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Original Article

The Prevalence and Predictive Risk Factors of Metabolic Syndrome Based on Health-Related Fitness Components in Omani Adolescents with Obesity

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Abstract

Background: Significant linear trends indicate that rising adolescent obesity rates will increase the prevalence of metabolic syndrome (MetS) and associated health risks. We aimed to initially determine the prevalence of MetS among adolescents (aged 13-16 yr) with obesity in the South Al Batinah governorate in Oman (n=3404) based on data collected in 2024. Then to predict the risk factors of MetS criteria based on health-related fitness (HRF) components to identify the most significant risk factors among them (n= 512, with BMIile% ≥95%).

Methods: A cross-sectional study was performed to determine the MetS prevalence. MetS criteria and HRF components were measured to examine key risk factors. Then, the predictive value of HRF variables for MetS incidence was assessed using multiple regression analysis.

Results: The descriptive results from screening adolescents with obesity indicated that 10.7% of them exhibited MetS. A notable correlation between fast blood glucose (FBG) and cardiorespiratory fitness; CRF (r=0.28, P=0.001), waist circumference; WC (r=0.39, P<0.0001), and BMI (r=0.46, P<0.0001) were revealed. There was a robust correlation between blood pressure; BP and CRF (r=0.19, P=0.025), WC (r=0.24, P=0.007), and BMI (r=0.43, P<0.0001). Multiple regression analysis showed a significant model for the high FBG prediction using the HRF variables, while the models predicted for BP were not significant.

Conclusion: Significant correlation between HRF level and MetS criteria revealed that field-based tests HRF components, can be used to recognize MetS criteria among adolescents with obesity.

Keywords: Metabolic syndrome; Muscle strength; Cardiovascular fitness; Body mass index; Adolescent; Oman; Health-related fitness

Introduction

One of the significant challenges of the 21st century is non-communicable diseases (NCDs), the leading cause of global mortality. Among these, Metabolic Syndrome (MetS), as a cluster of conditions, significantly increase the burden of chronic

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NCDs (1). It involves multiple risk factors associated with cardiovascular disease (CVD) and diabetes. These factors include abnormal blood glucose, elevated blood pressure, high triglyceride levels, low high-density lipoprotein (HDL), cholesterol levels, and obesity particularly, central adiposity indicated by waist circumference. If an individual has at least three out of these five risk factors, can be diagnosed with MetS (2,3).

The International Diabetes Federation has recently defined MetS in children and adolescents, as having an increased waist circumference (abdominal obesity) as a critical component, along with two or more other criteria (clinical or laboratory), such as low HDL, cholesterol, high blood pressure, elevated triglycerides, and high blood glucose level (4).

Metabolic Syndrome (MetS) affects approximately 30% of the global population, significantly increasing the risk of morbidity and mortality. In Omanis adults, the prevalence of MetS is around 23.6% (5). There is an increase in the prevalence of risk factors associated with the diagnosis of MetS (6). Projections indicated that Oman in 2030 will be among first fifty countries with the highest prevalence of obesity, with a thirty-three ranking globally and among the first tenth countries in the Middle East with the highest prevalence of obesity in children aged 5-19 (7).

Similarly, hypertension and raised total cholesterol prevalence in Oman were reported at 33% and 36%, respectively, which current trends suggest substantial increases in the proportion of the population meeting MetS criteria, placing the population at greater risk for chronic diseases and premature death (7). On the other hand, another factor as an essential health indicator is health-related fitness (HRF) level, which predicts morbidity and mortality for cardiovascular, metabolic, and NCDs in life (8). In addition, results of a study on Omani primary school children aged (9-10) yr showed that boys and girls with obesity had worse performance than children of average weight in running, agility, endurance and most physical fitness measures, which indicates that they will be more likely to develop NCDs in future (9).

