south and southeastern regions are socioeconomically underdeveloped [41]. Lower socioeconomic

**Table 3** Demographic and clinical characteristics of the population based on WHR

| | Total $N=8049$ | Normal risk $n=1895$ | Substantially increased risk[a] $n=6154$ | $P$ value | missing |
|---|---|---|---|---|---|
| Demographics | | | | | |
| Age category | | | | **< 0.001** | 0 |
| 35–44 | 2277 (28.3%) | 813 (42.9%) | 1464 (23.8%) | | |
| 45–54 | 2160 (26.8%) | 538 (28.4%) | 1622 (26.4%) | | |
| 55–64 | 1910 (23.7%) | 338 (17.8%) | 1572 (25.5%) | | |
| 65–74 | 1179 (14.6%) | 149 (7.9%) | 1030 (16.7%) | | |
| 75 + | 523 (6.5%) | 57 (3%) | 466 (7.6%) | | |
| Age, mean (SD) | 53.6 (12.61) | 48.8 (11.32) | 55.1 (12.62) | **< 0.001** | 0 |
| Gender | | | | **< 0.001** | 0 |
| Female | 4335 (53.9%) | 1221 (64.4%) | 3114 (50.6%) | | |
| Male | 3714 (46.1%) | 674 (35.6%) | 3040 (49.4%) | | |
| Tobacco use | | | | **< 0.001** | 7 |
| Never | 6161 (76.6%) | 1491 (78.7%) | 4670 (76%) | | |
| Past smoker | 321 (4%) | 45 (2.4%) | 276 (4.5%) | | |
| Current smoker | 1560 (19.4%) | 358 (18.9%) | 1202 (19.6%) | | |
| Opium consumption | 428 (5.3%) | 109 (5.8%) | 319 (5.2%) | 0.329 | 31 |
| Alcohol use | 721 (9%) | 170 (9%) | 551 (9%) | 0.98 | 37 |
| Physical activity level | | | | **< 0.001** | 62 |
| Low | 1381 (17.3%) | 221 (11.8%) | 1160 (19%) | | |
| Moderate | 4654 (58.3%) | 1094 (58.3%) | 3560 (58.3%) | | |
| High | 1952 (24.4%) | 562 (29.9%) | 1390 (22.7%) | | |
| Marital status | | | | **< 0.001** | 0 |
| Single | 58 (0.7%) | 14 (0.7%) | 44 (0.7%) | | |
| Married | 7795 (96.8%) | 1801 (95%) | 5994 (97.4%) | | |
| Divorced | 196 (2.4%) | 80 (4.2%) | 116 (1.9%) | | |
| Ethnicity | **0.026** | 3 | | | |
| Fars | 3897 (48.4%) | 883 (46.6%) | 3014 (49%) | | |
| Azari | 2405 (29.9%) | 559 (29.5%) | 1846 (30%) | | |
| Other | 1744 (21.7%) | 452 (23.9%) | 1292 (21%) | | |
| Education category | | | | **< 0.001** | 2 |
| Illiterate | 561 (7%) | 45 (2.4%) | 516 (8.4%) | | |
| 1–5 | 816 (10.1%) | 108 (5.7%) | 708 (11.5%) | | |
| 6–12 | 4210 (52.3%) | 1033 (54.5%) | 3177 (51.6%) | | |
| > 12 | 2460 (30.6%) | 709 (37.4%) | 1751 (28.5%) | | |
| Metabolic complications | | | | | |
| Hypertension | 2238 (27.8%) | 323 (17%) | 1915 (31.1%) | **< 0.001** | 3 |
| Diabetes status | | | | **< 0.001** | 139 |
| Normoglycemic | 4446 (56.2%) | 1362 (72.7%) | 3084 (51.1%) | | |
| IFG | 2028 (25.6%) | 342 (18.2%) | 1686 (27.9%) | | |
| Diabetic | 1436 (18.2%) | 170 (9.1%) | 1266 (21%) | | |
| Hyperlipidemia | 2616 (32.5%) | 451 (23.8%) | 2165 (35.2%) | **< 0.001** | 4 |
| CKD | 64 (0.8%) | 7 (0.4%) | 57 (0.9%) | **0.017** | 0 |
| Lab data | | | | | |
| HDL | 44.8 (12.4) | 47.8 (12.7) | 43.8 (12.16) | **< 0.001** | 337 |
| LDL | 113.2 (33.92) | 110.5 (31.82) | 114 (34.5) | **< 0.001** | 337 |
| TCH | 124 (88, 175) | 102 (74, 149) | 131 (94, 182) | **< 0.001** | 337 |
| TG | 97 (90, 107) | 94 (88, 100) | 99 (91, 110) | **< 0.001** | 337 |
| FBS | 0.8 (0.7, 0.94) | 0.77 (0.68, 0.89) | 0.81 (0.7, 0.96) | **< 0.001** | 16 |
| Creatinine | 0.8 (0.7, 0.94) | 0.84 (0.72, 0.98) | 0.77 (0.68, 0.9) | **< 0.001** | 32 |

