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Original Article

Neck circumference as a predictor of metabolic disorders and renal diseases in hospitalized patients

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SUMMARY

Background & aims: Malnutrition is one of the major problems in hospitalized patients which increases the risk of chronic diseases. This highlights the need for an appropriate indicator to predict the risk of cardiometabolic risk factors and numerous chronic diseases in these patients. Regarding of few studies in this context, we aimed to investigate a better understanding of associations between neck circumference (NC) with metabolic disorders and renal diseases in hospitalized patients.
Methods: This cross-sectional study conducted among 303 participants (167 77 and 136 men) hospitalized from March to June 2019 in internal disease wards of Imam Reza Hospital, Tabriz, Iran. Demographic information, anthropometric (NC, height, and weight), biochemical and nutritional supportive, were collected and evaluated.
Results: In the present study, the mean age of men and women in three tertiles of NC were 57.76 ± 18.22, 56.16 ± 16.78, and 60.78 ± 14.22 years, respectively and there was no significant difference in the age of the three tertiles ($P = 0.144$). Men showed to have higher NC compared with women ($p < 0.001$), and patients with obesity had higher NC compared with normal weight patients ($p < 0.001$). Urea and creatinine as kidney indices showed a significant correlation ($P < 0.001$) and albumin showed an inverse significant correlation with NC ($P = 0.025$). Potassium ($P < 0.001$) and SBP ($P = 0.033$) had a significant correlation with NC.

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Conclusions: NC as a feasible method can be used as a predictor of metabolic disorders and renal diseases in hospitalized patients.

1. Introduction

One of the major problems in hospitalized patients is malnutrition. It has harmful effects on the patient's treatment process by leading to weight loss, bedsores, impaired wound healing, impaired pulmonary, cardiac function, and thromboembolism [1–3]. Finally, it leads to an increase in hospitalization time and treatment costs, as well as increase the mortality [4]. The studies demonstrated that renal disease is one of the 5 main causes of hospitalization and malnutrition in hospitalized patients [5]. One of the good indicators for health assessment is nutrition status. Generally, nutritional assessments in hospitalized patients are possible via anthropometric, biochemical, clinical, and dietary evaluations. Recently, neck circumference (NC), as a simple and time-saving anthropometric measurement has attracted lots of attention. The distribution of body fat is an important factor that determines metabolic health. NC can predict upper body subcutaneous adiposity distribution. So, NC has been proposed as an effective predictor of cardiometabolic risk factors and numerous chronic diseases including cardiovascular events, metabolic disorders, and chronic kidney disease [6–8].

Vanessa Zen et al. conducted a case–control study among 376 chronic coronary patients aged 40 years or more and concluded that NC above the 90th percentile can double the chance of coronary artery disease (CAD) and it is considered as an independent predictor of CAD [9]. In a study performed by Jing-ya Zhou et al. among 4201 participants, it was revealed that NC was positively correlated with systolic blood pressure (SBP), diastolic blood pressure (DBP), fasting blood glucose (FBG), triglyceride (TG), total cholesterol (TC) and LDL-C and negatively correlated with HDL-c in males [10]. Natalia G et al. [11]. also, established that NC is positively associated with SBP, DBP, FBG, TG, uric acid, and high-sensitivity C-reactive protein, and negatively associated with HDL-c. In a study completed by Qin Li et al. among 2668 participants aged 18–89, appeared that the mean NC was greater in Non-alcoholic Fatty Liver Disease (NAFLD) subjects compared to other groups in both genders and correlated with BMI, WC, hip circumference, SBP, DBP, insulin, HOMA-IR, TG and alanine amino transferees (ALT), regardless to the gender of the participants [12]. About 1053 Brazilian adults participated in a cross-sectional study which was done by Christiane Stabe and it was declared that NC was positively correlated with WC, BMI, TG, FBG, fasting insulin, and HOMA-IR, and negatively associated with HDL-c [9].

These findings and alarming incensement of malnutrition in hospitalized patients highlight the need for anthropometric assessment among these patients. Given that these patients are in critical condition and anthropometry is not easy in hospitalized patients, and finding an easy, low-cost, and non-invasive way that can show the health and nutritional status of these patients will be important in the medical management of these patients, we decided to do this study. The aim of this study was to determine whether neck circumference predicts the metabolic disorders and renal diseases in hospitalized patients.