Improving health-related fitness components, including cardiorespiratory fitness (CRF), muscle strength (MS) and muscle endurance (ME), and body composition, is a way to highlight health improvement (10). Therefore, we aimed to initially evaluate the prevalence of MetS criteria among adolescents (13-16 yr) with obesity in the South Al Batinah governorate by measuring waist circumference (WC), blood pressure (BP), and fast blood glucose (FBG), secondly, to predict the most risk factors of MetS based on health-related fitness components (body composition, cardiorespiratory fitness, muscular strength, muscular endurance, and flexibility) among target population. This study hopes to open a view to having better educational health programs for children and adolescents with obesity in Oman.

Methods

Study design and sampling

This study took place in South Al Batinah Governorate, Oman, with a population of 536,724 (2024). The target group was adolescents aged 13-16 yr (N=12,056). Using multi-stage cluster sampling, 512 students with obesity were selected from 3,404 adolescents in eleven second-cycle schools. Participants were chosen based on a BMI percentile of 95% or greater. Exclusion criteria were genetic disorders, medical conditions, or current medication use (11). Subsequently, 135 adolescents with high WC and BMI%ile ≥95 were screened for MetS criteria and the high-risk factors based on HRF components measurements.

MetS Criteria

BP was measured using standard method. Blood pressures were measured in sitting position after a 5-min rest. Each participant had 3 measurements of blood pressure recorded at 1-min intervals; the average of all readings was used for analysis. FBG level was collected after a 12-hour fast on morning time. The healthcare professionals performed samples' analysis, using standard enzymatic methods (12). A direct measurement method with an automatic analyzer (LABOSPECT008, Hitachi

High-Technologies Corporation, Japan) was used to measure high-density lipoprotein cholesterol (13).

Health-related Fitness Components

First, BMI was calculated by dividing body mass (kg) by height in meters squared (m^2). CRF was evaluated using the 20-meter Shuttle Run test (Beep Shuttle Advanced Rev:3.2) program. The Beep Shuttle program was used to estimate VO_{2max} (ml/kg/min) (14), Muscular endurance (abdominal) or core strength was assessed using the Curl-ups test (13). Flexibility in the back was assessed by the sit-and-reach test. Muscle strength (upper extremity) was assessed using the hand grip strength test with a Smedley-type handheld dynamometer (Takei models TKK 5410, measured to the nearest 0.1 kg) (13).

Statistical analysis

Descriptive statistics, including means, standard deviation (SD), and 95% confidence intervals (95% CI) values used to determine the MetS prevalence. The normality tests (Kolmogorov-Smirnov) followed a normal distribution ($P>0.05$). Pearson correlation and multiple regression used to predict the most risk factors of MetS based on HRF components. Analyses were performed using IBM SPSS (v27) and GraphPad Prism (v9.0.1). Group means were compared using an independent samples *t*-test. The *P*-values less than 0.05 were considered as significant.

Inclusion/ Exclusion Criteria

The participants of this study were selected from the second-school students of South Al Batinah Governorate, Oman, whose age were between the 13 and 16 yr old. All students with a BMI greater than the 95th percentile were included. However, students with recent musculoskeletal injuries, genetic disorders, medical conditions, or those currently using medication were not included in the assessment. This approach ensures that the assessment results are not influenced by factors unrelated to BMI. Meanwhile, the nutrition and physical activity level were not assessed in this study, as the primary focus was on identifying predictive risk factors of MetS based on health-related fitness components.

Ethical considerations

Ethics approval was obtained from the Ethics Unit at Sultan Idris Education University (UPSI/PPPI/PYK/ETIKA(M)/2024-0262-01).

Results

MetS Prevalence

A multi-stage cluster sampling screened 512 students with obesity (192 girls; 320 boys) from 3404 adolescents based on BMI%ile≥ 95%. Screening by WC (≥80 cm for girls; 90 cm≥ for boys) showed 135 adolescents (54 girls, 76 boys) in the high WC category. Approximately 2/3 had the high BP and FBG (Table S1). According to the International Diabetes Federation, MetS in children (10–16 yr) requires central adiposity (≥90th) and two of the following: TG ≥ 150 mg/dl, HDL < 40 mg/dl, systolic BP ≥ 130 mmHg or diastolic BP ≥ 85 mmHg, FBG ≥ 100 mg/dl, or type 2 diabetes (15). Thus, 10.7% of obese adolescents (13-16 yr) in South Al Batinah, Oman, had MetS (Fig. 1). Only 23% of adolescents with obesity who had two risk factors (BMI ≥95th percentile, high WC) did not meet any MetS criteria (Table S2).

