EPIDEMIOLOGICAL ASPECTS OF THE ASSOCIATION OF THE HYPERTRIGLYCERIDEMIC WAIST PHENOTYPE WITH METABOLIC SYNDROME AND CARDIOVASCULAR RISK FACTORS IN MOROCCO. CASE THE AMAZIGH POPULATION FROM A GEOGRAPHIC REGION CALLED SOUSS

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ABSTRACT

Background. The global prevalence of metabolic syndrome (MetS) increases susceptibility to non-communicable diseases such as obesity, type 2 diabetes, and cardiovascular disease, posing significant health risks. Effective prevention and management require objective tools. The hypertriglyceridemic waist (TG+WC+) phenotype is proposed as a less expensive approach to identify individuals with metabolic syndrome and other cardiovascular risk factors.

Objective. The current aim of this investigation is to study the epidemiological characteristics of the hypertriglyceridemic waist phenotype and their correlations with cardiovascular risk factors and MetS in the Moroccan Amazigh ethnic group from the Souss region of Morocco.

Material and Methods. A total of 827 Amazigh adults from the Sousse region of Morocco were divided into four distinct phenotype groups: TG-WC-, TG+WC-, TG-WC+, and TG+WC+ (normal TG- or high TG+ triglycerides/normal WC- or high WC+ waist circumference). The association of the different phenotypes with MetS and other cardiovascular risk factors was established by logistic regression analysis.

Results. The prevalence of the TG+WC+ phenotype was 27.7% and varied according to age group and sex. Among subjects with the TG+WC+ phenotype, most were 41-60 years old (53.3%) and in women (74.2%). Participants with the TG+WC+ phenotype had the highest prevalence of dyslipidemia (87.3%), hypoHDLaemia (69.9%), and general obesity (37.12%). The three phenotypes TG-WC-, TG+WC- and TG-WC+ were less associated with MetS and other cardiovascular risk factors. Moreover, people with the TG+WC+ phenotype had a very high odds ratio for MetS.

Conclusion. These findings suggest that the TG+WC+ phenotype exhibits a robust correlation with MetS and additional variables connected to cardiovascular risk. The TG+WC+ phenotype serves as a valuable clinical instrument for detecting individuals vulnerable to MetS and cardiovascular diseases.

Keywords: hypertriglyceridemic waist phenotype, cardiovascular risk factors, metabolic syndrome, epidemiology, Morocco

INTRODUCTION

Metabolic syndrome (MetS), is characterized by a range of interconnected clinical and biochemical irregularities and dysfunctions. The combined impact of these elements represents a notable factor at risk for the onset of cardiovascular disease (CVD), type 2 diabetes (T2D), and additional health complications [1]. Metabolic syndrome prevalence is on the rise across the globe, varying from 12.5% to 31.4%, contingent upon the adopted definition and the geographical region studied. The Eastern Mediterranean and the Americas show the highest prevalence rates, which correlate with the standard of living and income levels [2].

The growing prevalence of MetS globally is attributed to the shift in epidemiological and nutritional patterns known as the epidemiological and nutritional transition that accompanies rapid economic growth. This phenomenon arises from unhealthy lifestyle choices, including sedentary behavior and inadequate...
dietary habits, which have become pervasive across all
countries due to continuous cultural globalization [3].

Morocco, like all other nations, has undergone an
epidemiological transition, leading to adverse outcomes
for both public health and the economy [3]. It was
reported that Moroccan population presents a high risk
of cardiovascular disease (37%), significantly elevated
in older adults [4]. It is evident that cardiovascular
disease continues to be the major reason behind
mortality [5, 6]. Also, the prevalence of MetS varies by
age, gender, ethnicity, and area [7]. However, there is no
national average, for example, among adult women in
southern Morocco, it was 16.3% in 2002 [8], but among
post-menopausal women in northern Morocco, it was
74.18% in 2020 [9].

