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Association of Age Body Shape Index (ABSI) and Body Roundness Index (BRI) with Triglyceride-Glucose-Waist Circumference (TyG-WC) Index as a Cardiometabolic Risk Predictor Among Normal and Overweight Police Officers with normal LDL Level in East Java, Indonesia

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ABSTRACT

Cardiometabolic disorders, including insulin resistance (IR) and visceral adiposity, are common in individuals with normal-low low-density lipoprotein (LDL) levels and non-obese body mass index (BMI). Police officers face higher risks due to occupational stress factors, but conventional screening often overlooks their metabolic risks. The Body Shape Index (ABSI) and Body Roundness Index (BRI) are innovative anthropometric measurements that could potentially offer more accurate predictions for insulin resistance (IR) when examining the combination of triglyceride-glucose index along with waist circumference (TyG-WC). To determine the association of ABSI and BRI with TyG-WC as a surrogate of cardiometabolic risk among Indonesian police officers with normal LDL and BMI. This cross-sectional study enrolled 524 active-duty officers. ABSI and BRI were derived from anthropometric measurements; TyG-WC was calculated from fasting triglycerides, glucose, and waist circumference. Spearman's correlation analysis was conducted, with a level of statistical significance established at $p < 0.05$. Noteworthy associations were found between ABSI and TyG-WC ($r = 0.622$, $p < 0.001$) as well as between BRI and TyG-WC ($r = 0.805$, $p < 0.001$). These findings suggest that higher central adiposity and body roundness are associated with elevated surrogate markers of insulin resistance, even in individuals without obesity or dyslipidemia. ABSI and BRI, particularly BRI, robustly associate with TyG-WC in normolipidemic police officers, suggesting their utility for early cardiometabolic risk stratification in high-stress occupations. Routine screening with these indices could enable targeted interventions before overt metabolic disease develops.

KEYWORDS: A Body Shape Index, Body Roundness Index, TyG-WC, Insulin Resistance, Central Obesity, Police Officers

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INTRODUCTION

Cardiometabolic diseases (CMDs), including cardiovascular disease (CVD), type 2 diabetes mellitus (T2DM), and metabolic syndrome (MetS), remain a major health issue affecting populations worldwide [1]. In Indonesia, these ailments are becoming ever more common, fueled by modern living such as bodies in repose, unwholesome eating patterns, and the relentless pressures of daily existence. Among occupational groups, police officers are particularly vulnerable due to their demanding work schedules, irregular hours, and high-stress environments. Despite being normolipidemic, many police officers exhibit elevated cardiometabolic risk, necessitating the identification of effective predictive markers [2].

Waist circumference (WC) and body mass index (BMI) serve as standard anthropometric parameters that have long been used to determine obesity levels and the associated risk of adverse health outcomes [3]. New indices like the Body Roundness Index (BRI) and A Body Shape Index (ABSI) have been created to overcome these restrictions [2]. ABSI is designed to assess central obesity while minimizing the influence of overall body size, and BRI offers a more accurate representation of body fat distribution, particularly visceral fat. These measures seem to be good at predicting heart and metabolic health problems, even when you don't consider someone's Body Mass Index (BMI) or Waist circumference (WC).

One of these, the Triglyceride-Glucose (TyG) index, which is figured out using simple blood tests for triglycerides and glucose after fasting, looks like a strong way to estimate how well your body responds to insulin. Poor insulin response is a key issue in many

metabolic problems that can lead to heart and metabolic diseases [4,5]. Recent studies have highlighted the synergistic effects of combining the TyG index with anthropometric measures to enhance predictive accuracy for CMDs [6]. For instance, the TyG-ABSI and TyG-BRI indices have demonstrated superior predictive capabilities for stroke and cardiovascular mortality compared to traditional measures [5].

In East Java, Indonesia, where police officers face unique occupational challenges, the application of these novel indices could provide valuable insights into their cardiometabolic health [7]. Considering the frequent occurrence of stress and inconsistent daily routines within this population, evaluating the collective predictive capabilities of ABSI, BRI, and TyG-WC may present a more thorough method for categorizing risk. This method has the potential to make it easier to identify individuals at risk early, leading to targeted interventions and preventive actions to reduce the development of CMDs.

