Relationship of neck circumference to some cardiometabolic risk parameters: a cross-sectional study among obese adult Egyptians

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Background
Neck circumference (NC) is an easy and reliable anthropometric measurement. The use of NC as an indicator of obesity among Egyptians was previously established. However, the relationship between NC and different cardiometabolic risk (CMR) parameters was not previously studied in the Egyptian population.
Objective
The aim of this work was to study the relationship between NC and some CMR parameters in obese adult Egyptian individuals.
Participants and methods
This cross-sectional study was carried out on 100 apparently healthy obese adult Egyptian participants (BMI $\geq$30 kg/m^2), above the age of 18 years, 50% of them were males and the other 50% were females. NC and other traditional anthropometric measurements were evaluated. Blood samples were assayed for glycosylated hemoglobin, total cholesterol, high-density lipoprotein cholesterol (HDL-C), non-HDL-C, and high-sensitivity C-reactive protein.
Results
There were significant positive correlations between NC and each of systolic and diastolic blood pressure [(r=0.527, $P<0.001$), (r=0.430, $P<0.001$), respectively], waist circumference (r=0.538, $P<0.001$), BMI (r=0.403, $P<0.001$), and high-sensitivity C-reactive protein (r=0.304, P=0.002). While a significant negative correlation was found between NC and HDL-C. Multivariate regression analysis revealed an independent association of NC with waist circumference in males and with systolic blood pressure in females.
Conclusion
This study does not only confirm the association of NC with anthropometric measurements in the Egyptian population, but it also establishes the NC association with CMR factors that support the possibility of using NC as a CMR marker among Egyptians.

Keywords:
cardiometabolic risk, neck circumference, obesity

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Introduction

The burden of obesity has been increasing globally [1]. Obesity rates have increased in all ages and both sexes, irrespective of geographical locality, ethnicity, or socioeconomic status [2]. Egypt Demographic and Health Survey stated that 33% of men aged 55–59 and 65% of women aged 45–59 were classified as obese [3]. Obesity is defined as an excessive accumulation of body fat or weight that exceeds the age- and gender-specific reference limits [4]. Obesity is widely correlated with cardiometabolic risk (CMR) and is strongly associated with diabetes, dyslipidemia, and hypertension [5]. Moreover, it increases the risk of respiratory problems and psychological disturbances [6]. It is well known that people with large amounts of visceral fat are at increased risk of insulin resistance, type-2 diabetes mellitus (DM), and cardiovascular disease (CVD) [7]. However, visceral adipose tissue does not account for all CMRs. Recently, ectopic fat depots in other areas are reported to contribute to the development of CVD [8].

There are many approaches for assessing obesity. Some anthropometric measurements, such as BMI, waist circumference (WC), and waist : hip ratio (WHR), are commonly used at primary care centers, while other measurements, such as computed tomography (CT) scan, MRI, and dual energy X-ray absorptiometry (DEXA) scan, are costly and largely used for research purposes [9]. BMI has been presently recommended by WHO to evaluate overweight and obesity in the general population. However, it does not differentiate between fat and other tissues, such as muscles, and does not account for regional fat distribution. BMI does not give any idea of central adiposity or visceral fat [10]. WC, as an index of central obesity, may be better for predicting obesity-related health risks than BMI. However, WC measurements may be difficult to attain in some situations, such as in morbid obesity. Furthermore, WC measurements are influenced by abdominal distention such as ascites, pregnancy, or postprandial distension. Moreover, respiratory movement and thick clothing may also affect the precision of WC measurements, WC requires removal of the clothes, which may be inconvenient in some situations [11].

Therefore, several studies have been carried out to assess the alternative anthropometric measure for diagnosing overweight, obesity, and metabolic syndrome. Recently, researchers have greatly focused on neck circumference (NC), a parameter of upper-body adiposity. Upper-body subcutaneous adipose tissue may confer additional risk for metabolic disorders beyond overall and abdominal obesity [12].

NC is easy to perform, quick, reliable, and inexpensive. Its measurement is convenient and not affected by the aforementioned factors that influence WC measurement and can be particularly useful in specific populations such as morbidly obese people, patients in bed rest, and pregnant women. NC could be measured without requirement for cloth removal [13]. The use of NC as an indicator of obesity among Egyptians was previously established. However, the relationship between NC and different CMR parameters was not previously studied in the Egyptian population.

Objectives

The aim of this work was to study the relationship between NC and some CMR parameters in obese adult Egyptian individuals.