Metabolic syndrome (MetS) is generally indicated
by the coexistence of at least three of the following
characteristics, although other health organizations
may have different diagnostic standards: obesity, either
general or central located, high triglyceride (TG), low
HDL-cholesterol, hypertension, and hyperglycemia
[10]. The main causes of MetS are considered to be
central obesity and insulin resistance [11]. According
to Engin [12], central obesity is the most observed aspect
of MetS. Waist circumference (WC) measurement
is considered the classic marker screening for MetS
and a more effective parameter for predicting CVD
risk indicators [13, 14]. But which index best predicts
MetS remains controversial. While WC is one of
the components of MetS [15], its limitations lie in
its inability to distinguish between subcutaneous
and visceral abdominal fat [16]. Indeed, it has been
demonstrated that visceral fat is strongly linked
with various cardiovascular risk triggers and CVD
[17, 18, 19]. The presence of elevated TG and WC is
known as the hypertriglyceridemic waist phenotype
that males displaying atherogenic metabolic traits and
facing a heightened risk of coronary heart disease
might be detectable through an inexpensive screening
approach involving the assessment and analysis of waist
circumference and triglyceride levels.

Recent studies have employed the TG+WC+
phenotype, an inexpensive index to identify hypertension
[21], type 2 diabetes [22, 23] and MetS as part of initial
population screening efforts. For identifying metabolic
problems, hypertriglyceridemic waist phenotypes may
be more predictive value than individual anthropometric
markers [24, 25]. One of the most potent indicators
of breast cancer risk is the TG+WC+ phenotype [26].
For screening the risk of cardiovascular disease, this marker
may be a useful tool [27].

The objective of this study is to elucidate the
epidemiological characteristics of the TG+WC+
phenotype and investigate its possible associations
with MetS and cardiovascular factors at risk in a cross-
sectional sample drawn from the Moroccan Amazigh
ethnic group in the Souss region of Morocco.

**MATERIAL AND METHODS**

**The target population**

This is a prospective epidemiological study carried
out between January 2023 and December 2023 at the
Hassan 1st Provincial Hospital in Tiznit city. The study
involved a population of Amazigh origin, 827 healthy
individuals (254 men and 573 women aged between 20
and 80). The study was carried out in conjunction with
a lipid panel. Participants are volunteers and each of
them had written consent prior to their inclusion in this
study. We excluded pregnant women, disabled people,
senile individuals over 80, hemodialysis patients, cancer
patients, and cardiac patients.

**Anthropometric measurements**

Weight measurements were taken utilizing an
electronic scale with a sensitivity of 0.1 kg, with
participants being weighed wearing only light
underwear. The height of each subject was assessed
with precision, to the nearest millimeter using a wall
measuring device. The subjects were placed with
their backs to the wall, with their feet, buttocks, back,
shoulders and head in contact with the surface. WC was
determined using a tape measure halfway between the
last rib of the thorax and the tip of the hip bone at the
end of a natural exhalation. The test subject is required
to stand with their feet 25 cm [28].

**Blood pressure measurement**

The automated sphygmomanometer (MICOLIF,
Germany) was utilized to test the blood pressure. While
the subjects were at rest, measurements were taken.
Three measurements of the blood pressure were made,
and the analysis was done using the mean value.

**Blood tests**

After a 12-hour overnight fast, blood samples
were obtained by venipuncture from trained medical
personnel. The lipid profile analysis was conducted at
the medical biology unit of the Provincial Hospital in
Tiznit city using an automated analyzer (BioSystems
BA400).

**Definitions**

MetS is defined according to the harmonized
criteria outlined in the Joint Interim Statement (JIS)
definition [29], considering specific WC cut-off points
for Mediterranean region. When three or more of
the following risk-factors indicators were met, the patient
was considered with MetS: WC in women ≥80 cm and
in men ≥94 cm; fasting plasma glucose (FPG) ≥1 g/L
or taking anti-diabetic drugs; systolic blood pressure
(SBP) ≥130 mmHg and/or diastolic blood pressure (DBP) ≥85 mmHg or confirmed treatment history of hypertension, elevated fasting triglycerides (FGT) ≥1.5 g/L or under treatment for hypertriglyceridemia and low HDL-cholesterol <0.40 g/L in male and <0.5 g/L in female or under therapy for hypoHDLemia. Elsewhere, hypertension is manifested by systolic pressure value ≥140 mmHg, diastolic pressure value ≥90 mmHg, or taking anti-hypertensive drugs [30].

Type 2 diabetes is defined as a fasting blood glucose ≥1.26 g/L, HbA1c ≥6.5%, or taking anti-diabetic drugs [31].