Metabolic disorders, such as insulin resistance and atherosclerosis, remain a significant health issue for individuals with normal or overweight body mass index (BMI), particularly those in high-pressure careers like law enforcement. Traditional risk markers such as elevated LDL cholesterol often fail to accurately predict cardiovascular and metabolic risks in individuals with normal LDL cholesterol levels. The importance of accurate anthropometric measurements is emphasized, especially with the A Body Shape Index (ABSI) which considers waist circumference, BMI, and height to evaluate visceral fat and related health dangers more effectively. Recent research indicates that ABSI could be a more reliable indicator of atherosclerosis and insulin resistance than traditional obesity measures, especially among those with normal LDL levels.

Police officers, due to their sedentary work environment and irregular shift patterns, are at increased risk of metabolic dysfunction, even without overt obesity or *dyslipidemia*. This study investigates the role of ABSI as an early predictor of atherosclerosis and insulin resistance in normal and overweight police officers with normal LDL levels. By examining the correlation between ABSI, Atherogenic Index of Plasma (AIP) and Triglyceride-glucose index (TyG), this study aims to provide evidence for ABSI as a practical screening tool in occupational health settings.

RESEARCH METHOD

Study Design and Participants

This cross-sectional observational study aimed to evaluate the predictive role of A Body Shape Index (ABSI) for atherosclerosis and insulin resistance in police officers with normal LDL levels. The study was conducted among active-duty police officers at the East Java Regional Police Headquarters in 2024. From 3308 eligible officers, 524 participants were included based on inclusion criteria and data availability. The study's inclusion criteria were active-duty status, willingness to participate, LDL level <100mg/dl, and BMI<30.

The research protocol received endorsement from the Faculty of Medicine's Ethical Review Board at Universitas Airlangga, Surabaya, Indonesia (Approval No: 17/EC/KEPK/FKUA/202), confirming its compliance with the ethical principles outlined in the Declaration of Helsinki. Prior to enrollment, all subjects provided informed consent in written form after a comprehensive presentation of the study design. Participants were unequivocally advised of their right to discontinue involvement at any time without penalty.

ABSI calculated as:[8]

$$ABSI = \frac{WC(m)}{BMI^{2/3} \times height^{1/2}(m)}$$

Atherogenic Index of Plasma (AIP) calculated as :[9]

$$AIP = \log\left(\frac{TG(mg/dL}{HDL(mg/dL}\right)$$

Triglyceride-glucose index (TyG) calculated as: [10]

$$TyG = ln\left[\frac{TG(mg/dL) \times fasting\ glucose\ (mg/dL)}{2}\right]$$

RESULTS AND DISCUSSION

Baseline Characteristic of Study

Table 1 displayed the initial traits of the research. A total of 524 individuals took part, with the majority being males at 90.1% and females only making up 9.9%. The average age was 51 years, with a range of ages from 33 to 70 years. The median body mass index (BMI) was 26.76 kg/m² (IQR: 10.40–56.12), and the median waist circumference (WC) was 90 cm (IQR: 58–133). The A Body Shape Index (ABSI) and Body Roundness Index (BRI) showed medians of 0.076 (IQR: 0.046–0.146) and 3.92 (IQR: 1.00–12.97), respectively.

Table 1: Baseline Characteristic of Data

Variable		n (%)	median (IQR)
Gender	Male	472 (90.1%)	-
	Female	52 (9.9%)	-
Age (year)		-	51 (33 - 70)
BMI (kg/m²)		-	26.76 (10.40 - 56.12)
WC (cm)		-	90 (58 - 133)
ABSI		-	0.076 (0.046 - 0.146)
BRI		-	3.92 (1.00 - 12.97)
TG		-	143 (50 - 900)
LDL		-	90 (10 - 99)
Cholesterol		-	210 (114 - 409)
HDL		-	48 (18 - 83)
Glucose		-	93 (71 - 460)
IAP		-	0.49 ((-0.03) - 1.24)
TyG		-	8.83 (7.65 - 11.18)

In terms of lab findings, the middle triglyceride (TG) level was 143 mg/dL with a range of 50-900, and the middle low-density lipoprotein (LDL) cholesterol was 90 mg/dL with a range of 10-99. The median total cholesterol was 210 mg/dL (IQR: 114–409), and high-density lipoprotein (HDL) cholesterol was 48 mg/dL (IQR: 18–83). The median fasting glucose level among participants was 93 mg/dL (IQR: 71–460). For additional metabolic risk indicators, the median index of abdominal obesity (IAP) was 0.49 (IQR: -0.03–1.24), and the triglyceride-glucose (TyG) index had a median value of 8.83 (IQR: 7.65–11.18). These findings provide an overview of the demographic distribution and metabolic risk profile of the study population, serving as the foundation for further analysis of associations and clinical outcomes.