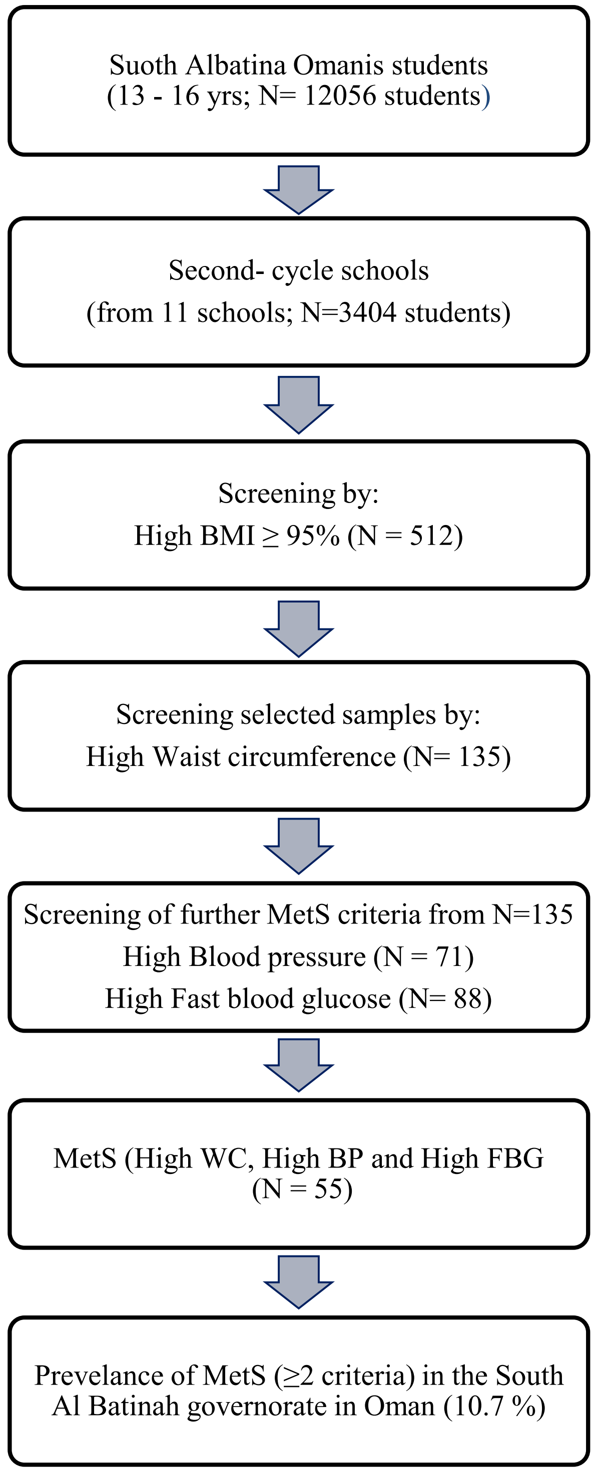

Fig. 1: The schematic presentation of MetS prevalence statistics

Table 1 shows the descriptive data (Mean ± SD) of MetS components (n=135) by gender. ANOVA showed no significant differences in MetS criteria between boys and girls ($P<0.05$). HRF components analysis by independent sample t-test showed significant differences ($P<0.0001$) between boys and girls (Fig. 2).