**Anthropometric indices**

The body mass index (BMI), also referred to as the Quetelet index, is calculated by dividing an individual’s weight in kilograms by the square of their height in meters (kg/m²) [32]. Thus, general obesity has been defined by a BMI≥30.0 kg/m².

**Definition of the triglyceridemic-waist circumference phenotype**

To identify triglyceridemic-waist phenotypes TGWC, subjects were divided into four phenotypic categories according to strict JIS criteria based on fasting serum TG levels and WC [29].

- **Phenotype TG-WC-** was considered normal phenotype: WC<94 cm in male and <80 cm in female; TG<1.50 g/L.
- **Phenotype TG+WC-**: WC<94 cm in male and <80 cm in female; TG≥1.5 g/L.
- **Phenotype TG-WC+:** WC≥94 cm for male and ≥80 cm for female; TG<1.5 g/L.
- **Phenotype TG+WC+ known as hypertriglyceridemic waist phenotype**: WC≥94 cm for male and ≥80 cm for female; TG≥1.50 g/L.

**Statistical analysis**

The data is presented in the form of mean values accompanied by standard deviation or as a numerical percentage. Analysis of variance (ANOVA) was performed to compare quantitative characteristics and the chi-square test for qualitative characteristics. The link between MetS and cardiovascular factors at risk with the TG+WC+ phenotype were tested using logistic regression models. Model 1 can fit. In Model 2, adjustments were made for both age and sex. Model 3 further expanded upon Model 2 by incorporating additional adjustments for all examined variables: MetS, diabetes mellitus, dyslipidemia, general obesity, hypertension, hypercholesterolemia, hyperLDLemia, and hypoHDLemia.

The results are expressed as odds ratios (OR) along with their corresponding 95% confidence intervals (CI) in both univariate and multivariate analyses. IBM SPSS Statistics 25.0 software was utilized for all statistical computations and data analysis.

**RESULTS**

Our study has enrolled 827 adults (mean age 52.9±14.7); 30.7% were men (mean age 56.5±14.9 years) and 69.3% were women (mean age 51.2±14.4 years). Subjects were grouped into four groups based on their phenotype (TGWC). The prevalence of the TG- WC-, TG+ WC-, TG- WC+ and TG+ WC+ phenotypes were 14.4%, 1.9%, 56%, and 27.7%, respectively (Tables 1 and 2). Among subjects with the TG+WC+ phenotype, 8.7% were people aged 20 to 40 years, 53.3% were adults aged 41 to 60 years and 38% were senior adults aged 61 to 80 years (Figure 1.a). According to the sex, the distribution was unequal. Indeed, in men the prevalence was 23.2%, while in women it was 29.7% (Figure 1.b). However, women had the highest TG-WC+, 81.2%, closely followed by TG+WC+, 74.2%. Conversely, men had the highest TG+WC- (87.5%) and TG-WC- (79%) (Table 2).

