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Exploring the Utility of MUAC in Classifying Adult Metabolic Syndrome Using NHANES 2015-16

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Exploring the utility of MUAC in classifying adult metabolic syndrome risk using NHANES 2015-16

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Abstract:

INTRODUCTION: Metabolic syndrome (MetS) is a constellation of cardiometabolic risk factors (visceral adiposity, dyslipidemia, hyperglycemia, and hypertension) that, when presented in tandem, exponentially increases the risk of heart disease and insulin resistance. The utility of mid-upper arm circumference as a metric of MetS risk has not been widely explored. Finding a simple and validated screening method is critical to proactively intervene and attenuate the development of these cardiometabolic diseases, thereby improving healthcare outcomes such as quality of life and associated costs. There is paucity in the literature exploring the relation between mid-upper arm circumference (MUAC) and MetS. **PURPOSE:** This study defined and validated a risk criterion for MetS using MUAC as a valid alternative criterion for MetS classification risk. **METHODS**: The target sample was derived from National Health & Nutrition Examination Survey (NHANES) 2015-2016 data that included adults over the age of 18 (N = 9,971). MetS was defined using the NCEP ATP III 2005 MetS diagnosis criteria. A recursive partitioning methodology (RPM), using the Classification & Regression Tree Algorithm, was employed to create binary MUAC criterion by sex, using 75% of the total sample. Validation of the criteria was performed with the remaining 25% of the total sample, selected at random. **RESULTS**: Seventeen percent (17%) of the total sample presented with the MetS. The RPM resulted in sex specific MetS criteria with the MUAC criterion being >32cm ($p = 0.024$) and >29cm ($p = 0.024$) for males and females, respectively. Specifically, those presenting with the risk criteria were 9.84, for males, and 9.23, for females, times more likely to present with MetS than without the MUAC criterion. The overall classification accuracy for both the training and validation models were 83% with no statistical difference between models ($p = 0.983$). **CONCLUSION**: MUAC shows promise in being an effective screening method for

MetS in guiding further diagnostic tests to prevent associated cardiometabolic morbidity and mortality.

Introduction:

Metabolic syndrome (MetS) is a constellation of cardiometabolic risk factors (visceral adiposity, dyslipidemia, hyperglycemia, and hypertension) that, when presented in tandem, exponentially increases the risk of heart disease and insulin resistance (Kaur, 2014). There are a multitude of diseases associated with MetS, including cardiovascular disease (coronary heart disease, stroke, heart failure, and hypertension) and diabetes mellitus (Churilla and Zoeller, 2008). MetS' ties with related diseases, some are the leading causes of death in the United States, mark this syndrome of utmost importance. MetS is an extremely prevalent disease in America. A study conducted in 2018, found that for each region in the United States at least 29.0% of the adult population was diagnosed with MetS. The region with the lowest percentage was the Pacific at 29.0% and the highest was West North Central at 40.0% (Gurka, Filipp, & DeBoer, 2018). The rate of MetS has been increasing each year. The purpose of this investigation was to identify an indicative screening tool that is simple, economical, and feasible for MetS evaluation for the general population.

The current MetS classification according to the National Cholesterol Education Program (NCEP) ATP III Guidelines state that a patient who presents with three of the following five criteria are diagnosed with MetS: waist circumference (WC) > 102 cm (male) or > 88 cm (female), fasting glucose (FPG) $\geq$ 100 mg/dl, fasting triglycerides (TG) $\geq$ 150 mg/dl, high-density lipoprotein (HDL) cholesterol < 40 mg/dl (male) and < 50 mg/dl (female), and blood pressure (BP) > 130/85 mmHg (NCEP, 2002). These criteria require a blood test and a measurement of central adiposity. This is not extremely feasible for much of the general population in order to quickly determine MetS status. With a simple tool, a patient can be easily screened for new criteria and positive screenings would be followed by a referral for more specific testing to determine MetS status.