Table 1: Descriptive Data of MetS criteria of the adolescents with obesity based on gender (Mean ± SD)

	Gender	No. of participants Total =135	Mean	SD	Mean Difference P-value
Systolic BP (mmHg)	Girl	57	135.96	11.32	0.43
	Boy	78	134.59	8.65	
Diastolic BP (mmHg)	Girl	57	84.46	6.95	0.36
	Boy	78	85.67	7.68	
FBG (mmol/L)	Girl	57	5.83	0.80	0.44
	Boy	78	5.71	0.96	

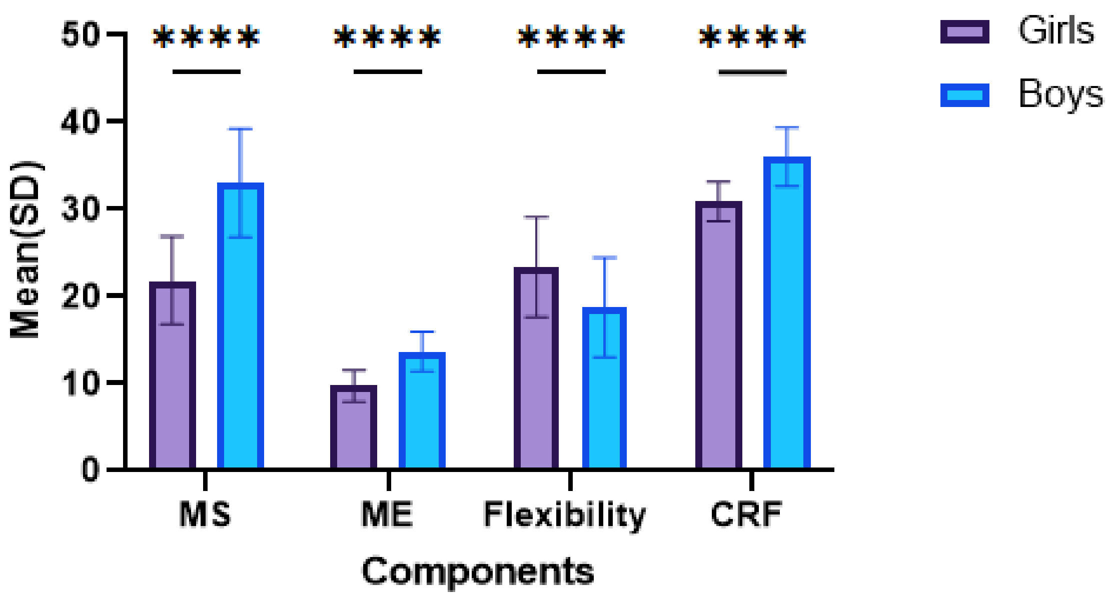

Fig. 2: Comparison of HRF components based on gender (**** *P*-value <0.0001)

Predictive of MetS Risk factors Based on HRF

Demographic characteristics and the descriptive data of HRF components and MetS criteria by gender are shown in Tables S4- S6. Pearson analysis (Table 2) revealed significant correlations between various HRF components (CRF, MS, ME, flexibility) and MetS criteria (P<0.05). WC positively correlated with systolic BP (r=0.236), diastolic BP (r=0.336), and FBG (r=0.391).

Table 2: The Pearson's correlation coefficients between HRF components and MetS criteria (N=135)

First variable	Second variable	Pearson correlation (r)	Sig. *P*-value
WC (cm)	Systolic BP	0.236***	0.007
	Diastolic BP	0.336****	0.000
	FBG	0.391****	0.000
	CRF	0.062	0.484
	Muscle strength	0.449****	0.000
	Muscular endurance	0.223*	0.011
	Flexibility	-0.355****	0.000
	BMI	0.545****	0.000
FBG (mmHg)	Systolic BP	0.421****	0.000
	Diastolic BP	0.299***	0.001
	CRF	-0.283***	0.001
	Muscle strength	0.127	0.151
	Muscular endurance	-0.079	0.369
	Flexibility	-0.169	0.055
	Body composition	0.391****	0.000
	BMI	0.458****	0.000
Systolic BP (mmol/L)	CRF	-0.193*	0.028
	Muscle strength	0.148	0.094
	Muscular endurance	-0.138	0.118
	Flexibility	-0.034	0.698
	Body composition	0.236**	0.007
	BMI	0.432****	0.000
Diastolic BP (mmol/L)	CRF	-0.055	0.531
	Muscle strength	0.211*	0.016
	Muscular endurance	-0.075	0.398
	Flexibility	0.012	0.894
	Body composition	0.336****	0.000
	BMI	0.441****	0.000