Based on the four TGWC phenotypes, Table 1 presents the anthropometric and biochemical measurements of the subjects. It was observed a significant increase in all measured quantitative indicators within the four groups. The TG+WC+ phenotypic participants showed the highest values, while, the TG-WC- phenotype participants had the lowest values. Table 2 shows that the TG+WC+ phenotypic participants had the highest prevalence of cardiovascular risk-factors including 69.9% hypoHDLemia, 37.12% obesity, and 87.3%...
<table>
<thead>
<tr>
<th>TG+W-C phenotype</th>
<th>All (%). N=292 (100)</th>
<th>TG+W-C phenotype</th>
<th>All (%). N=292 (100)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clinical data</strong></td>
<td></td>
<td><strong>Laboratory data</strong></td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>Min: 20, Max: 80</td>
<td>Min: 20, Max: 80</td>
<td>16.22 ± 9.59 to 14.27 ± 9.59</td>
</tr>
<tr>
<td></td>
<td>±4.71 ± SD 25.93</td>
<td>±4.71 ± SD 25.93</td>
<td><strong>TC</strong> (mg/dL) 100.00</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>Min: 42 to 592</td>
<td>Max: 125 to 718</td>
<td>175.53</td>
</tr>
<tr>
<td></td>
<td>±46.21 ± 14.71</td>
<td>±14.71 ± 14.66</td>
<td><strong>TG</strong> (mg/dL) 207</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>Min: 64 to 196</td>
<td>Max: 135 to 180</td>
<td>126.78</td>
</tr>
<tr>
<td></td>
<td>±9.63 ± 0.85</td>
<td>±0.85 ± 0.85</td>
<td><strong>DBP</strong> (mm Hg) 140.00</td>
</tr>
<tr>
<td>BMI – body mass index</td>
<td>Min: 0.75 to 5.72</td>
<td>Max: 1.51 to 2.19</td>
<td>109.53</td>
</tr>
<tr>
<td>WC – waist circumference</td>
<td>Min: 83.99 to 5.72</td>
<td>Max: 1.51 to 2.19</td>
<td>165.59</td>
</tr>
<tr>
<td>SBP – systolic blood pressure</td>
<td>Min: 32.05 to 1.51</td>
<td>Max: 2.19 ± 0.90</td>
<td><strong>LDL-C</strong> (mg/dL) 125</td>
</tr>
<tr>
<td>DBP – diastolic blood pressure</td>
<td>Min: 80.75 to 1.51</td>
<td>Max: 2.19 ± 0.90</td>
<td><strong>HDL-C</strong> (mg/dL) 125</td>
</tr>
<tr>
<td>FPG – fasting plasma glucose</td>
<td>Min: 0.43 to 0.43</td>
<td>Max: 2.19 ± 0.90</td>
<td><strong>TG</strong> (mg/dL) 207</td>
</tr>
<tr>
<td>p-value &lt;0.05 significant across four phenotypes</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
dyslipidemia. Except for hypertension and diabetes mellitus which showed the highest values in TG+WC- phenotypic group (75.0% and 62.5%, respectively), their prevalence in TG+WC+ group were 62.9% and 59.8%, respectively. Concerning the TG-WC- phenotype group had the lowest values. In Figure 2, it was observed that the TG+WC+ phenotype group was associated with the highest prevalence of MetS (97.8%), whereas the TG-WC- phenotype was associated with the lowest prevalence (9.2%).

The use of univariate and multivariate binary logistic regression to identify any relationship between cardiovascular risk factors or MetS and the four TGWC phenotypes has showed that the three phenotypes TG-WC-, TG+WC- and TG-WC+ were less associated to MetS and the cardiovascular disease risk factor with an odds ratio (OR) ranging from 0.01 to 0.86 (Table 3). After caring out adjustment in Models 2 and 3, there was a significant increased risk of 13.89 times (OR) of dyslipidemia in the TG+WC- phenotype. Furthermore, the TG+WC+ phenotype showed a stronger and statistically significant positive association with MetS (p<10^{-3}) and the other cardiovascular risk factors (p<10^{-3}) in both Model 1 and adjusted Model 2. Indeed, individuals with the TG+WC+ phenotype had very high odds ratio for MetS and dyslipidemia, as well as high odds ratio for the other risk factors of cardiovascular diseases. The probability of participants exhibiting the TG+WC+ phenotype developing was for hypertension OR=1.65; for a 95% CI: [1.21 to 2.25]; (p<10^{-3}), adjusted by age and gender OR=1.43; for a 95% CI: [1.03 to 1.99]; (p<0.05); for hypercholesterolemia OR=3.98; for a 95% CI: [2.61 to 6.06]; (p<10^{-3}), adjusted by age and gender OR=3.69; for a 95% CI: [2.03 to 4.41]; (p<10^{-3}), adjusted by age and gender OR =2.71; for a 95% CI: [1.83 to 4.02]; (p<10^{-3}); and for hypoHDLemia OR=2.87; for a 95% CI: [2.08 to 3.98]; (p<10^{-3}), adjusted by age and gender OR=2.86; for a 95% CI: [2.05 to 3.98]; (p<10^{-3}). It should be considered that, according to the data of this study, the TG+WC+ phenotype is highly correlated with MetS, and the underlying risk factors with cardiovascular disease. After adjustment by all predictors in analysis Model 3, the association of MetS (p<10^{-3}), dyslipidemia (p<10^{-3}), for hyperLDLemia (p<10^{-3}), hypoHDLemia (p<10^{-3}), and TG+WC+ persisted. The risk of MetS was doubled, dyslipidemia and hypertension halved, while hypercholesterolemia remained stable.