Participants and methods

The minimum sample size to achieve a power of 80% was calculated at 5% level of significance based on data reported by Ben-Noun and Laor 2003 [14] who found a significant correlation between NC and obesity markers, namely BMI and WC, as well as CMR factors, namely blood pressure, triglyceride, and LDL cholesterol with correlation coefficient that ranged from 0.42 to 0.71. A minimum sample of 90 overweight/obese adults (45 women and 45 men) is required to test the hypothesis. Calculation was done using G*Power software version 3.1.9.4 (Institute of Experimental Psychology, Heinrich Heine University, Dusseldorf, Germany) [15].

The study was approved by Alexandria University Faculty of Medicine ethics committee and it was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki.

Based on this calculation of sample size, our cross-sectional study was carried out on 100 apparently healthy obese adult Egyptian participants (BMI $\geq$30 kg/m^2), above the age of 18 years, 50% of them were males and the other 50% were females.

Participants were recruited from the outpatient clinics of the Alexandria Main University Hospital. The study was conducted according to the criteria set by the Declaration of Helsinki and an informed consent was signed by each participant before participating in the study.

Exclusion criteria included goiter, cervical lymphadenopathy, cystic or mass lesion in the neck or anatomical abnormality of neck region, ascites, intra-abdominal organomegaly, intra-abdominal or extra-abdominal mass lesion, kyphosis, scoliosis, or any anatomical abnormality of waist and hip region, pregnancy, known history of DM, established atherosclerotic CVDs, and advanced hepatic, renal, or cancerous diseases. Moreover, participants with acute or chronic inflammatory diseases and participants with a history of the intake of antihypertensive drugs, antidiabetic drugs, antihyperlipidemic drugs, aspirin, diuretics, or hormonal therapy in the previous 3 months were excluded.

All study participants were subjected to full demographic and medical history assessment, including history of smoking and history or family history of diabetes, hypertension, dyslipidemia, and cardiovascular events. Detailed drug history, including antidiabetic, lipid-lowering, and antihypertensive drugs, was also performed.

Complete physical examination was done, including pulse pressure and blood pressure measurement. The following anthropometric measurements were measured:

BMI was calculated as weight/height^2 in meters. WC was recorded in centimeters using plastic tape measure at the midpoint between the costal margin and iliac crest in the mid-axillary line, with the participant standing and at the end of a gentle expiration. Hip circumference (HC) was measured in centimeters using a plastic tape measure, at the horizontal level of greater trochanters, with the legs close together. WHR was obtained by dividing the WC by the HC. NC: NC of participants was taken in centimeters to the nearest 1 mm, using plastic tape measure. It was taken in a plane as horizontal as possible, at a point just below the thyroid cartilage (just below Adam's apple in males) and perpendicular to the long axis of the neck (the tapeline in front of the neck at the same height as the tapeline in the back of the neck). While taking this reading, the participant was asked to look straight ahead, with shoulders down, but not hunched. Care was taken not to involve the shoulder/neck muscles (trapezius) in the measurement [16].

Cutoff values of greater than 40.25 cm for men and greater than 37.25 cm for women were found to be the best cutoff points for determining Egyptian participants with obesity [17].

Blood sampling was done in the morning randomly without fasting. The collected venous samples were divided into two parts. Red vacutainer was used to assess the high-sensitivity C-reactive protein (hs-CRP), random lipid assay; the other part of blood sample was collected on dipotassium EDTA tube for assessment of glycosylated hemoglobin (HbA1C). The samples processed were used to assess the following: HbA1c, total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), non-HDL-C, and hs-CRP.

Statistical methods

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0 (IBM Corp., Armonk, New York, USA). Significance of the obtained results was judged at the 5% level. χ^2 test was used for categorical variables to compare between different groups. Student's *t*-test was used for normally distributed quantitative variables to compare between two studied groups. Mann–Whitney test was used for abnormally distributed quantitative variables to compare between two studied groups. Multivariate and univariate regression analysis were performed to detect the independent factors associated with NC.

Results

This cross-sectional study included sample size of 100 obese patients (50 males and 50 females).

There were no statistically significant differences between male and female groups as regards age, systolic blood pressure (SBP), diastolic blood pressure (DBP), HbA1C, non-HDL, and hs-CRP. While BMI, WC, WHR, and HDL were significantly higher in the female group. The baseline characteristics of the studied participants are shown in Table 1.