Sig. **P*<0.05; ***P*<0.01; ****P*<0.001; *****P*<0.0001
Correlation study was performed based on Pearson model using IBM SPSS (v27)

FBG had the strongest correlation with BMI (r=0.458) and a negative correlation with CRF, indicating higher blood glucose is linked to lower fitness levels. FBG also showed moderate positive correlations with body composition, WC, and systolic BP, indicating higher body composition and BP are associated with higher fasting glucose levels, a sign of MetS. Muscle strength had a high positive correlation with MetS criteria (P<0.05), while muscular endurance and flexibility did not show significant correlations.

Modeling HRF components on MetS risk

Linear regression analysis showed that HRF variables did not significantly predict MetS criteria, except for FBG. The model in Equation 1 explains 26.5% of the variance in FBG levels ($R^2 = 0.265$). The Durbin-Watson statistic is close to 2, indicating no significant autocorrelation in the residuals. The ANOVA indicates the model significantly predicts FBG levels (F (5, 124) = 8.938, *P*<0.001), confirming a good fit. In this model (Eq. 1), BMI has a positive coefficient (B=0.066), showing that higher BMI increases FBG, while CRF has a negative coefficient (B= -0.055), indicating higher CRF reduces FBG. CRF and BMI correlations are significant ($P<0.05$). Collinearity statistics suggest multicollinearity is not a concern.

Eq. 1:

FBG= 5 -0.055 *CRF* + 0.016 *MS* + 0.018 *ME* - 0.009 *Flexibility* + 0.066 *BMI* (R=0.515, p <0.0001)

For blood pressure, Equations 2 and 3 were calculated for systolic and diastolic BP, respectively. Although the models are statistically significant, the constants and coefficients were not. These models predicted BP with up to 33% precision ($R^2 = 0.33$). Weight significantly affects systolic BP ($P<0.05$).

Eq.2:

Systolic BP= 3.698 -0.035 CRF + 0.185 MS - 0.317 ME + 0.141 Flexibility + 0.25 Weight + 0.026 BMI -0.193 WC (R=0.515, *P*<0.0001)

For diastolic BP, only flexibility and weight significantly affect diastolic BP ($P<0.05$), despite unexpected negative correlations between BMI, WC, and diastolic BP.

Eq.3:

Diastolic BP= -128.035 +0.29 CRF + 0.138 MS -0.322 ME + 0.203 Flexibility + 0.203 Weight - 0.2 BMI -0.058 WC (R=0.579, *P*<0.0001)

Discussion

The multi-stage cluster sampling in South Al Batinah, Oman, found 10.7% prevalence of MetS in adolescents aged 13-16. A Similar study among 714 in-school children in Oman found 12.3% overweight, 16.3% obesity, and 21.4% central obesity (16). A study in Brazil on overweight and obese adolescents (10-19 yr) showed a 9.6% MetS prevalence (17), comparable to our findings. A systematic review reported MetS prevalence in adolescents ranged from 2.9% in East Asia to 6.7% in high-income English-speaking countries, while 9.8% in UAE (18), aligning with our study.

The correlation between HRF components and MetS criteria revealed a positive association between WC and systolic/diastolic BP, FBG, muscle strength, muscular endurance, and BMI. An inverse relationship was found between WC and flexibility, suggesting increased WC reduces flexibility. Similar studies in Germany indicated that greater BMI and WC were linked to higher postural SBP, though WC's impact lessened after adjusting for BMI. These results support the complex interplay between these variables (19).

Our study found that FBG negatively correlates with CRF, indicating that higher FBG levels are linked to decreased CRF. Similar findings in adults show low CRF is associated with early abnormal glucose metabolism and insulin resistance, critical factors in the development of MetS due to skeletal muscle's role in glucose use (20). This may be related to reduce mitochondrial oxidative capacity, leading to intramuscular lipid accumulation and insulin resistance. As the largest insulin-responsive tissue, skeletal muscle is crucial for glucose use, and its insulin resistance is key to metabolic issues related to obesity and inactivity, contributing to MetS (21).