2. Materials and methods

2.1. Subjects

The current cross-sectional study is performed among 303 (167 women and 136 men) patients hospitalized in internal disease wards of Imam Reza Hospital, Tabriz, Iran. The patients were admitted during March–June 2019. General characteristics of study participants including demographic information, past and current medical history, and medication use were obtained from medical hospital records and by asking from the patients. This information included any history of diabetes mellitus (DM), hypertension (HTN), kidney disease (KD), heart disease and stroke, edema, pneumonia, alcohol consumption or smoking, and vital signs.

2.2. Demographic, anthropometric, biochemical, vital and nutritional supportive status

Anthropometric parameters including weight and height were obtained from medical records; NC was measured below the level of the thyroid cartilage, perpendicular to the vertical axis of the neck by a measurement tape, and was recorded in centimeters. There is no identical and definite cut point to show the NC index as a risk factor, and different studies show different cut points. According to the Hingorjo et al. study, NC $\geq$ 35.5 cm for men and $\geq$32 cm for women classified as the cutoff points for overweight/obesity [10]. Yang et al. have also demonstrated an NC of >35 cm for women and >39 cm for men as the cutoff point that best correlates with metabolic syndrome [13]. Also, NC $\geq$ 34.75 cm in men and $\geq$31.75 cm in women are to be considered overweight and men with NC $\geq$ 35.25 cm and women with NC $\geq$ 34.25 cm are to be considered obese. NC $\geq$ 35.25 cm in men and NC $\geq$ 31.25 cm in women were the best cutoff value for abdominal obesity [14]. Therefore, due to the lack of agreement between the NC cut point as a risk factor, NC was divided into three tertile (1st tertile: NC < 32 cm; 2nd tertile: 32$\leq$NC $\leq$ 37; 3rd tertile: NC > 37 cm).to investigate if NC can be used as a predictor of metabolic disorders and renal diseases in hospitalized patients. We classified the BMI according to the Centers for Disease Control and Prevention (CDC) definition: underweight, if BMI is less than 18.5; normal weight: if BMI is 18.5–24.9; overweight: if BMI is 25.0–29.9, and obese: if BMI is 30.0 or higher [15]. Physical activity levels were determined using the International Physical Activity Questionnaire [16] and classified as low and high levels. Due to the importance of nutritional supportive status in the malnutrition of hospitalized patients, current nutrition status classified as parentral and entral nutrition and nothing by mouth (NPO). Also, the effect of education and type of job on the development and duration of chronic diseases, education was divided into the parts as an illiterate, diploma or under diploma, university degrees and jobs into the parts as no job, employee, self-employment, retired. Also, due to the effect of income on the access to healthy foods, as well as preventive and treatment opportunities, and regarding that, the lowest income of the national labor law is about 10 million rials, so, the income was divided into<10 million, 10–30 million and >30 million rials (Iranian currency). Non-fasting or after 12 h of overnight fasting blood samples, according to the type of analysis, were taken and analyzed by the laboratory unit of the hospital to get biochemical, hematological parameters and, blood electrolytes. The information about the history of the disease, drug use, dietary intakes including the use of dietary supplement, were obtained by asking of the patients as well as from medical records.

2.3. Sample size calculation

Primary data for calculating sample size was taken from Laura De La Higuera et al. study [17] and finally, the sample size estimated to include 300 participants by considering 95% confidence level, 80% power, 5% error, and it has been estimated from Cochran formula as below: (in this formula: n, study sample size; N = statistical population; z, confidence level ;p, a proportion of the population without a definite attribute ;q, 1-p ; d, degree of confidence)

$$n = \frac{Nz^2pq}{Nd^2 + z^2pq}$$

2.4. Statistical analysis of data

Data were analyzed using SPSS version 16.0 software (SPSS Inc. IL., Chicago, USA). After evaluating of normality of data by a one-sample Kolmogorov–Smirnov test, the independent t-test, and Mann–Whitney test was used for normal and abnormal data distribution respectively, ANOVA test was used for data normalization, for the comparison of 3 groups, and the Kruskal–Wallis test was used in the case of abnormal data. The evaluation of the relationship between quantitative variables was performed by Pearson correlation coefficient for normal data and Spearman correlation coefficient for abnormal data. A chi-square test was used to determine the relationship between qualitative variables.

3. Results

3.1. Demographic, anthropometric and clinical characteristics assessment

The demographic, anthropometric, and clinical characteristics of the participating in the study are presented in Table 1. The mean age of participants in three tertiles of NC was 57.76± 18.22, 56.16± 16.78, and 60.78±14.22 years, respectively and there was no significant difference regarding age between three tertile of NC value. We observed a significant association between sex, BMI, and current nutrition with NC *(P<0.05)*. Men showed to have higher NC compared with women and patients with obesity had higher NC compared with normal weight patients. Other demographic, anthropometric, and clinical characteristics were not significantly different between three tertile of NC (Table 1).