Correlation between Parameters with IAP and TyG

The association analysis between metabolic indices and various clinical parameters revealed several statistically significant findings. Analysis revealed that the index of abdominal obesity (IAP) correlated significantly with body mass index (BMI) ($p < 0.001$), A Body Shape Index (ABSI) ($p = 0.002$), triglyceride (TG) concentration ($p < 0.001$), and high-density lipoprotein (HDL) cholesterol ($p < 0.001$). However, no statistically significant associations were detected between IAP and age ($p = 0.119$), waist circumference (WC) ($p = 0.414$), body roundness index (BRI) ($p = 0.145$), low-density lipoprotein (LDL) cholesterol ($p = 0.063$), or total cholesterol ($p = 0.817$).

In the same way, the TyG index showed strong connections with BMI, ABSI, TG, and LDL cholesterol (all $p < 0.001$). However, there were no notable links found between TyG and age ($p = 0.327$), WC ($p = 0.650$), BRI ($p = 0.217$), total cholesterol ($p = 0.322$), or HDL cholesterol ($p = 0.082$). These results demonstrate that both IAP and TyG are most strongly associated with BMI and TG, highlighting their utility as markers for metabolic risk, while other parameters such as age, WC, BRI, and total cholesterol did not show statistically significant relationships with these indices in this study.

Table 2: Statistical Correlation of Clinical Variables with IAP and TyG

Parameters	IAP (p-value)	TyG (p-value)
Age	0.119	0.327
BMI	<0.001	<0.001
WC	0.414	0.650
ABSI	0.002	<0.001
BRI	0.145	0.217
TG	<0.001	<0.001
LDL	0.063	<0.001
Cholesterol	0.817	0.322
HDL	<0.001	0.082

Correlation between ABSI and BRI with TyG-WC

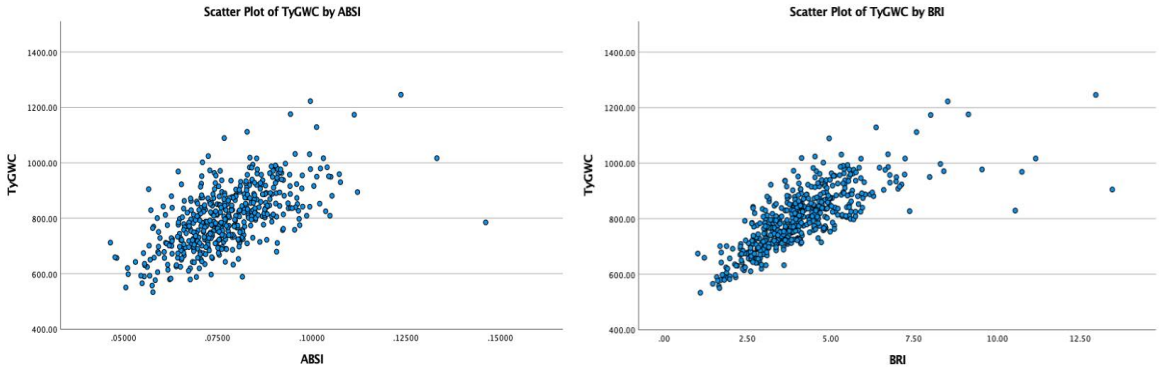

Figure 1: Scatter Plot Diagram

Scatter plots showing the relationships of A Body Shape Index (ABSI) (left) and Body Roundness Index (BRI) (right) with Triglyceride-Glucose Waist Circumference (TyG-WC) among 524 police officers in East Java with normal or overweight BMI and normal LDL levels. Spearman's correlation analysis revealed that both ABSI ($r = 0.622$, $p < 0.001$) and BRI ($r = 0.805$, $p < 0.001$) were significantly and positively associated with TyG-WC, with BRI demonstrating a stronger correlation.

Discussion

Cardiometabolic Risk in Normolipidemic Police Officers

The worldwide occurrence of cardiometabolic conditions (CMCs), an assemblage encompassing impaired insulin sensitivity (IS), type 2 diabetes (T2D), metabolic syndrome (MetS), and cardiovascular diseases (CVD), has exhibited a pronounced increase in frequency over recent periods [7]. The situation of law enforcement in East Java, Indonesia, highlights the important influence of work-related stress on the onset of such ailments, even in people with regular LDL levels and a normal to slightly overweight BMI. Police officers are particularly vulnerable because of their unpredictable work hours, lack of physical activity, and exposure to high levels of mental strain, all of which contribute to an increased risk of heart and metabolic problems [4,11]. This research offers new perspectives on identifying risk early on by highlighting the effectiveness of using newer anthropometric measurements like the Body Roundness Index (BRI) and the Body Shape Index (ABSI) to forecast cardiometabolic risk in individuals at high risk for such conditions.