Both systolic and diastolic BP positively correlated with WC and BMI. Systolic BP also negatively correlates with CRF, suggesting higher BP is linked to lower fitness in this study. Endurance training leads to reductions in systemic vascular resistance, sympathetic nervous system activity, and plasma renin activity. Therefore, reduction of BP and insulin resistance, as well as, the improvement of liver and kidney functions might be associated in the improvement of CRF (22). In Brazil, CRF moderates the relationship between body fat percentage and BP in children and adolescents (23). Our study indicates CRF and ME reduce systolic BP, thus lowering MetS risk, though this effect was not seen for diastolic BP. Unexpectedly, WC negatively affected both systolic and diastolic BP, differing from studies in Iraqi adults (24), and other populations where WC positively correlated with BP (25-27).

Different correlations in our study may result from selecting adolescents with obesity, high WC, and BMI. While WC and BP show a clear positive association in adults, this relationship is less consistent in children, especially in younger and lower socioeconomic groups. More research is needed to clarify WC's utility as a screening tool for elevated BP in pediatric populations. The relevant study highlighted that microvascular dysfunction associated with obesity is multifactorial and complex, involving several interacting mechanisms (28). In that a key contributing factor was the imbalance between the vasodilatory action of nitric oxide and the vasoconstrictive effect of endothelin-1.

In fact, the causes of microvascular dysfunction related to obesity are intricate and involve various factors. One factor contributing to this condition is the disruption between the vasodilatory effects of nitric oxide and the vasoconstrictive influence of endothelin-1. Moreover, adipokines produced by visceral fat are linked to the disruption of insulin-mediated vasodilation and the elevation of blood pressure (25). Additionally, both proinflammatory and anti-inflammatory adipokines have been acknowledged for their roles in the onset of microvascular dysfunction. These processes together likely play a significant role in the emergence of microvascular dysfunction associated with obesity. Understanding these diverse pathways is essential for creating targeted strategies to reduce microvascular issues linked to obesity (28). However, BP is primarily influenced by cardiovascular factors like heart rate, blood volume, and arterial resistance, which do not significantly affect muscle strength. Muscle strength and endurance are influenced by muscle fiber composition, neural activation, and metabolic pathways (26). Brazilian studies show that children and adolescents with low CRF and abdominal resistance have a higher prevalence of metabolic risk (29), supporting our findings.

Although a study finding revealed a significant positive correlation between reduced flexibility and metabolic syndrome in a community-based geriatric population, in which the association remained consistent even after adjusting for potential confounding factors such as age, gender, body composition, and functionality measurements (30), no association was found between flexibility and metabolic risk in current study on adolescents. On the other hand, the relationship between BMI and flexibility, has been the subject of several studies. Interestingly, non-significant results were consistently found across multiple studies, aligning with previous research indicating no significant difference in hamstring and lower back flexibility between obese and non-obese adults. Possible explanations for this incongruity may include gender and maturational state differences. Notably, regardless of gender, the relationship between in-person BMI and flexibility scores tended to be inverse. Consequently, it appears that a person's body mass does not have a significant impact on their flexibility (31).

The study underscores the importance of evaluating physical fitness, especially CRF and abdominal resistance in managing and preventing MetS. Overall, these findings highlight the importance of addressing components of HRF in managing and preventing MetS, emphasizing the need for comprehensive fitness programs that target muscle strength, endurance, flexibility, and cardiorespiratory fitness.

Rather than valuable findings of the current study powered in the randomized controlled cross-sectional study on teenage students, it is imperative to admit several limitations. The utilization of a cross-sectional design restricts the ability to establish causal relationships due to the absence of longitudinal data. Furthermore, the absence of chronic disease data in the survey may have influenced the assessment of physical fitness. Additionally, the findings are constrained to Omani's adolescents between 13-16 yr old, thereby limiting their generalizability to other age groups and demographic characteristics. Moreover, the study did not explore variances within age groups. To address these limitations, future research should consider using a longitudinal design and include participants from various age groups or specific populations to provide a more thorough understanding of the topic.