The measurement of mid-upper arm circumference (MUAC) was explored in this study. MUAC is an easily accessible location and requires little training on the health professional's part in order to administer. The use of a rapid preliminary screening tool facilitates reaching the at-risk population sooner. This will also enable a larger amount of the population to be screened and evaluated for MetS earlier thereby increasing the likelihood of those testing positive to undergo more in-depth screening. Creating and instituting a simple to use, validated screening method may serve as a critical intervention to proactively attenuate the development of cardiometabolic diseases associated with MetS, thereby improving healthcare outcomes such as quality of life and associated healthcare costs.

There is a paucity in research exploring the relation between MUAC and MetS. A study conducted by the University of Malawi found a significant correlation between MUAC and intra-abdominal fat (Finch, 2017). However, relation to MetS was not explored. In another study piloted in South Africa found that a MUAC cut off of $\geq$ 33 cm was related to obesity (Puoane, 2002). An Istanbul study found that there was approximately a two cm difference in MUAC between those tested with and without MetS (Sagun, 2017). In the same study, the predictive value of MUAC related to MetS was found to be 57.58% (Sagun, 2017). These findings support the limited research exploring associations between MUAC and a MetS diagnosis. The use of decision trees (DT) has been previously used to link different MetS criteria to MetS. A study compared different DT pathways to see if these pathways could detect MetS before other classification models (Miller & Fridline, 2015). Another study found similar success in the use of DT to identify MetS risk (Miller, Fridline, Liu, & Marino, 2014). Chi-squared automatic interaction detection (CHIAD) DT analysis with waist circumference user-specified as the first level was utilized. The study suggests that the use of DT as a preliminary detection of MetS may be a feasible possibility (Miller, Fridline, Liu, & Marino, 2014). The use of MUAC has been studied for adolescent malnutrition, with little research on its relation to obesity and related diseases.

The present investigation aims to purposively assess the utility of MUAC in estimating MetS risk using a sample from National Health & Nutrition Examination Survey (NHANES) data (2015-2016), guided by two aims. The first aim was to create a classification criterion for MetS using predictive analytics (decision trees) by sex. The second was to validate the criteria based on sensitivity, specificity, and accuracy.

Methods:

The sample was derived from NHANES 2015-16 data made public by the Center for Disease Control and Prevention (CDC). It included adults over the age of 18 (N = 9,971). MetS was defined using the NCEP ATP III 2005 MetS diagnosis criteria: patient must meet three of the following; abdominal obesity: WC > 102 cm for males and > 88 cm for females; TG: ≥ 150 mg/dL; HDL cholesterol: < 40 mg/dL for males, < 50 mg/dL for females; BP: ≥ 130 / ≥ 85 mmHg; and FPG: ≥ 110 mg/dL.

A recursive partitioning methodology (RPM) using the Classification and Regression Tree (CART) algorithm was employed to create binary MUAC criterion by sex, using 75% of the total sample (n = 7,523). A second tree was used to validate the criteria and was performed with the remaining 25% of the total sample (n = 2,448), randomly selected. The model performance was described using sensitivity, specificity, and accuracy based on MUAC criteria classifying each MetS criteria and MetS itself. Pearson's product moment correlation coefficient (r) was used to explore the association between each MetS and MUAC variable with significance set at $p \leq 0.05$.

Results:

Criteria	Sensitivity	Specificity	Accuracy	Correlation*
WC	89.3%	82.8%	85.2%	0.926
TG	74.7%	65.9%	67.9%	0.189
HDL	69.7%	64.3%	65.5%	-0.291
BP	68.9%	62.6%	63.8%	
SBP				0.343
DBP				0.322
FPG	70.8%	62.1%	63.4%	0.187
MetS	**87.0%**	**66.6%**	**70.5%**	

*All correlations (*r*) significant to the $p \leq 0.001$ level

N = 8,976

Table 1. Classification metrics by MetS Criteria and MUAC.