Table 2. Prevalence of cardiovascular risk factors in the triglyceridemia-waist circumference phenotypes

<table>
<thead>
<tr>
<th>Phenotype</th>
<th>Metabolic syndrome</th>
<th>Diabetes mellitus</th>
<th>Dyslipidemia</th>
<th>General obesity</th>
<th>Central obesity</th>
<th>Hypertension</th>
<th>Hypercholesterolemia</th>
<th>HyperLDLemia</th>
<th>HypoHDLemia</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TG-WC- N=119 (14.4%)</td>
<td>14 (87.5%)</td>
<td>45 (37.8%)</td>
<td>1 (0.8%)</td>
<td>0 (0%)</td>
<td>12 (75%)</td>
<td>47 (39.5%)</td>
<td>7 (5.9%)</td>
<td>9 (7.6%)</td>
<td>33 (27.7%)</td>
<td>0.000</td>
</tr>
<tr>
<td>TG+WC- N=16 (1.9%)</td>
<td>1 (9.2%)</td>
<td>2 (12.5%)</td>
<td>2 (12.5%)</td>
<td>0 (0%)</td>
<td>12 (75%)</td>
<td>47 (39.5%)</td>
<td>7 (5.9%)</td>
<td>9 (7.6%)</td>
<td>33 (27.7%)</td>
<td>0.000</td>
</tr>
<tr>
<td>TG-WC+ N=463 (56%)</td>
<td>300 (64.8%)</td>
<td>261 (56.4%)</td>
<td>138 (29.8%)</td>
<td>463 (100%)</td>
<td>244 (52.7%)</td>
<td>239 (100%)</td>
<td>3 (18.8%)</td>
<td>54 (11.7%)</td>
<td>229 (49.5%)</td>
<td>0.000</td>
</tr>
<tr>
<td>TG+WC+ N=229 (27.7%)</td>
<td>224 (97.8%)</td>
<td>200 (87.3%)</td>
<td>85 (37.1%)</td>
<td>229 (100%)</td>
<td>144 (62.9%)</td>
<td>58 (25.3%)</td>
<td>54 (11.7%)</td>
<td>62 (27.1%)</td>
<td>160 (69.9%)</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Figure 2. Prevalence of metabolic syndrome in the triglyceridemia-waist circumference phenotypes
Table 3. Binary logistic regression analysis evaluating associations between triglyceridemia-waist circumference phenotypes and cardiovascular risk factors and metabolic syndrome