NC ranged from 40.0 to 52.0 cm with a mean of 43.59 ±2.10 in males and 38.0–50.0 cm with a mean of 43.18 ±2.35 in females with no significant difference between both groups (P=0.360).

As shown in Tables 2 and 3, similar results were found upon correlation between NC, WC, BMI, and the studied parameters.

The univariate regression analysis showed that HDL-C, hs-CRP, SBP, DBP, WC, and BMI are all associated with NC whether in the total sample (Table 4) or in either the male group (Table 5) or the female group of the study (Table 6), while HbA1c, total cholesterol, non-HDL-C, and WHR were not associated with NC in the total sample as well as in both male and female groups.

The multivariate regression analysis demonstrated that only the SBP and WC were the independent parameters associated with NC in the total sample of the study (Table 4).

In the male group, the multivariate regression analysis showed that the WC was the only parameter that independently associated with NC (Table 5), while the SBP was the parameter that independently associated with NC in the female group of the study (Table 6).

Discussion

Obesity is commonly associated with CMR factors and is strongly linked with type-2 DM, dyslipidemia, hypertension, and chronic inflammation.

Table 1 Baseline characteristics of the studied participants

	Total (*n*=100)	Males (*n*=50)	Females (*n*=50)	*P*
Age				
Mean±SD	52.18±15.45	53.20±16.15	51.16±14.82	0.512
Systolic BP				
Mean±SD	128.8±15.39	130.84±16.18	126.68±14.43	0.178
Diastolic BP				
Mean±SD	84.09±10.15	84.90±10.18	83.28±10.16	0.428
BMI (kg/m^2)				
Mean±SD	38.01±5.05	37.0±5.19	39.02±4.75	0.045*
WC				
Mean±SD	108.4±18.86	104.66±16.62	112.12±20.35	0.047*
WHR				
Mean±SD	0.85±0.11	0.82±0.10	0.87±0.13	0.049*
NC				
Mean±SD	43.38±2.23	43.59±2.10	43.18±2.35	0.360
HBA1C				
Mean±SD	6.57±1.98	6.57±1.86	6.56±2.11	0.984
HDL-C				
Mean±SD	43.96±11.05	40.34±11.15	47.58±9.79	0.001*
Non-HDL				
Mean±SD	147.2±35.89	144.24±35.48	150.09±36.43	0.418
Hs-CRP				
Mean±SD	12.23±16.39	13.79±21.65	10.67±8.30	0.122

BP, blood pressure; HBA1C, glycosylated hemoglobin; HDL-C, high-density lipoprotein cholesterol; Hs-CRP, high-sensitivity C-reactive protein; NC, neck circumference; *P*, *P* value for comparing between male and female; WC, waist circumference; WHR, waist : hip ratio. *Statistically significant at $P \leq 0.05$.

Table 2 Correlation of neck circumference, WC, BMI with age, blood pressure, and anthropomertric parameters

	Total (*n*=100)		Males (*n*=50)		Females (*n*=50)	
	R	*P*	*r*	*P*	*r*	*P*
Age (years)						
NC	−0.046	0.652	0.048	0.739	−0.150	0.298
WC	−0.093	0.358	−0.095	0.512	−0.071	0.624
BMI	−0.099	0.325	−0.129	0.371	−0.039	0.789
Systolic blood pressure (mmHg)						
NC	0.527	<0.001*	0.495	<0.001*	0.555	<0.001*
WC	0.409	<0.001*	0.395	0.005*	0.510	<0.001*
BMI	0.315	0.001*	0.384	0.006*	0.314	0.026*
Diastolic blood pressure (mmHg)						
NC	0.430	<0.001*	0.475	<0.001*	0.383	0.006*
WC	0.325	0.001*	0.294	0.038*	0.397	0.004*
BMI	0.308	0.002*	0.282	0.047*	0.387	0.005*
Waist circumference (cm)						
NC	0.538	<0.001*	0.668	<0.001*	0.499	<0.001*
BMI	0.494	<0.001*	0.502	<0.001*	0.457	0.001*
Waist : hip ratio						
NC	−0.153	0.130	−0.162	0.260	−0.118	0.414
WC	0.227	0.023*	0.186	0.197	0.195	0.175
BMI	0.494	<0.001*	0.502	<0.001*	0.457	0.001*
BMI (kg/m^2)						
NC	0.403	<0.001*	0.455	0.001*	0.414	0.003*

NC, neck circumference; *r*, Pearson coefficient; WC, waist circumference. *Statistically significant at $P \leq 0.05$.