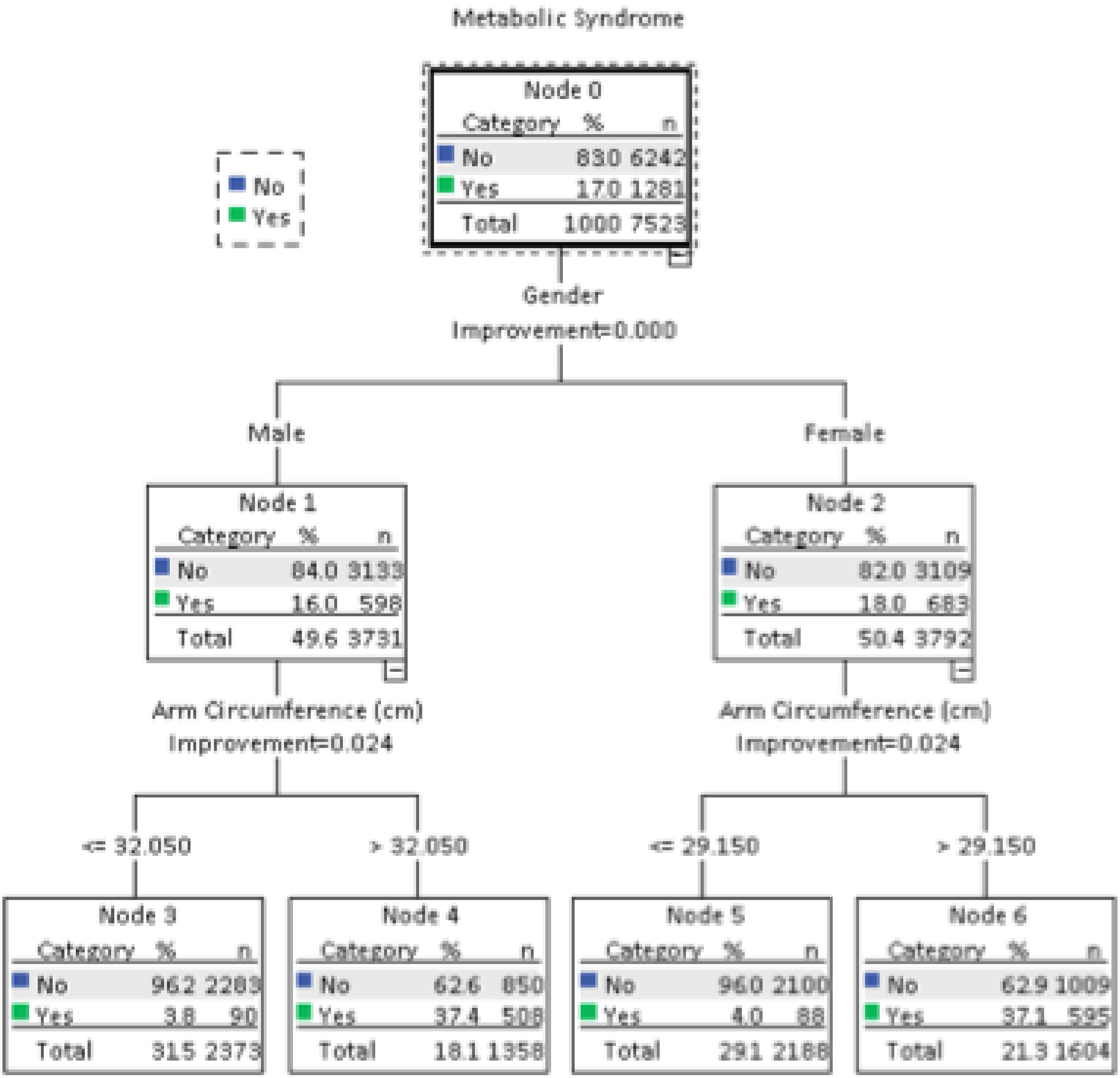

Figure 1. CART Decision Tree of MetS by Sex & MUAC

The NHANES 2015-16 data utilized was split using 75% in the first tree to determine the threshold and the remaining 25% to test the validity in the second tree. Of the 75%, 6,242 participants did not have MetS and 1,281 did have MetS, with a total sample size of 7,523. There were 3,731 males and 3,792 females in the set. Nodes 1 and 2 show 598 males and 683 females classified for MetS according to NCEP ATP III guidelines. The computed cutoff was 32.050 cm and 29.150 cm for males and females, respectively.