We observed also, low PA positively correlated with NC *(P<0.05)* and the married patients had higher NC than single participants*(P=0.033)*. The occupation variable showed that patients how were self-employed, have significantly higher NC compared with other jubes*(P<0.001)* (Table S1).

3.2. Frequency of the disease and drug use assessment

There was a significant relationship between NC augmentation and DM, HTN, and KD ($P < 0.05$) and subsequently, with the drugs used for these diseases (Table 2 and Table S2). Furthermore, the

Table 1
Demographic, anthropometric, and clinical characteristics among tertiles of neck circumference value.

Variables(n)	1st tertile of NC	2nd tertile of NC	3rd tertile of Nc	*P*
Gender (303)				
Male (136)	35 (32.1%)	35 (36.1%)	66 (68.0%)	<0.001*
Female (167)	74 (67.9%)	62 (63.9%)	31 (32.0%)	
Age (302)[a]	57.76±18.22	56.16±16.78	60.78±14.22	0.144
BMI (303)				
Underweight (4)	3 (2.8%)	1 (1.0%)	0 (0.0%)	<0.001*
Normal weight (127)	76 (69.7%)	31 (32.0%)	20 (20.6%)	
Overweight (121)	26 (23.9%)	48 (49.5%)	47 (48.5%)	
Obese (51)	4 (3.7%)	17 (17.5%)	30 (30.9%)	
Current Nutrition (303)				
PN (2)	1 (0.9%)	1 (1.0%)	0 (0.0%)	0.004*
EN (2)	1 (0.9%)	1 (1.0%)	0 (0.0%)	
NPO (56)	32 (29.4%)	17 (17.5%)	7 (7.2%)	
Oral (243)	75 (68.8%)	78 (80.4%)	90 (92.8%)	
Hospitalization (302)[b]	3.5±2.86	3.34±2.28	2.99±2.89	0.396
Sleep duration (302)[a]	7.06±1.69	6.85±1.54	6.86±1.37	0.515

Note: PN, Parentral Nutrition; EN, Entral Nutrition; NPO, Nothing by mouth.
1st tertile: NC < 32 cm; 2nd tertile: 32≤NC ≤ 37; 3rd tertile: NC > 37 cm.
Chi-square test used for categorical and one-way ANOVA test used for continues variables.
**P-value* is calculated by Chi-square and $p < 0.05$ was considered as a significance level.
[a] Mean ± SD.
[b] Number of hospitalization days.

consumption of some drugs such as statins, anti-coagulants, and supplements has shown to be significantly correlated with NC ($P < 0.05$) (Table S2).

3.3. Biochemical indices and blood pressure assessment

Biochemical indices assessments of patients showed that albumin ($P = 0.025$), urea, and creatinine ($P < 0.001$), as kidney disease indices, showed a significant correlation with NC. Potassium ($P < 0.001$) among all electrolytes and SBP ($P = 0.033$) showed a significant correlation with NC. Hematological parameters and vital signs in Table S3 showed that MCV($P = 0.001$), MCH ($P = 0.009$), and BT ($P = 0.014$) had a significant correlation with NC (see Table 3).

4. Discussion

Over the years, many studies have described, the detrimental effects of obesity and its association with the risk of metabolic disorders. In addition, total body fat mass, fat mass localization is an essential and well-established risk factor of metabolic and cardiovascular comorbidities [18]. Although many studies have found both upper and lower body fat mass to be detrimental to health, in recent years, with increasing studies in this area, scientists have suggested that upper body fat mass has more complications than lower body fat mass. Some studies have even suggested that upper body (abdominal) fat mass is almost involved in cardiometabolic disorders, while lower body fat mass may have an overall protective effect against morbidity/mortality [19,20]. In this cross-sectional study among patients hospitalized in Imam Reza hospital, Tabriz, Iran, we investigated whether NC, which indicates upper body fat mass, is associated with metabolic risk factors and renal diseases or not. We observed a significant association between gender, BMI, PA, and medical history with NC.

The current study showed that men have a higher NC compared to women and consistent with Ben-Noun et al. [21], which showed that obese patients had higher NC compared with normal weight patients. Even though NC changes parallel with changes in weight, a study by Ben-Noun showed that small changes in weight or short-term changes of age could not cause noticeable changes in NC. They showed that subjects were 1.6 years older at the second observation compared to the baseline, or 0.5 Kg reduction in weight, by controlling of dietary energy intake and physical activity, didn't have any change in the NC and related diseases such as DM or other cardiovascular diseases. Therefore, they

Table 2
The frequency of the disease among tertiles of neck circumference value.