**Table 3** (continued)

| | Total $N=8049$ | Normal risk $n=1895$ | Substantially increased risk[a] $n=6154$ | $P$ value | missing |
|---|---|---|---|---|---|
| Anthropometric | | | | | |
| BMI | 28 (4.8) | 26.2 (4.86) | 28.5 (4.64) | **< 0.001** | 36 |
| Weight | 76.1 (14.49) | 70.9 (13.05) | 77.7 (14.54) | **< 0.001** | 8 |
| Height | 164.7 (10.45) | 164.6 (9.55) | 164.8 (10.71) | 0.458 | 8 |

*CKD*: chronic kidney disease; *WHR*: waist-to-hip ratio; *HDL*: high-density lipoprotein; *LDL*: low-density lipoprotein; *TCH*: total cholesterol; *TG*: triglyceride; *FBS*: fasting blood sugar; *IFG*: impaired fasting glucose. Categorial variables are displayed as *n* (%), and continuous variables as mean (SD). a. Central obesity based on WHR-SIRMC

$P<0.05$ was considered as significant and *P*-value for these variables are shown in bold

**Table 4** The age and sex-weighted prevalence of obesity indices based on the 2016 Tehran census results

| prevalence % (95% CI) | Total | Female | Male |
|---|---|---|---|
| BMI (overweight) | 42.2 (39, 45.4) | 37.5 (34.5, 40.6) | 47 (43.6, 50.3) |
| BMI ≥ 30 (obese) | 29.3 (26.4, 32.3) | 35.5 (32.6, 38.6) | 22.9 (20.1, 25.8) |
| Central obesity (WC)[a] | 49.2 (46.3, 52.2) | 67.9 (65.1, 70.6) | 30.1 (27, 33.3) |
| Central obesity (WHR)[b] | 75.5 (72.7, 78.1) | 70.5 (67.7, 73.1) | 80.6 (77.9, 83.1) |

*WHR*: waist-to-hip ratio; *WC*: waist circumference; *BMI*: body mass index; a. Central obesity based on WC-SIRMC; b. Central obesity based on WHR-SIRMC