In the second tree in Figure 1, the aforementioned MUAC cut-off was applied to the remaining 25% of data (n = 2,448) to test the validity. In Node 3, males with a MUAC < 32.050 cm were compared to their MetS status. Participants with a MUAC below the threshold did not have MetS accounted for 96.2%. Node 4 shows that of the males who's MUAC was > 32.050 cm, 37.4% also had MetS. In Nodes 5 and 6 females are examined with the threshold of 29.150 cm. In Node 5, females with a MUAC < 29.150 cm were compared with their MetS status and it was found that 96.0% did not have MetS. In Node 6, of the females with a MUAC > 29.150 cm, 37.1% had MetS.

In Table 1, the classification metrics of MetS set forth by the NCEP were analyzed in comparison to the MUAC threshold computed in this study against sensitivity, specificity, accuracy, and correlation. WC's sensitivity, specificity, accuracy and correlation were 89.3%, 82.8%. 85.2%, and 0.926, respectively. TG's sensitivity, specificity, accuracy and correlation were 74.7%, 65.9%. 67.9%, and 0.189, respectively. HDL's sensitivity, specificity, accuracy and correlation were 69.7%, 64.3%. 65.5%, and -0.291, respectively. BP's sensitivity, specificity, accuracy and was 68.9%, 62.6%, and 63.8%, respectively, with correlations of 0.343 and 0.322 for SBP and DBP respectively. FPG's sensitivity, specificity, accuracy and correlation was

70.8%, 62.1%. 63.4%, and 0.187, respectively. Finally, MetS' sensitivity was 87.0%, specificity of 66.6%, and an accuracy of 70.5%.

Discussion:

The purpose of this study was to ascertain an indicative screening tool that is simple, economical, and feasible for MetS evaluation for the general population. The aims were to create a classification criterion for MetS with the use of predictive analytics by sex and to subsequently, validate the criteria based on sensitivity, specificity, and accuracy in relation to each of the NCEP criteria. The sample utilized was derived from NHANES 2015-16 data made public by the CDC. It included adults over the age of 18 and were randomly selected (N = 9,971). MetS diagnosis was based on NCEP ATP III guidelines.

From the total data, 17% classified for MetS and 83% did not. A previous study using NHANES 2001-2012 data to classify MetS prevalence found 28% with MetS and 72% without (Mazidi, Pennathur, and Afshinnia, 2017). Another study utilizing NHANES 1999-2014 found that in the United States divided by region between 29.0% and 40.0% were diagnosed with MetS (Gurka, Filipp, & DeBoer, 2018). A study using NHANES data from 2009-10 had 20% with MetS and 80% without MetS (Miller, Fridline, Liu, & Marino, 2014). Each set of data shows a range of MetS prevalence with the use of NHANES data, with the amount from this study slightly below the others, but still in range.

The cutoffs the CART identified that associated MUAC with MetS were 32.050 cm and 29.150 cm for males and females, respectively. There is a scarcity of research that associates MUAC with MetS and obesity as most of the literature links MUAC with adolescent malnutrition. This link between the two shows promise in the utility of MUAC with adult obesity. The results showed strong sensitivity, specificity, accuracy and correlation with WC to MUAC. This is not surprising as each are a measurement of girth.

A limitation noted during this study is the presence of muscle-mass as a potential misrepresentation in categorization. However, as the aim of this study is for the general population, or those at risk for MetS, it can be assumed that there is little discernible muscle-mass skewing the MUAC measurements for the intended population. There are many strengths to the methods used to abate limitations and errors. NHANES data provides a sample that does not have any self-reported measures and is rigorously collected under the CDC. The split of the data for creating the classification and to validate was completed by the CART algorithm and with random selection.