History of Diseases				
Variables (n)	1st tertile of NC	2nd tertile of NC	3rd tertile of Nc	P
DM(303) YES(93)	20 (18.3%)	27 (27.8)	45 (46.4%)	<0.001*
CVD (303) YES(40)	11 (10.1%)	12 (12.4%)	17 (17.5%)	0.278
HTN (303) YES(151)	42 (38.5%)	50 (51.5%)	59 (60.8%)	0.006*
KD (303) YES(96)	14 (12.8%)	33 (34.0%)	49 (50.5%)	<0.001*
HLP (303) YES(30)	10 (9.2%)	11 (11.3%)	9 (9.3%)	0.867
GI-Disease (303) YES(26)	10 (9.2%)	12 (12.4%)	4 (4.1%)	0.118
Drug Use				

Note: DM, Diabet Mellitus; CVD, Cardio Vascular Diseases; HTN, Hyper Tension; KD, Kidney Disease; HLP, Hyper Lipid Profile; GI-Diseases, Gastro Intestinal-Diseases.
1st tertile: NC < 32 cm; 2nd tertile: 32≤NC ≤ 37; 3rd tertile: NC > 37 cm.
Chi-square test used for categorical and one-way ANOVA test used for continues variables.
*P-value is calculated by Chi-square and $p < 0.05$ was considered as a significancy level.

Table 3
Biochemical indices and blood pressure among neck circumference tertiles.

Variable	1st tertile of NC[a]	2nd tertile of NC[a]	3rd tertile of NC[a]	Total[a]	*P*
FBS (mg/dl)	119.70 ± 71.60	115.89 ± 47.21	137.50 ± 72.21	126.93 ± 65.40	0.333
BS (mg/dl)	134.19 ± 70.90	181.29 ± 136.87	157.21 ± 108.07	156.27 ± 107.27	0.291
BUN (mg/dl)	89.95 ± 60.53	124.83 ± 44.73	100.98 ± 47.76	101.84 ± 49.72	0.413
Cholestrol (mg/dl)	148.07 ± 46.17	191.06 ± 78.23	161.46 ± 41.08	164.75 ± 52.13	0.064
TG (mg/dl)	124.31 ± 50.28	151.16 ± 93.87	180.44 ± 86.00	162.85 ± 84.31	0.055
LDL-C (mg/dl)	95.83 ± 29.08	116.22 ± 65.02	104.50 ± 31.87	106.02 ± 41.64	0.643
HDL-C (mg/dl)	47.14 ± 15.91	36.77 ± 9.94	34.76 ± 9.80	37.59 ± 11.83	0.050
P (mmol/L)	4.23 ± 1.84	4.83 ± 1.83	5.11 ± 1.90	4.80 ± 1.89	0.077
CRP (mg/L)	27.80 ± 27.64	38.20 ± 15.81	24.03 ± 13.85	27.49 ± 18.04	0.321
Alb (mg/dl)	3.72 ± 0.79	3.56 ± 0.92	14.14 ± 0.88	3.83 ± 0.85	0.025[b]
Ca (mg/dl)	8.80 ± 0.8	8.65 ± 0.8	8.50 ± 0.90	8.60 ± 0.8	0.469
Na (mEq/L)	139.00 ± 3.00	139.00 ± 2.00	139.00 ± 3.00	139.00 ± 3.00	0.885
K (mEq/L)	4.00 ± 0.4	4.25 ± 0.60	4.06 ± 0.70	4.20 ± 0.67	<0.001[b]
Urea (mg/dl)	31.00 ± 16	64.50 ± 52	94.50 ± 54.00	54.00 ± 56	<0.001[b]
Creatinine (mg/dl)	1 ± 0.45	2.64 ± 3.81	6.62 ± 4.33	2.59 ± 4.78	<0.001[b]
SBP (mmHg)	1.56 ± 0.94	1.95 ± 1.15	1.82 ± 1.17	1.76 ± 1.09	0.033[b]
DBP (mmHg)	1.17 ± 0.46	1.24 ± 0.51	1.21 ± 0.40	1.20 ± 0.46	0.563

Note: TG, Triglyceride; LDL-C, Low Density Lipoprotein-Cholesterol; HDL-C, High Density Lipoprotein-Cholesterol; CRP, C-Reactive Protein; Alb, Albumin; SBP, Systolic Blood Pressure; DBP, Diastolic Blood Pressure; PR, Pulse Rate; RR, Respiratory Rate. One-way ANOVA test used for normal data and Kruskal–Wallis H used for abnormal data.
1st tertile: NC < 32 cm; 2nd tertile: 32≤NC ≤ 37; 3rd tertile: NC > 37 cm.
[a] Mean ± SD.
[b] Statically significant.

suggested that in order to achieve the positive effects of NC reduction, weight reduction should be considerable and significantly [21].