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Phenotype TG-WC- N=119</th>
<th>Phenotype TG+WC- N=16</th>
<th>Phenotype TG-WC+ N=463</th>
<th>Phenotype TG+WC+ N=229</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Odds ratio (95%CI)</td>
<td>p-value</td>
<td>Odds ratio (95%CI)</td>
<td>p-value</td>
</tr>
<tr>
<td>Metabolic syndrome</td>
<td>Model 1</td>
<td>0.03 (0.02 to 0.06)</td>
<td>0.000</td>
<td>0.02 (0.02 to 0.06)</td>
</tr>
<tr>
<td></td>
<td>Model 2</td>
<td>0.02 (0.01 to 0.04)</td>
<td>0.000</td>
<td>0.02 (0.01 to 0.05)</td>
</tr>
<tr>
<td></td>
<td>Model 3</td>
<td>0.01 (0 to 0.02)</td>
<td>0.000</td>
<td>5.10 (0.91 to 28.55)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>Model 1</td>
<td>0.63 (0.42 to 0.94)</td>
<td>0.026</td>
<td>0.63 (0.42 to 0.94)</td>
</tr>
<tr>
<td></td>
<td>Model 2</td>
<td>0.57 (0.35 to 0.93)</td>
<td>0.025</td>
<td>0.57 (0.35 to 0.93)</td>
</tr>
<tr>
<td></td>
<td>Model 3</td>
<td>2.64 (0.96 to 7.26)</td>
<td>0.061</td>
<td>0.46 (0.12 to 1.84)</td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td>Model 1</td>
<td>0.30 (0.20 to 0.45)</td>
<td>0.000</td>
<td>0.30 (0.20 to 0.45)</td>
</tr>
<tr>
<td></td>
<td>Model 2</td>
<td>0.37 (0.23 to 0.58)</td>
<td>0.000</td>
<td>0.37 (0.23 to 0.58)</td>
</tr>
<tr>
<td></td>
<td>Model 3</td>
<td>1.41 (0.21 to 9.3)</td>
<td>0.720</td>
<td>13.89 (1.28 to 150.37)</td>
</tr>
<tr>
<td>Obesity general</td>
<td>Model 1</td>
<td>0.02 (0.00 to 0.13)</td>
<td>0.000</td>
<td>0.02 (0 to 0.13)</td>
</tr>
<tr>
<td></td>
<td>Model 2</td>
<td>0.03 (0.00 to 0.18)</td>
<td>0.000</td>
<td>0.03 (0 to 0.18)</td>
</tr>
<tr>
<td></td>
<td>Model 3</td>
<td>0.03 (0.00 to 0.33)</td>
<td>0.004</td>
<td>0.36 (0.04 to 3.51)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>Model 1</td>
<td>0.50 (0.34 to 0.75)</td>
<td>0.001</td>
<td>0.5 (0.34 to 0.75)</td>
</tr>
<tr>
<td></td>
<td>Model 2</td>
<td>0.34 (0.21 to 0.55)</td>
<td>0.000</td>
<td>0.34 (0.21 to 0.55)</td>
</tr>
<tr>
<td></td>
<td>Model 3</td>
<td>1.14 (0.47 to 2.76)</td>
<td>0.771</td>
<td>1.15 (0.26 to 5.14)</td>
</tr>
<tr>
<td>Hypercholesterolemia</td>
<td>Model 1</td>
<td>0.39 (0.176 to 0.86)</td>
<td>0.019</td>
<td>0.39 (0.18 to 0.86)</td>
</tr>
<tr>
<td></td>
<td>Model 2</td>
<td>0.44 (0.19 to 1.07)</td>
<td>0.060</td>
<td>0.44 (0.19 to 1.04)</td>
</tr>
<tr>
<td></td>
<td>Model 3</td>
<td>1.46 (0.22 to 9.78)</td>
<td>0.697</td>
<td>0.84 (0.08 to 8.42)</td>
</tr>
<tr>
<td>HyperLDLemia</td>
<td>Model 1</td>
<td>0.41 (0.20 to 0.82)</td>
<td>0.012</td>
<td>0.4 (0.2 to 0.82)</td>
</tr>
<tr>
<td></td>
<td>Model 2</td>
<td>0.48 (0.22 to 1.04)</td>
<td>0.063</td>
<td>0.48 (0.22 to 1.04)</td>
</tr>
<tr>
<td></td>
<td>Model 3</td>
<td>0.83 (0.14 to 4.99)</td>
<td>0.843</td>
<td>0.22 (0.01 to 3.42)</td>
</tr>
<tr>
<td>HypoHDLemia</td>
<td>Model 1</td>
<td>0.31 (0.20 to 0.47)</td>
<td>0.000</td>
<td>0.20 (0.47 to 0.00)</td>
</tr>
<tr>
<td></td>
<td>Model 2</td>
<td>0.38 (0.24 to 0.62)</td>
<td>0.000</td>
<td>1.62 (4.18 to 0.00)</td>
</tr>
<tr>
<td></td>
<td>Model 3</td>
<td>1.75 (0.28 to 10.74)</td>
<td>0.547</td>
<td>0.05 (0.01 to 0.45)</td>
</tr>
</tbody>
</table>

The abbreviations are as presented in Table 1. Model 1 is applicable. Model 2 was adjusted for age and sex. Model 3 was adjusted for Model 2 in addition to all variables studied, namely metabolic syndrome, diabetes mellitus, dyslipidemia, general obesity, hypertension, hypercholesterolemia, hyperLDLemia, and hypoHDLemia.
DISCUSSION

To our knowledge, there is no comparative data linking triglyceridemic-waist circumference (TGWC) phenotypes with MetS or cardiovascular risk factors among different ethnic groups in Morocco. This epidemiological investigation is the first study conducted among the Amazigh population in the geographic region called Souss, aiming to examine the relationship between TGWC phenotypes and MetS or some other cardiovascular diseases risk factors.

According to the finding of this survey, 27.7% of Amazigh participants presented a WC+TG+ phenotype, with a higher prevalence among women (29.7%) compared to men (23.2%).