Relationship Between ABSI, BRI, and TyG-WC

Strong positive connections between ABSI, BRI, and the Triglyceride-Glucose Waist Circumference (TyG-WC) index a valid indicator of insulin resistance were found in the study's findings. Specifically, ABSI and TyG-WC had a correlation of 0.622 ($p < 0.001$), while BRI exhibited a stronger correlation with TyG-WC at 0.805 ($p < 0.001$).The evaluation of adiposity phenotypes, particularly the abdominal obesity indicators such as the A Body Shape Index (ABSI) and Body Roundness Index (BRI), has gained traction in predicting cardiometabolic risks among populations, including police officers, who are often subjected to high-stress environments. Recent literature highlights the efficacy of these indices in assessing abdominal fat distribution and its correlation with various cardiometabolic disorders [12,13].

ABSI, as a substitute measure for central obesity, proves to be more beneficial than the usual metrics such as BMI and WC. Studies suggest that ABSI, in combination with BRI, exhibits a more profound correlation with indications of cardiometabolic risks compared to BMI, effectively pinpointing those at higher risk for health issues linked to excessive visceral fat, like type 2 diabetes and premature death due to obesity [14,15]. The findings have important consequences, particularly for certain groups of workers such as police officers, who have a higher occurrence of metabolic syndrome because of their lifestyle habits and job-related stress. The Triglyceride-Glucose-Waist Circumference index (TyG-WC), a composite measure that combines indicators of triglyceride levels and abdominal adiposity, has also been recognized for its predictive capabilities regarding cardiometabolic outcomes. This composite index illustrates superior prediction for conditions like non-alcoholic fatty liver disease (NAFLD) and cardiovascular diseases compared to traditional metrics such as TyG-BMI and just WC [6,16]. The TyG-WC index not only integrates these crucial metabolic parameters but also reflects the multifaceted nature of cardiometabolic risks, further underscoring its relevance among police officers who may exhibit distinctive abdominal obesity patterns resulting from stress and sedentary work [17,18].

Limitations of Traditional Measures

Waist circumference (WC) and body mass index (BMI) are two traditional anthropometric measurements that have long been used to evaluate obesity and associated health hazards [19,20]. However, these measures have limitations, especially in assessing visceral

fat distribution and its relationship to cardiometabolic diseases. BMI, for instance, fails to differentiate between fat and lean mass, making it an imperfect measure of fat distribution. Waist circumference provides a better indicator of abdominal obesity, but it still does not capture all aspects of visceral fat distribution.

In contrast, the ABSI and BRI indices are designed to address these limitations. For instance, ABSI takes into account the ratio of waist circumference to height and BMI, providing a more specific measurement of central fat accumulation. In the same way, BRI is designed to assess body shape and provide a more precise depiction of fat distribution, particularly visceral fat. These indices offer a more comprehensive understanding of body composition and its association with insulin resistance and other cardiometabolic risks, which is especially important in populations such as police officers who may not exhibit traditional signs of obesity but are still at risk for metabolic dysfunction.

Comparison with Existing Literature

The usefulness of the TyG index as a trustworthy indicator of insulin resistance and cardiovascular risk has been demonstrated by earlier research [21,22]. In particular, the combination of the TyG index with novel anthropometric indices like ABSI and BRI has shown promise in enhancing the predictive accuracy for cardiometabolic diseases. He *et al.* found that the TyG-ABSI and TyG-BRI indices were superior to traditional measures in predicting stroke and cardiovascular mortality. Similarly, Yue *et al.* showed that TyG-related indices and stroke risks were strongly correlated, which lends credence to the notion that these indices can provide a more accurate risk assessment than conventional anthropometric measurements [23].

In the context of police officers, these findings are particularly relevant, as studies have shown that individuals in high-stress occupations are at elevated risk for metabolic disorders, even without the traditional risk factors of obesity or *dyslipidemia* [2]. The current study offers fresh evidence supporting the use of ABSI and BRI alongside the TyG-WC index for predicting cardiometabolic risk among this particular population.