Table 3 Correlation between neck circumference, WC, BMI, and the studied laboratory parameters

	Total (*n*=100)		Males (*n*=50)		Females (*n*=50)	
	R	*P*	*r*	*P*	*r*	*P*
HbA1c %						
NC	0.085	0.400	0.067	0.642	0.099	0.493
WC	0.112	0.267	0.065	0.653	0.151	0.296
BMI	0.097	0.338	0.202	0.159	0.001	0.992
Total cholesterol (mg/dl)						
NC	0.045	0.654	−0.121	0.403	0.229	0.109
WC	0.117	0.246	−0.049	0.734	0.220	0.125
BMI	0.103	0.309	0.016	0.909	0.151	0.295
HDL-C						
NC	−0.320	0.001*	−0.292	0.040*	−0.329	0.020*
WC	−0.200	0.046*	−0.295	0.038*	−0.286	0.044*
BMI	−0.217	0.030*	−0.300	0.034*	−0.312	0.027*
Non-HDL-C						
NC	0.004	0.972	−0.212	0.139	0.205	0.153
WC	0.075	0.459	−0.116	0.423	0.200	0.163
BMI	0.072	0.476	−0.030	0.837	0.150	0.300
Hs-CRP (mg/dl)						
NC	0.304	0.002*	0.357	0.011*	0.286	0.044*
WC	0.218	0.029*	0.281	0.048*	0.279	0.049*
BMI	0.243	0.015*	0.283	0.046*	0.306	0.031*

HBA1C, glycosylated hemoglobin; HDL-C, high-density lipoprotein cholesterol; Hs-CRP, high-sensitivity C-reactive protein; NC, neck circumference; *r*, Pearson coefficient; WC, waist circumference. *Statistically significant at $P \leq 0.05$.

Table 4 Univariate and multivariate linear-regression analysis for the parameters affecting neck circumference for the total sample

	Univariate		Multivariate[a]	
	P	*B* (95% CI)	*P*	*B* (95% CI)
HbA1c	0.400	0.096 (–0.129–0.321)		
Total cholesterol (mg/dl)	0.654	0.002 (–0.008–0.013)		
HDL-C	0.001*	–0.065 (–0.103 to –0.026)	0.095	–0.028 (–0.061–0.005)
Non-HDL-C	0.972	0.000 (–0.012–0.013)		
High-sensitivity CRP (mg/dl)	0.002*	0.041 (0.015–0.067)	0.201	0.014 (–0.008–0.037)
Age (years)	0.652	–0.007 (–0.035–0.022)		
Blood pressure (mmHg)				
Systolic	<0.001*	0.076 (0.052–0.101)	0.030*	0.039 (0.004–0.073)
Diastolic	<0.001*	0.094 (0.055–0.134)	0.568	0.015 (–0.036–0.065)
Waist circumference (cm)	<0.001*	0.064 (0.044–0.083)	0.001*	0.037 (0.015–0.059)
Waist : hip ratio	0.130	–2.965 (–6.816–0.886)		
BMI (kg/m^2)	<0.001*	0.178 (0.097–0.258)	0.337	0.039 (–0.041–0.119)

CI, confidence interval; HBA1C, glycosylated hemoglobin; HDL-C, high-density lipoprotein cholesterol; Hs-CRP, high-sensitivity C-reactive protein. [a]All variables with $P<0.05$ were included in the multivariate.

Table 5 Univariate and multivariate linear-regression analysis for the parameters affecting neck circumference for males

	Univariate		Multivariate[a]	
	P	*B* (95% CI)	*P*	*B* (95% CI)
HbA1c	0.642	0.076 (–0.251–0.403)		
Total cholesterol (mg/dl)	0.403	–0.006 (–0.020–0.008)		
HDL-C	0.040*	–0.055 (–0.107 to –0.003)	0.387	–0.019 (–0.062–0.024)
Non-HDL-C	0.139	–0.013 (–0.029–0.004)		
High-sensitivity CRP	0.011*	0.035 (0.008–0.061)	0.305	0.011 (–0.011–0.033)
Age (years)	0.739	0.006 (–0.031–0.044)		
Blood pressure (mmHg)				
Systolic	<0.001*	0.064 (0.031–0.097)	0.817	–0.006 (–0.057–0.045)
Diastolic	<0.001*	0.098 (0.045–0.151)	0.087	0.067 (–0.010–0.144)
Waist circumference (cm)	<0.001*	0.084 (0.057–0.112)	<0.001*	0.062 (0.031–0.093)
Waist : hip ratio	0.260	–3.514 (–9.706–2.679)		
BMI (kg/m^2)	0.001*	0.184 (0.080–0.289)	0.565	0.029 (–0.071–0.128)

CI, confidence interval; HBA1C, glycosylated hemoglobin; HDL-C, high-density lipoprotein cholesterol; Hs-CRP, high-sensitivity C-reactive protein. [a]All variables with $P<0.05$ were included in the multivariate.