According to the previous published papers, the prevalence of WC+TG+ phenotype in our studied sample was close to that observed in Norfolk, UK, which is 27.81% in women and 31.20% in men [33], higher to the ones found in a study carried out in Nigeria 23.4% [34], in the municipality of Shanghai 21.2% [35] and almost double that the ones recorded in China 15.22% and 15.93% [36, 37]. However, it is lower than that observed in other countries or regions like in Spain (38.2%) [38], South Asian Indians (35.4%) [39], and in Quebec City metropolitan area (80%) [20].

Regarding the MetS prevalence, the lowest (9.2%) was observed in individuals with the TG-WC- phenotype, and the highest value (97.8%) was recorded within individuals with the TG+WC+ phenotype group which indicates that individuals with the TG+WC+ phenotype are predominantly affected by multiple abnormal metabolic parameters. This same finding was also reported in South African by Prakashandara and Naidoo in 2022 [39] in which the prevalence of MetS was equal to 88.7% in the TG+WC+ phenotype group. Therefore, it may be suggested that the TG+WC+ phenotype constitutes a more accurate predictor of MetS than previously thought and can be used as a way for early screening and identification of individuals with an elevated risk of developing MetS. It is well known that MetS is a condition that includes a cluster of risk factors specific for cardiovascular disease, thus this study reports higher, even alarming, prevalence of cardiovascular risk factors in individuals exhibiting the TG+WC+ phenotype compared to those who are considered normal (TG-WC-). Indeed, the prevalence of seven risk factors investigated in this study were 87.3%, 62.9%, 69.9%, 59.8%, 37.12%, 25.3% and 27.1% for dyslipidemia, hypertension, low HDL levels, type 2 diabetes, obesity, hypercholesterolemia and hyperLDLemia, respectively.

Also, subjects with the TG+WC+ phenotype seems to be at a higher risk than those with other phenotypes to develop MetS (37 to 68 times more), dyslipidemia (4 to 6 times more), type 2 diabetes (3 to 2 times more), hypertension (1 to 2 times more), hypercholesterolemia (4 times more), general obesity (2 to times more), hyperLDLemia and low HDL (3 times more).

This finding confirms what was previously published from several studies. Gazi and all reported that people with the TG+WC+ phenotype presented also a dyslipidemia, high LDL-cholesterol, and low HDL cholesterol [40, 41]. In a meta-analysis study carried out by Ma and all on a sample of 242 879 subjects from the general population of 19 countries, the pooled odds ratio for type 2 diabetes related to the TG+WC+ phenotype was equal to 2.89 in non-diabetic subjects [42]. In a prospective cohort study of 95 015 participants in China reported that the TG+WC+ phenotype is associated with a nearly 1.24 to 2 times increased risk of developing CVD [43]. Moreover, in a cohort study conducted in Norfolk, UK, it was observed that men and women who had the TG+WC+ phenotype faced 2.4 and 3.84 times higher risk of developing coronary heart disease in comparison to healthy population (TG-WC-) [33] confirming the ability of TG+WC+ phenotype to identify individuals at elevated risk factors for CVD [17, 33, 37].

CONCLUSIONS

This study presents novel findings regarding the prevalence of the TG+WC+ phenotype and confirms its relation to metabolic syndrome and cardiovascular diseases risk factors among the Amazigh population living in Morocco. The findings suggest that the TG+WC+ phenotype is associated with a heightened risk of MetS and cardiovascular diseases risk factors, persisting even after adjusting for confounding factors such as sex, age, and other relevant risk factors.

The simplicity, reproducibility, and low cost of the TG+WC+ phenotype make it a valuable and practical tool to identify individuals at an elevated risk of cardiovascular disease. However, further studies involving other ethnic groups from Morocco are recommended to confirm the present findings and evaluate the efficacy of using TG+WC+ phenotype as a clinical or epidemiological tool.

This study presents the first data on the prevalence of the TG+WC+ phenotype and its association with MetS and cardiovascular diseases risk factors in a representative sample of the Amazigh ethnic group from the geographical region of Souss in Morocco.

Ethics statement

The protocol for this survey has been reviewed and validated by the Ethics Committee (Nº IRB00012973) and authorized by the Ministry of Health and Social Protection. Participants were informed of the aims and objectives of the study, and informed consent was obtained in writing.
The authors disclose no conflicts of interest.

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Conflict of interest
The authors disclose no conflicts of interest.

REREFENCES


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