Implications for Occupational Health

Furthermore, studies have substantiated that combining ABSI and BRI with TyG-WC enhances the predictive accuracy for metabolic abnormalities. This is particularly critical in policing professionals who may display altered fat distribution associated with higher cardiovascular burden due to their occupational stressors and lifestyle habits [24,25]. The association of BRI with metabolic syndrome has been consistently documented across different populations, establishing its reliability as a screening tool to identify those at risk within specific demographic groups [15,26].

The study's conclusions have significant ramifications for East Javan police officers' health and wellbeing as well as those of other high-stress professions. Despite being normolipidemic and without overt obesity, police officers are still at significant risk for developing cardiometabolic disorders, primarily due to their high-stress environment, sedentary nature of their work, and irregular working hours. Therefore, traditional screening methods that focus solely on LDL cholesterol levels or BMI may miss individuals who are at risk for conditions like insulin resistance and metabolic syndrome.

ABSI and BRI, as demonstrated in this study, can serve as valuable tools for early detection and risk stratification. By incorporating these novel indices into routine screening practices, health professionals could identify individuals at risk for cardiometabolic diseases before overt symptoms appear. The need for targeted screening in police officers is underscored by their unique stress profiles and lifestyle, which put them at an elevated risk for cardiometabolic diseases. Research that links ABSI and TyG-WC indicates that these measures not only reveal current health concerns but also play a role in enhancing our grasp of the future health trends within this group [27,28].

CONCLUSION

In conclusion, both ABSI and BRI, in conjunction with TyG-WC, present significant promise as effective predictors of cardiometabolic risks, particularly in high-stress occupational groups such as police officers. Their application could lead to an improved understanding and management of metabolic syndrome and related health conditions in this unique population.

Further investigation is necessary to confirm these results in bigger and more varied groups, and also to consider the possibility of merging ABSI, BRI, and TyG-WC with other indicators of metabolic issues. Additionally, long-term research projects could offer a deeper understanding of how these measures impact the progression of heart conditions and other lasting ailments.

REFERENCES

[1] Abdalhamid, M. A., Abdelmageed, A. A., Grisanti, L. A., Sun, D.-K., Zhang, N., Liu, Y., Qiu, J.-C., Tse, G., Li, G.-P., Roever, L., Liu, T., Gallego, M., Zayas-Arrabal, J., Alquiza, A., Apellaniz, B., Casis, O., Ward, C. T., Fiza, B., Prabhakar, A., Budhrani, G., Moll, V., Mezal, R. J., Hauda El Rasyid, Nasution, S. A., Alwi, I., Subekti, I., Yamin, M., Suhendro, Harimurti, K., Immanuel, S., Majid, A., Elizabeth, E., Azali, C. N., Berk, J., Wade, R., Baser, H. D., Lado, J., Tse, G., Lai, E. T. H., Tse, V., Yeo, J. M., Regufe, V. M. G., Pinto, C. M. C. B., Perez, P. M. V. H. C., Agarwal, G., Singh, S., Misra, S., Chaturvedi, A., & Misra, N. C. (2020). Arrhythmia Mechanism on Diabetes Mellitus: A Narrative Review. *Indian Journal of Endocrinology and Metabolism*, *6*(5), 1764–1772. https://doi.org/10.37275/bsm.v6i5.511

[2] Maessen, M. F. H., Eijsvogels, T. M. H., Verheggen, R. J. H. M., Hopman, M. T. E., Verbeek, A. L. M., & Vegt, F. de. (2014). Entering a New Era of Body Indices: The Feasibility of a Body Shape Index and Body Roundness Index to Identify Cardiovascular Health Status. *PLOS ONE*, *9*(9), e107212.

[3] Hidayah, L., Darmawan, E., & Yuliani, S. (2022). The Increased Risk of Random Blood Glucose, Body Mass Index, and Abdominal Circumference in Schizophrenic Patients Using Clozapine and Quetiapine. *Pharmacology, Medical Reports, Orthopedic, and Illness Details (Comorbid)*, *1*(1), 83–92. https://doi.org/10.55047/comorbid.v1i1.67

[4] Rattanatham, R., Tangpong, J., Chatatikun, M., Sun, D., Kawakami, F., Imai, M., & Klangbud, W. K. (2023). Assessment of eight insulin resistance surrogate indexes for predicting metabolic syndrome and hypertension in Thai law enforcement officers. *PeerJ*, *11*, 1–19. https://doi.org/10.7717/peerj.15463