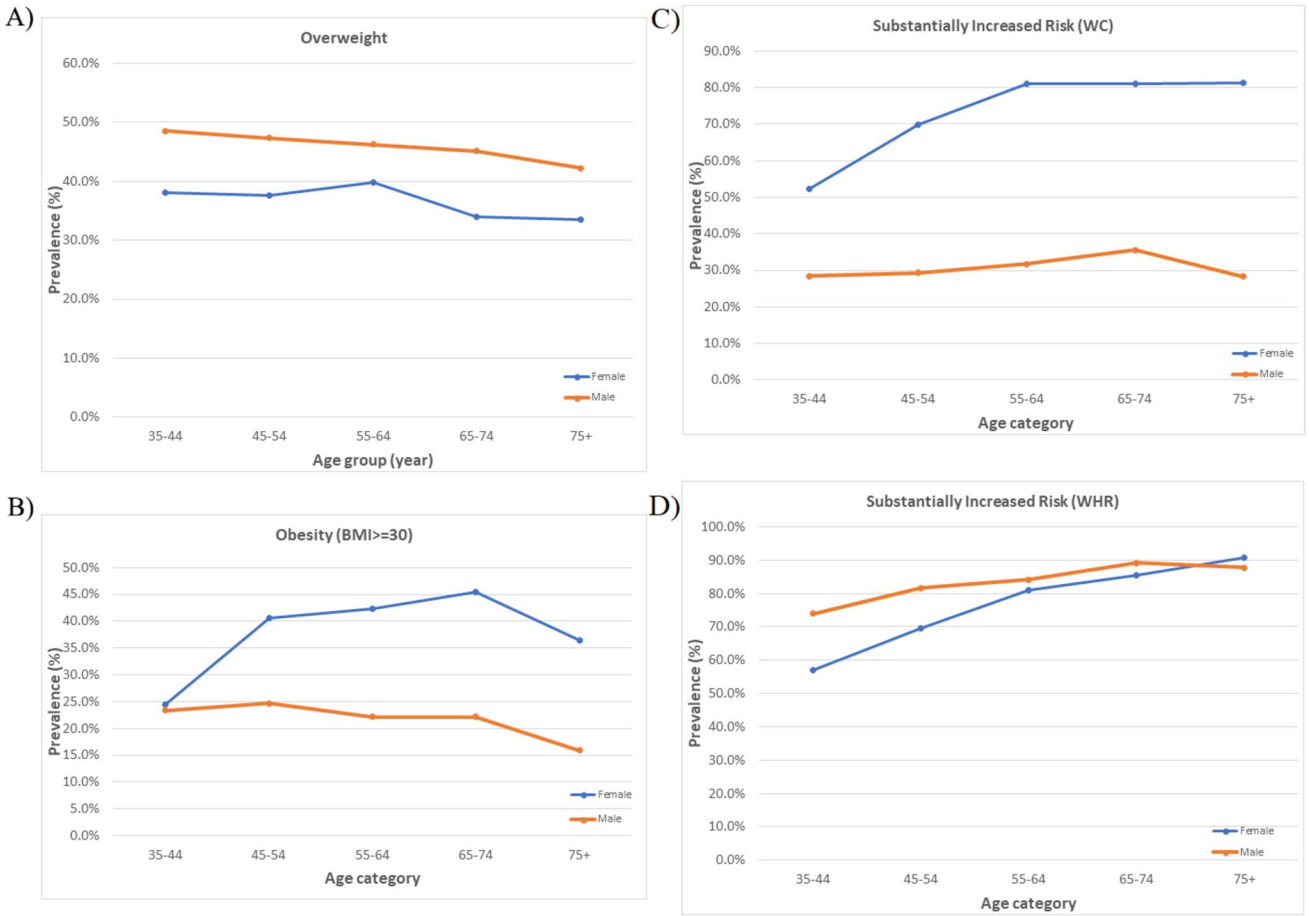


**Fig. 1** Prevalence of overweight (**A**) and obesity (**B**) based on age and sex groups**;** Prevalence of central obesity based on waist circumference (**C**) and waist-to-hip ratio (**D**)