Table 6 Univariate and multivariate linear-regression analysis for the parameters affecting neck circumference for females

	Univariate		Multivariate[a]	
	P	*B* (95% CI)	*P*	*B* (95% CI)
HbA1c	0.493	0.111 (–0.212–0.433)		
Total cholesterol (mg/dl)	0.109	0.014 (–0.003–0.031)		
HDL-C	0.020*	–0.079 (–0.145 to –0.013)	0.328	–0.029 (–0.089–0.030)
Non-HDL-C	0.153	0.013 (–0.005–0.032)		
High-sensitivity CRP	0.044*	0.081 (0.002–0.160)	0.179	0.048 (–0.023–0.118)
Age (years)	0.298	–0.024 (–0.069–0.022)		
Blood pressure (mmHg)				
Systolic	<0.001*	0.091 (0.051–0.130)	0.009*	0.072 (0.019–0.126)
Diastolic	0.006*	0.089 (0.027–0.151)	0.623	–0.018 (–0.090–0.055)
Waist circumference (cm)	<0.001*	0.058 (0.029–0.087)	0.291	0.018 (–0.016–0.052)
Waist : hip ratio	0.414	–2.212 (–7.606–3.182)		
BMI (kg/m^2)	0.003*	0.205 (0.074–0.336)	0.301	0.071 (–0.066–0.208)

B, unstandardized coefficients; CI, confidence interval; HBA1C, glycosylated hemoglobin; HDL-C, high-density lipoprotein cholesterol; Hs-CRP, high-sensitivity C-reactive protein. [a]All variables with $P<0.05$ were included in the multivariate. *Statistically significant at $P\leq0.05$.

Cardiovascular illness is the main cause of mortality or disability in the world [18]. Many methods for evaluating obesity have been used, like WC, WHR, and BMI, which are commonly used in primary centees, while methods like ultrasound, CT scan, and MRI, are costly and hence mostly used for research purposes [19]. There are continuous determinations by scientists to find enhanced indices for screening obese patients due to the confines of WC and BMI [13]. The measurement of NC is easy to do, fast, reliable, and cheap.

Because there is heterogeneity in body size among different ethnic populations, cutoff values for anthropometric indices such as BMI and WC and their predictive potential for CMR are varied [20].

Current studies have revealed that NC is linked with CMR beyond that of BMI and WC and is an index of upper-body subcutaneous adipose tissue distribution, which is a good tool to classify overweight and obesity [17].

Diverse people differ in genetic, geographic characteristics, altered levels of food accessibility, and physical activity influences to the development of obesity. It is not easy to arrive at conclusions that are the same for all inhabitants. Nevertheless, NC measurement is a good indicator of obesity for all of them [21,22].

In the present study, there was a statistically significant positive correlation between NC with each of WC and BMI with a *P* value of less than 0.001 in both genders. In agreement with our results, Onat *et al.* [23] showed that NC was positively correlated with WC and BMI in a cross-sectional study of population sample of 1912 Turkish middle-aged obese men and women. Moreover, another pilot study on adult Turkish general population of 411 individuals (174 men and 237 women) showed significant positive correlations between NC, WC, and BMI in males and females [24]. Similar to our findings, Hingorjo *et al.* [25], in a cross-sectional study of 871 adult Bangladeshi general population, reported that NC had a significant positive correlation with WC and BMI in both males and females. Moreover, Hingorjo *et al.* [26], in a case–control study of 215 adult Pakistani general population aged between 25 and 65 years, showed a strong positive correlation between NC and both BMI and WC in males and females.

In contrast to our results are the findings of Pei *et al.* [27], who found that young Chinese general population of 1169 individuals aged between 18 and 25 years did not show statistically significant correlations between NC, BMI, and WC. This difference may be attributed to the young age of the studied population in their cohort.

Regarding WHR, in the present study, there was no statistically significant correlation between NC and WHR in both males and females. In contrast to the present study, the aforementioned studies [23–26] elicited a statistically significant positive correlation between NC and WHR in males and females. The difference could be explained by the larger sample size and different age groups as depicted in the above-mentioned studies.