These findings lend themselves to indicate the auspiciousness in lowering overall healthcare costs for MetS and related diseases. With an earlier diagnosis and intervention, patients can attenuate the progression of MetS and affiliated cardiometabolic diseases. As aforementioned, the prevalence of MetS and related diseases in the United States proves the relevance and imperativeness of early attenuation. Referring patients who fit the MUAC criteria for testing of the current NCEP criteria, could reduce the number of unnecessary testing. In addition, if MetS is diagnosed earlier, less advanced interventions would need to be implemented. These points all aid in lowering overall healthcare costs and improving quality of life. This measurement could be attained at a health fair to quickly address the potential need for further testing to diagnose MetS.

As there is a lack of research in the use of MUAC with MetS, this pioneering study sets up additional avenues of exploration addressing the utility of MUAC. A prospective study and replication should be performed. To further the relevance of MUAC, criteria should be identified to more accurately categorize and refer patients for additional testing. Recommendations based on age and race should be studied to increase the preciseness of using MUAC in relation to MetS.

This study successfully identified an indicative screening tool that is simple, economical, and feasible for MetS evaluation for the general population. A classification criterion was created using predictive analytics by sex. Additionally, the sex criteria were validated based on sensitivity, specificity, and accuracy against each of the current NCEP MetS criteria using NHANES data from 2015-16 with positive results.

References

Churilla JR, Zoeller R. (2008). Physical activity: physical activity and the metabolic syndrome: a review of the evidence. *Am J Lifestyle*. 2008; 2:118-25.

Finch, P. (2017). Intra-abdominal fat: comparison of computed tomography fat segmentation and bioimpedance spectroscopy. *Malawi Medical Journal: The Journal Of Medical Association Of Malawi*, *29*(2), 155–159.

Gurka, M. J., Filipp, S. L., & Deboer, M. D. (2018). Geographical variation in the prevalence of obesity, metabolic syndrome, and diabetes among US adults. *Nutrition & Diabetes,8*(1). doi:10.1038/s41387-018-0024-2

Kaur, J. (2014). A comprehensive review on metabolic syndrome. *Cardiology Research and Practice*, *2014*, 943162. http://doi.org/10.1155/2014/943162.

Mazidi, M., Pennathur, S., & Afshinnia, F. (2017). Link of dietary patterns with metabolic syndrome: analysis of the national health and nutrition examination survey. *Nutrition & Diabetes,7*(3). doi:10.1038/nutd.2017.11

Miller, B., & Fridline, M. (2015). Development and validation of metabolic syndrome prediction and classification-pathways using decision trees. *Journal of Metabolic Syndrome,04*(01). doi:10.4172/2167-0943.1000173

Miller, B., Fridline, M., Liu, P., & Marino, D. (2014). Use of CHAID Decision Trees to formulate pathways for the early detection of metabolic syndrome in young adults. *Computational and Mathematical Methods in Medicine,2014*, 1-7. doi:10.1155/2014/242717

National Cholesterol Education Program (NCEP): Expert panel on detection and treatment of high blood cholesterol in adults (2002). third report of the national cholesterol education program (ncep) expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (adult treatment panel iii) final report. Circulation 106, 3143–3421

Puoane, T. , Steyn, K. , Bradshaw, D. , Laubscher, R. , Fourie, J. , Lambert, V. and Mbananga, N. (2002), Obesity in south africa: the south african demographic and health survey. Obesity Research, 10: 1038-1048. doi:10.1038/oby.2002.141.

Sagun, G., Oguz, A., Karagoz, E., Filizer, A. T., Tamer, G., & Mesci, B. (2014). Application of alternative anthropometric measurements to predict metabolic syndrome. *Clinics (Sao Paulo, Brazil)*, *69*(5), 347-53.