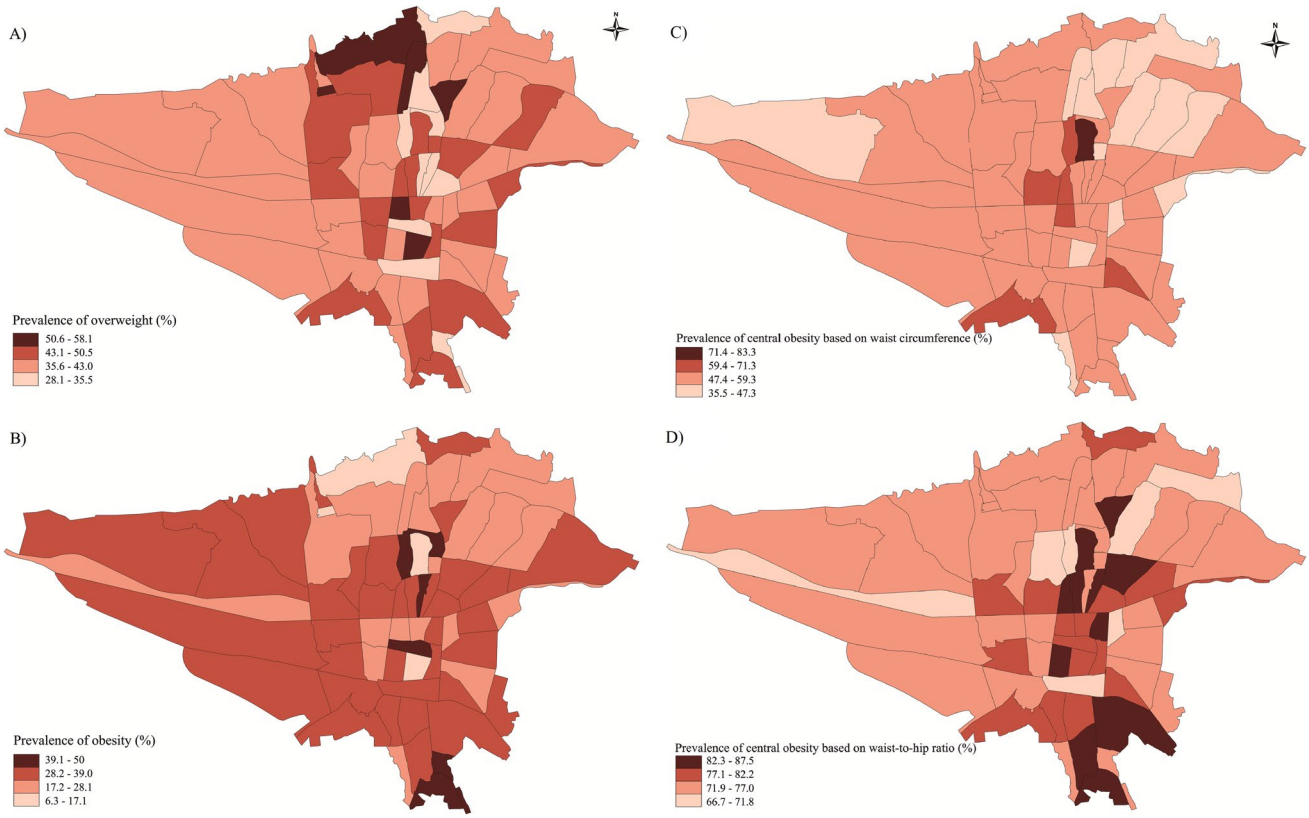


**Fig. 2** Prevalence of overweight (**A**) and obesity (**B**) in different districts of Tehran**;** Prevalence of substantially increased risk of metabolic complications based on waist circumference (**C**) and waist-to-hip ratio (**D**) in different districts of Tehran

status may result in lower education levels and poor diet, putting the population at risk of obesity [41]. A 2017 study in Tehran also reported other health outcomes to be worse in lower-income and education districts of the city [42].

### Limitations

A major limitation of the current study was that we only investigated adults above 35 years of age. Thus, the overall prevalence of obesity/overweight and central obesity in the total population of Tehran may be different; however, the provided findings can still demonstrate the obesity prevalence in a high-risk population for cardiovascular diseases, which is generally over 35 years old. In addition, any causal inferences between obesity and risk factors should be made with caution due to the study's cross-sectional design. Finally, data about physical activity level was self-reported and may be influenced by recall bias.

## Conclusion

The increasing prevalence of general and central obesity in Tehran, especially among older people, women, and socioeconomically underdeveloped districts, is an alarm sign that requires immediate implementation of adult population weight-reduction strategies to prevent a further increase in severe cardiovascular events.

**Abbreviations** *ANOVA*: Analysis of Variance; *BMI*: Body Mass Index; *CI*: Confidence Interval; *CVD*: Cardiovascular Disease; *DALYs*: Disability-Adjusted Life Years; *FBS*: Fasting Blood Sugar; *HC*: Hip Circumference; *IPA*: Insufficient Physical Activity; *OR*: Odds Ratio; *SD*: Standard Deviation; *SIRMC*: Substantially Increased Risk of Metabolic Complications; *TeCS*: Tehran Cohort Study; *WC*: Waist Circumference; *WHO*: World Health Organization; *WHR*: Waist-to-Hip Ratio

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**Authors' contributions** AS and KH hypothesized this work.
AS, SN, and MSN wrote the main manuscript.
AS, SN, AJ, and MSN prepared the figures.
AJ cleaned the data and did the statistical analysis.
AS, SN, AJ, AVF, OHF, and MSN revised the manuscript.
AJ, FA, and SoS designed the cohort.
FA and FM contributed to data collection and management.
SaS, MB, AK, and OHF supervised the project. All authors reviewed and approved the manuscript.