Cardiovascular-related diseases, including myocardial infarction, high blood pressure, stroke, diabetes, and dyslipidemia, which are linked to obesity, are the main reason for mortality among Egyptians, responsible for 47% of deaths according to the Egyptian Central Agency for Mobilization and Statistics [28]. In the present study, there was a statistically significant positive correlation between NC and both SBP and DBP in males and females (*P*? 0.001). In agreement with our research, Kuciene and colleagues, in adolescent and adult Lithuanian general population aged between 15–18 years and 18–25 years, respectively, found that greater NC was linked with four-times risk for hypertension. Moreover, they found a positive correlation between NC and both SBP and DBP in males and females [29]. In support of our study findings, a meta-analysis of 18 studies by Jafari *et al.* [30] assessed the correlation between NC and blood pressure, seven of these studies included adult obese healthy individuals and exhibited statistically significant positive correlations between NC and blood pressure in both genders. Similarly, in the previously mentioned study of Onat *et al.* [23], they reported that NC correlated positively with blood pressure in both groups of males and females. Moreover, Zhou *et al.* [31], in their cross-sectional study on 4201 obese adult Chinese healthy individuals, found similar results coinciding with our study that NC had positive correlation with blood pressure in both genders.

In the present study, there was a statistically significant negative correlation between NC and HDL-C in both genders. In alignment with our results, Byun *et al.* [32], in their large cross-sectional study on 8958 healthy Korean general individuals, showed NC to have a negative significant correlation with HDL-C levels. Similarly, Stabe *et al.* [33] showed that NC was negatively correlated with HDL-C in males and females in their study of 1053 obese healthy Brazilian individuals aged between 18 and 60 years. Adding strength to our study findings, Preis *et al*. [34], in the Framingham Heart Study of 3307 general population aged between 25 and 65 years, showed significant negative correlation between NC and HDL-C. Cizza *et al*. [35] also reported, in an Italian study of 120 obese healthy individuals of which 92 were women, that NC was associated with metabolic syndrome and was negatively correlated with HDL-C. Caro *et al*. [36] reported similar findings in a large Chilean cross-sectional study of 4607 obese general population above 18 years of age that NC had significant negative correlation with HDL-C in males and females.

In this study, there was no statistically significant correlation between NC and total cholesterol or non-HDL-C, *P*-values of 0.246 and 0.459, respectively. In contrast to our results, all of the aforementioned above studies showed a statistically significant positive correlation between NC and both of TC and non-HDL-C.

In the present study, NC showed a significant positive correlation with hs-CRP in both groups. Limited data are available regarding the correlation between NC and hs-CRP in healthy individuals. In agreement with our study, Sudhakar *et al*. [37] reported in a cross-sectional study of 42 obese healthy participants that NC has a positive correlation with hs-CRP.

On the other hand, a cross-sectional study conducted by Pokharel *et al*. [38], on a population of 845 retired national football-league players, did not show a significant correlation between NC and hs-CRP. This discrepancy could be explained by the different age group of the studied population.

Finally, in the present study, the univariate regression analysis showed that HDL-C, hs-CRP, both SBP and DBP, WC, and BMI were all associated with NC in the whole sample of the study as well as in either the male or the female group separately. Therefore, it can be deduced that NC, similar to the traditional anthropometric measures like WC and BMI, has a significant association with many of the CMR parameters.

From the results of the present study, it is also possible to hypothesize that upper subcutaneous fat has similar pathophysiological characteristics as abdominal visceral fat. NC is also related to oxidative stress, dysfunction, and injury to the endothelium [22,39]. It is also correlated with visceral adipose tissue, as depicted by CT [22,40]. Thus, NC is an important anthropometric indicator to classify patients with a high CMR [40].

Conclusion

This study does not only confirm the association of NC with anthropometric measurements in the Egyptian population, but it also establishes the NC association with CMR factors that support the possibility of using NC as a CMR marker among Egyptians.

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The authors confirm that the paper has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. The authors further confirm that the order of authors listed in the paper has been approved by all the authors.

The authors confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing, we confirm that we have followed the regulations of our institutions concerning intellectual property.

The authors understand that the corresponding author is the sole contact for the editorial process (including editorial manager and direct communications with the office). He is responsible for communicating with the other authors about progress, submissions of revisions, and final approval of proofs.

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Conflicts of interest

There are no conflicts of interest.

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