Conclusion

During 2023-2024, 10.7% of adolescent students with obesity in northern Oman, exhibited MetS. Significant correlations were identified between

MetS criteria and HRF components, particularly muscle strength and blood pressure, though no individual correlation exceeded 50%. While multi-regression analysis linked MetS with HRF components, low R^2 values (<0.7) and high *P*-values (>0.05) indicated limited precision. Overall, HRF components are closely associated with MetS, suggesting that enhancing HRF through targeted physical activity could reduce MetS prevalence.

Journalism Ethics considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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Conflicts of interest statement

The authors declare that they have no conflicts of interests.

Availability of supplementary data

All supplementary data, are present in journal website. Besides, they are accessible after send email to the corresponding author based on reasonable application.

References

1. Cissé K, Samadoulougou DRS, Bognini JD, et al (2021). Using the first nationwide survey on non-communicable disease risk factors and different definitions to evaluate the prevalence of metabolic syndrome in Burkina Faso. *PLoS One*, 16:e0255575.
2. Alberti KGMM, Eckel RH, Grundy SM, et al (2009). Harmonizing the Metabolic Syndrome. *Circulation,* 120:1640-1645.
3. Silveira Rossi JL, Barbalho SM, Reverete de Araujo R, et al (2022). Metabolic syndrome and cardiovascular diseases: Going beyond traditional risk factors. *Diabetes Metab Res Rev*, 38 (3): e3502.
4. Saeed W, Al-Habori M, Saif-Ali R, Al-Eryani E (2020). Metabolic Syndrome and Prediabetes Among Yemeni School-Aged Children. *Diabetes Metab Syndr Obes*, 13:2563-2572.
5. El-Aty MA, Mabry R, Morsi M, et al (2014). Metabolic Syndrome and Its Components: Secondary analysis of the World Health Survey, Oman. *Sultan Qaboos Univ Med J*, 14 (4): e460-467.
6. Yousif JH, Khan FR, Zia K, Saadi NA (2021). Analytical Data Review to Determine the Factors Impacting Risk of Diabetes in North Al-Batinah Region, Oman. *Int J Environ Res Public Health*, 18 (10): 5323.
7. Ampofo AG, Boateng EB (2020). Beyond 2020: Modelling obesity and diabetes prevalence. *Diabetes Res Clin Pract*, 167:108362.
8. Kaminsky LA, Arena R, Ellingsen Ø, et al (2019). Cardiorespiratory fitness and cardiovascular disease - The past, present, and future. *Prog Cardiovasc Dis,* 62 (2): 86-93.
9. Delextrat A, Hayes L, Al Ghannami SS, et al (2019). Physical fitness characteristics of Omani primary school children according to body mass index. *J Sports Med Phys Fitness*, 59 (3):440-448
10. Appelqvist-Schmidlechner K, Vaara JP, Vasankari T, et al (2020). Muscular and cardiorespiratory fitness are associated with health-related quality of life among young adult men. *BMC Public Health*, 20 (1):842.
11. Wei R, Ogden CL, Parsons VL, et al (2020). A method for calculating BMI z-scores and percentiles above the 95th percentile of the CDC growth charts. *Ann Hum Biol,* 47 (6): 514-521.
12. Siwarom S, Aekplakorn W, Pirojsakul K, et al (2021). Metabolic syndrome in Thai adolescents and associated factors: the Thai