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**Data availability** The dataset of the present study is not publicly available due to the current policy of the Tehran Cohort Study; however, it is available upon reasonable request from the corresponding author.

## Declarations

**Ethics approval and consent to participate** The Tehran University of Medical Sciences ethics committee approved the TeCS cohort (IR.TUMS.MEDICINE.REC.1399.074). All participants provided written informed consent at the start of the study. The study was carried out according to the Helsinki Declaration.

**Consent for publication** Not applicable.

**Competing interests** None declared.

## References

1. WHO fact sheet on obesity and overweight. https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight. Accessed 18 Dec 2023.
2. Wong MCS, Huang J, Wang J, et al. Global, regional and time-trend prevalence of central obesity: a systematic review and meta-analysis of 13.2 million subjects. Eur J Epidemiol. 2020;35(7):673–83. https://doi.org/10.1007/s10654-020-00650-3.
3. Waist circumference and waist-hip ratio: report of a WHO expert consultation. Geneva; 2008. https://www.who.int/publications/i/item/9789241501491. Accessed 18 Dec 2023.
4. Huai P, Liu J, Ye X, Li W-Q. Association of Central Obesity With All Cause and Cause-Specific Mortality in US Adults: A Prospective Cohort Study. Front Cardiovasc Med. 2022;9. https://doi.org/10.3389/fcvm.2022.816144.
5. Muthiah Vaduganathan, Mensah George A, Varieur Turco Justine, Valentin Fuster, Roth Gregory A. The Global Burden of Cardiovascular Diseases and Risk. J Am College Cardiol. 2022;80(25):2361–71. https://doi.org/10.1016/j.jacc.2022.11.005.
6. Najafipour H, Bagheri M, Saberi S, Farokhi M, Amirzadeh R, Mirzazadeh A. Epidemiological update on prevalence and incidence of overweight and obesity in adults in the south-east of the Islamic Republic of Iran: findings from the Kerman Coronary Artery Diseases Risk Factors Study (KERCADRS). East Mediterr Health J. 2021;27(9):874–83. https://doi.org/10.26719/emhj.21.035.
7. Pourfarzi F, Sadjadi A, Poustchi H, Amani F. Prevalence of overweight and obesity in Iranian population: A population-based study in northwestern of Iran. J Public Health Res. 2021;11(1). https://doi.org/10.4081/jphr.2021.2475
8. Trends in adult body-mass index in 200 countries from 1975 to 2014: a pooled analysis of 1698 population-based measurement studies with 19·2 million participants. The Lancet. 2016;387(10026):1377–1396. https://doi.org/10.1016/S0140-6736(16)30054-X
9. Barzin M, Valizadeh M, Serahati S, Mahdavi M, Azizi F, Hosseinpanah F. Overweight and Obesity: Findings from 20 Years of the Tehran Lipid and Glucose Study. Int J Endocrinol Metab. 2018;16(4 Suppl): e84778. https://doi.org/10.5812/ijem.84778.