Furthermore, low PA positively correlated with NC, and also patients with a history of DM, HTN, and KD had higher NC. These results are similar to several recent studies findings that have revealed NC as a simple and feasible anthropometric marker of upper-body fat deposits [12]. Consistent with the current study, Ferrari et al. showed significant associations between PA and NC, independent of age, sex, educational and socioeconomic level [22]. According to the biochemical results of the current study, urea, creatinine, potassium, and albumin levels are significantly associated with NC. These findings are consistent with previous studies that demonstrated, NC as a simple and convenient anthropometric tool, associated with cardiometabolic risk factors and renal diseases [9]. Shen et al. concluded that high NC is associated with hyperuricemia, which is similar to our results. Although hyperuricemia is asymptomatic, it is associated with several health outcomes such as gout, kidney stones, and chronic kidney diseases. It seems upper body fat estimated by NC, has a critical role in hyperuricemia pathology [23]. NC could be considered as a valid and reliable predictor of metabolic syndrome in the adult population [13,24] and subsequently is associated with insulin resistance. On the other hand, insulin resistance can reduce uric acid exertion through Na tubular reabsorption increases [9]. Besides that, free fatty acid excretion from upper body fat is the other reason that NC can affect hyperuricemia, because, the free fatty acid increase is associated with oxidative stress and insulin resistance [23]. With regard to these mechanisms, it is better to detect potential risk factors to decrease the risk of hyperuricemia related to chronic diseases.

In a study performed by Jing-ya Zhou et al. among 4201 participants, it was revealed that NC was positively correlated with SBP and DBP, FBG, TG, TC, and LDL-C and negatively correlated with HDL-c in males [9,25]. Our findings are in agreement with those studies about SBP. In addition, NC has been related to increased levels of SBP, DBP, FBG, TG, uric acid and high-sensitivity C-reactive protein, and decreased levels of HDL-c in Natalia G et al. study [11]. A common form of dyslipidemia is characterized by elevated TG, small LDL particles, and reduced HDL-c [11]. Because of the aforementioned results of NC and lipid profile association, NC can be considered as a potential indicator of cardiovascular risk factors. Excessive release of potentially harmful cytokines and a decrease in the release of beneficial adipokines may result in abnormal subcutaneous fat (SC) function, which in turn reduces circulating triglyceride fatty acid stores, along with excess free fatty acids (FFA) in some circumstances [11]. Upper-body subcutaneous adipose tissue FFA release accounts for the systemic FFA and suppression of insulin [11]. So, NC measurements maybe is an effective screening tool for insulin resistance and indicator for improving T2DM as well as an indicator for predicting dyslipidemia and incident CKD events. However, in general, there is limited data about NC and CKD association.

5. Limitations

Our study has some limitations. First, because of its cross-sectional study design, we could not discover the causal relationships between NC and biochemical parameters. Second, this study was conducted in a particular geographic location, which affects the external validity of the study. Third, failure to adjust for potential confounders. So, it is suggested to conduct in a larger sample size to yield additional information about NC association with renal disease risk factors.

6. Conclusion

To the best of our knowledge, this is the first study in Iran which reports NC as a reasonable indicator for predicting metabolic disorders and kidney diseases in hospitalized patients. Further studies with high sample size and different geographical areas are suggested to determine whether this measurement is capable of complementing or replacing the measurement for routine anthropometric assessments such as BMI, WC to assess the nutritional status in hospitalized patients.

Authors' contributions

ShT and MM conducted the analysis and collaborated in writing the first draft of the paper, and was co-investigator responsible for devising methods and study design. ShT revised the final step of the article. MAF and MM wrote the first draft of the paper and conducted the analysis, and was the corresponding author, responsible for devising methods and study design. TF, EB, MK, NR, FV were the co-investigator responsible for in preparing samples for data preparation. All authors contributed to the interpretation of the results and read and approved the final manuscript.

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Ethics approval and consent to participate

This study was approved by the Ethics Committee of Tabriz University of Medical Sciences (Code number: 65579). Written informed consent was obtained from all of participants.

Consent for publication

Not applicable.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.nutos.2021.02.002.

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