National Health Examination Survey V (NHES V). *BMC Public Health*, 21 (1):678.
13. Kidokoro T, Edamoto K (2021). Improvements in Physical Fitness are Associated with Favorable Changes in Blood Lipid Concentrations in Children. *J Sports Sci Med*, 20 (3): 404-412.
14. Kolimechkov S, Petrov L, Alexandrova A, et al (2018). BeepShuttle Junior: Software for the Administration of the 20m Shuttle Run Test in Children and Adolescents. *J adv sport technol,* 2 (2):35-40.
15. Bitew ZW, Alemu A, Ayele EG, et al (2020). Metabolic syndrome among children and adolescents in low and middle income countries: a systematic review and meta-analysis. *Diabetol Metab Syndr*, 12:93.
16. Al-Saadi A, Al Yahiaee L, Ahmed E, et al (2023). Obesity and lifestyle behaviours among in-school children in Oman. *East Mediterr Health J*, 29 (9): 716-724.
17. Dejavitte RAS, Enes CC, Nucci LB (2020). Prevalence of metabolic syndrome and its associated factors in overweight and obese adolescents. *J Pediatr Endocrinol Metab*, 33 (2): 233-239.
18. Noubiap JJ, Nansseu JR, Lontchi-Yimagou E, et al (2022). Global, regional, and country estimates of metabolic syndrome burden in children and adolescents in 2020: a systematic review and modelling analysis. *Lancet Child Adolesc Health*, 6(3):158-170.
19. Moreno Velásquez I, Jaeschke L, Steinbrecher A, et al (2022). Association of general and abdominal adiposity with postural changes in systolic blood pressure: results from the NAKO pretest and MetScan studies. *Hypertens Res*, 45 (12): 1964-1976.
20. Wang R, Liu X, Liu L, et al (2025). Cardiorespiratory fitness in the population with different glucose metabolic statuses: low cardiorespiratory fitness increases the risk of early abnormal glucose metabolism. *Minerva Endocrinol* (*Torino*), 50(1):61-71.
21. Wilkinson TJ, Yates T, Baker LA, et al (2022). Sarcopenic obesity and the risk of hospitalization or death from coronavirus disease 2019: findings from UK Biobank. *JCSM Rapid Commun,* 5:3-9.
22. Diaz EC, Weber JL, Adams SH, et al (2021). Cardiorespiratory Fitness Associates with Blood Pressure and Metabolic Health of Children-The Arkansas Active Kids Study. *Med Sci Sports Exerc*, 53 (11): 2225-2232.
23. Brand C, Sehn AP, Fochesatto CF, et al (2022). Body fat percentage, cardiorespiratory fitness and arterial blood pressure in children and adolescents: a longitudinal analysis. *BMC Cardiovasc Disord*, 22 (1): 267.
24. Tawfeek H (2002). Relationship between waist circumference and blood pressure among the population in Baghdad, Iraq. *Food Nutr Bull,* 23 (4): 402-406.
25. Farideh S, Kajbafi M, Saki A, et al (2015). The Relationship between Waist Circumference and Serum Adiponectin Levels, Dietary Intake and Blood Pressure in Normal Weight, Overweight, and Obese Women. *J Obes Metab Res*, 2 (2): 97.
26. Pazin DC, da Luz Kaestner TL, Olandoski M, et al (2020). Association Between Abdominal Waist Circumference and Blood Pressure In Brazilian Adolescents With Normal Body Mass Index: Waist circumference and blood pressure in Adolescents. *Glob Heart*, 15 (1):27.
27. Tebar WR, Ritti-Dias RM, Farah BQ, et al (2018). High blood pressure and its relationship to adiposity in a school-aged population: body mass index vs waist circumference. *Hypertens Res,* 41 (2):135-140.
28. Díez-Fernández A, Sánchez-López M, Nieto JA, et al (2017). Relationship between cardiorespiratory fitness and blood pressure in young adults: a mediation analysis of body composition. *Hypertens Res,* 40 (5): 511-515.
29. Kränkel N, Bahls M, Van Craenenbroeck EM, et al (2019). Exercise training to reduce cardiovascular risk in patients with metabolic syndrome and type 2 diabetes mellitus: How does it work*? Eur J Prev Cardiol,* 26 (7): 701-708.
30. Chang K-V, Hung C-Y, Li C-M, et al (2015). Reduced Flexibility Associated with Metabolic Syndrome in Community-Dwelling Elders. *PLoS One*, 10 (1): e0117167.
31. Shalabi K, AlSharif Z, Alrowaishd S, et al (2023). Relationship between body mass index and health-related physical fitness: a cross-sectional study. *Eur Rev Med Pharmacol Sci*, 27 (20): 9540-9549.