10. Lin X, Li H. Obesity: Epidemiology, Pathophysiology, and Therapeutics. Frontiers in Endocrinol. 2021;12. https://doi.org/10.3389/fendo.2021.706978.
11. Okati-Aliabad H, Ansari-Moghaddam A, Kargar S, Jabbari N. Prevalence of Obesity and Overweight among Adults in the Middle East Countries from 2000 to 2020: A Systematic Review and Meta-Analysis. J Obes. 2022;2022:8074837. https://doi.org/10.1155/2022/8074837.
12. Djalalinia S, Saeedi Moghaddam S, Sheidaei A, et al. Patterns of Obesity and Overweight in the Iranian Population: Findings of STEPs 2016. Front Endocrinol. 2020;11. https://doi.org/10.3389/fendo.2020.00042.
13. Shafiee A, Saadat S, Shahmansouri N, et al. Tehran cohort study (TeCS) on cardiovascular diseases, injury, and mental health: Design, methods, and recruitment data. Global Epidemiology. 2021;3: 100051. https://doi.org/10.1016/j.gloepi.2021.100051.
14. World Health Organization: Diagnosis and management of type 2 diabetes (HEARTS-D). 2020 (WHO/UCN/NCD/20.1) Licence: CC BY-NC-SA 3.0 IGO. https://www.who.int/publications/i/item/who-ucn-ncd-20.1. Accessed 20 Nov 2023.
15. Williams B, Mancia G, Spiering W, et al. 2018 ESC/ESH Guidelines for the management of arterial hypertension: The Task Force for the management of arterial hypertension of the European Society of Cardiology (ESC) and the European Society of Hypertension (ESH). Eur Heart J. 2018;39(33):3021–104. https://doi.org/10.1093/eurheartj/ehy339.
16. Shafiee A, Oraii A, Jalali A, et al. Epidemiology and prevalence of tobacco use in Tehran; a report from the recruitment phase of Tehran cohort study. BMC Public Health. 2023;23(1):740. https://doi.org/10.1186/s12889-023-15629-4.
17. Ahmad Kiadaliri A, Jafari M, Vaez Mahdavi M-R, Faghihzadeh S, Kalantari N, Asadi-Lari M. The prevalence of adulthood overweight and obesity in Tehran: findings from Urban HEART-2 study. MJIRI. 2015;29(1):152–160. http://mjiri.iums.ac.ir/article-1-2696-en.html. Accessed 18 Dec 2023.
18. Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. The Lancet. 2016;388(10053):1659–1724. https://doi.org/10.1016/S0140-6736(16)31679-8
19. Jafari-Adli S, Jouyandeh Z, Qorbani M, Soroush A, Larijani B, Hasani-Ranjbar S. Prevalence of obesity and overweight in adults and children in Iran; a systematic review. J Diabetes Metab Disord. 2014;13(1):121. https://doi.org/10.1186/s40200-014-0121-2.
20. Reilly JJ, El-Hamdouchi A, Diouf A, Monyeki A, Somda SA. Determining the worldwide prevalence of obesity. The Lancet. 2018;391(10132):1773–4. https://doi.org/10.1016/S0140-6736(18)30794-3.
21. Reue K. Sex differences in obesity: X chromosome dosage as a risk factor for increased food intake, adiposity and co-morbidities. Physiol Behav. 2017;176:174–82. https://doi.org/10.1016/j.physbeh.2017.02.040.

22. Djalalinia S, Mehdipour P, Mohajer B, et al. Levels and Trends of BMI, Obesity, and Overweight at National and Sub-national Levels in Iran from 1990 to 2016; A Comprehensive Pooled Analysis of Half a Million Individuals. Arch Iran Med. 2021;24(5):344–53. https://doi.org/10.34172/aim.2021.51.
23. Csongová M, Volkovová K, Gajdoš M, et al. Gender-associated differences in the prevalence of central obesity using waist circumference and waist-to-height ratio, and that of general obesity, in Slovak adults. Cent Eur J Public Health. 2018;26(3):228–33. https://doi.org/10.21101/cejph.a4719.
24. Ahmad N, Adam SIM, Nawi AM, Hassan MR, Ghazi HF. Abdominal Obesity Indicators: Waist Circumference or Waist-to-hip Ratio in Malaysian Adults Population. Int J Prev Med. 2016;7:82. https://doi.org/10.4103/2008-7802.183654.
25. Serna-Gutiérrez A, Castro-Juarez AA, Romero-Martínez M, et al. Prevalence of overweight, obesity and central obesity and factors associated with BMI in indigenous yaqui people: a probabilistic cross-sectional survey. BMC Public Health. 2022;22(1):308. https://doi.org/10.1186/s12889-022-12702-2.
26. Tekalegn Y, Solomon D, Sahiledengle B, et al. Prevalence of central obesity and its associated risk factors among adults in Southeast Ethiopia: A community-based cross-sectional study. PLoS ONE. 2022;17(8): e0265107. https://doi.org/10.1371/journal.pone.0265107.
27. Djalalinia S, Peykari N, Qorbani M, Larijani B, Farzadfar F. Inequality of obesity and socioeconomic factors in Iran: a systematic review and meta- analyses. Med J Islam Repub Iran. 2015;29:241.
28. Cohen AK, Rai M, Rehkopf DH, Abrams B. Educational attainment and obesity: a systematic review. Obes Rev. 2013;14(12):989–1005. https://doi.org/10.1111/obr.12062.
29. Mohebi F, Mohajer B, Yoosefi M, et al. Physical activity profile of the Iranian population: STEPS survey, 2016. BMC Public Health. 2019;19(1):1266. https://doi.org/10.1186/s12889-019-7592-5.
30. Dieleman JL, Baral R, Birger M, et al. US Spending on Personal Health Care and Public Health, 1996–2013. JAMA. 2016;316(24):2627–46. https://doi.org/10.1001/jama.2016.16885.
31. Aparecida Silveira E, Vaseghi G, de Carvalho Santos, Annelisa Silva, et al. Visceral Obesity and Its Shared Role in Cancer and Cardiovascular Disease: A Scoping Review of the Pathophysiology and Pharmacological Treatments. Int J Mol Sci. 2020;21(23). https://doi.org/10.3390/ijms21239042
32. Darsini D, Hamidah H, Notobroto HB, Cahyono EA. Health Risks Associated with High Waist Circumference: A Systematic Review. J Public Health Res. 2020;9(2):jphr.2020.1811. https://doi.org/10.4081/jphr.2020.1811.
33. Elagizi A, Kachur S, Carbone S, Lavie CJ, Blair SN. A Review of Obesity, Physical Activity, and Cardiovascular Disease. Curr Obes Rep. 2020;9(4):571–81. https://doi.org/10.1007/s13679-020-00403-z.
34. Qian JD, Li XM, Chen DS, Zhu JQ, Liu XZ. Comparative analysis of the association between traditional and lipid-related obesity indicators and isolated systolic hypertension. BMC Cardiovasc Disord. 2022;22(1):119. https://doi.org/10.1186/s12872-022-02564-2.
35. Siani A, Cappuccio FP, Barba G, et al. The Relationship of Waist Circumference to Blood Pressure: The Olivetti Heart Study*. Am J Hypertens. 2002;15(9):780–6. https://doi.org/10.1016/S0895-7061(02)02976-X.
36. Sun J-Y, Hua Y, Zou H-Y-Y, et al. Association Between Waist Circumference and the Prevalence of (Pre) Hypertension Among 27,894 US Adults. Frontiers in Cardiovascular Medicine. 2021;8. https://doi.org/10.3389/fcvm.2021.717257.
37. Abolhasani M, Maghbouli N, Sazgara F, Karbalai Saleh S, Tahmasebi M, Ashraf H. Evaluation of Several Anthropometric and Metabolic Indices as Correlates of Hyperglycemia in Overweight/Obese Adults. Diabetes Metab Syndr Obes. 2020;13:2327–36. https://doi.org/10.2147/DMSO.S254741.
38. Abolhasani M, Maghbouli N, Karbalai Saleh S, et al. Which anthropometric and metabolic index is superior in hypertension prediction among overweight/obese adults? Integr Blood Press Control. 2021;14:153–61. https://doi.org/10.2147/IBPC.S340664.
39. Koo HC, Tan LK, Lim GP, Kee CC, Omar MA. Obesity and Its Association with Undiagnosed Diabetes Mellitus, High Blood Pressure and Hypercholesterolemia in the Malaysian Adult Population: A National Cross-Sectional Study Using NHMS Data. Int J Environ Res Public Health. 2023;20(4). https://doi.org/10.3390/ijerph20043058
40. Bonsignore, M.R. (2021). Obesity and Obstructive Sleep Apnea. In: Eckel, J., Clément, K. (eds) From Obesity to Diabetes. Handbook of Experimental Pharmacology, vol 274. Springer, Cham. https://doi.org/10.1007/164_2021_558
41. Sadeghi R ZN. The Inequality of Development in the 22 Districts of Tehran Metropolis. Social Welfare Quarterly 2017;17(66):149–184. http://refahj.uswr.ac.ir/article-1-3026-en.html. Accessed 18 Dec 2023.
42. Baigi V, Nedjat S, Hosseinpoor AR, Sartipi M, Salimi Y, Fotouhi A. Socioeconomic inequality in health domains in Tehran: a population-based cross-sectional study. BMJ Open. 2018;8(2): e018298. https://doi.org/10.1136/bmjopen-2017-018298.

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