[5] Chen, C., Zhu, W., Sun, T., Zhao, H., Liu, H., Zhang, C., Hao, M., Liang, Q., Tian, G., Jing, D., & Li, K. (2025). Triglyceride-glucose index and remnant cholesterol in acute ischemic stroke — a cross-sectional study. *Endokrynologia Polska*, *76*(2), 212–219. https://doi.org/10.5603/ep.104158

[6] Ahn, S. H., Lee, H. S., & Lee, J. (2024). Triglyceride-Glucose-Waist Circumference Index Predicts the Incidence of Cardiovascular Disease in Korean Populations: Competing Risk Analysis of an 18-Year Prospective Study. *European Journal of Medical Research*, *29*(1). https://doi.org/10.1186/s40001-024-01820-9

[7] Febyan, ., Wetarini, K., Rendy, ., Thintarso, C. S., & Suastika, K. (2020). A Clinical Profile of Metabolic Syndrome and Its Determinants among Police Officers in Bali. *European Journal of Medical and Health Sciences*, *2*(6), 2–6. https://doi.org/10.24018/ejmed.2020.2.6.619

[8] Fahami, M., Hojati, A., & Farhangi, M. A. (2024). Body shape index (ABSI), body roundness index (BRI) and risk factors of metabolic syndrome among overweight and obese adults: a cross-sectional study. *BMC Endocrine Disorders*, *24*(1), 230. https://doi.org/10.1186/s12902-024-01763-6

[9] Sujatha, R., & Kavitha, S. (2017). Atherogenic indices in stroke patients: A retrospective study. *Iranian Journal of Neurology*, *16*(2), 78–82.

[10] Zhang, H., Tu, Z., Liu, S., Wang, J., Shi, J., Li, X., Shi, R., Chen, M., Yue, T., Luo, S., Ding, Y., & Zheng, X. (2025). Association of different insulin resistance surrogates with all-cause and cardiovascular mortality among the population with cardiometabolic multimorbidity. *Cardiovascular Diabetology*, *24*(1). https://doi.org/10.1186/s12933-025-02576-0

[11] Lima-Dos-Santos, A. L., Domingos-Gomes, J. R., Dantas Andrade, O. S., Cirilo-Sousa, M. do S., Domingos da Silva Freitas, E., Gomes Silva, J. C., Galdino Izidorio, P. J., & Aniceto, R. R. (2018). Health-related physical fitness of military police officers in Paraiba, Brazil. *Revista Brasileira de Medicina Do Trabalho : Publicacao Oficial Da Associacao Nacional de Medicina Do Trabalho-ANAMT*, *16*(4), 429–435. https://doi.org/10.5327/Z1679443520180304

[12] Ding, L., Fan, Y., He, J., Wang, R., He, Q., Cui, J., Ma, Z., Zheng, F., Gao, H., Dai, C., Wei, H., Li, J., Cao, Y., Hu, G., & Liu, M. (2021). Different Indicators of Adiposity and Fat Distribution and Cardiometabolic Risk Factors in Patients with Type 2 Diabetes. *Obesity*, *29*(5), 837–845. https://doi.org/https://doi.org/10.1002/oby.23151

[13] Elffers, T. (Dorine. W., De Mutsert, R., Lamb, H. J., De Roos, A., Willems Van Dijk, J. A. P. (Ko., Rosendaal, F. R., Jukema, J. W. (Wouter., & Trompet, S. (2017). Body fat distribution, in particular visceral fat, is associated with cardiometabolic risk factors in women with obesity. *Atherosclerosis*, *263*, e175. https://doi.org/10.1016/j.atherosclerosis.2017.06.559

[14] Krakauer, N. Y., & Krakauer, J. C. (2012). A New Body Shape Index Predicts Mortality Hazard Independently of Body Mass Index. *Plos One*, *7*(7), e39504. https://doi.org/10.1371/journal.pone.0039504

[15] Xu, J., Zhang, L., Wu, Q., Zhou, Y., Jin, Z., Li, Z., & Zhu, Y. (2021). Body Roundness Index Is a Superior Indicator to Associate With the Cardio-metabolic Risk: Evidence From a Cross-sectional Study With 17,000 Eastern-China Adults. *BMC Cardiovascular Disorders*, *21*(1). https://doi.org/10.1186/s12872-021-01905-x

[16] Song, S., Son, D., Baik, S. J., Cho, W.-J., & Lee, Y. (2022). Triglyceride Glucose-Waist Circumference (TyG-WC) Is a Reliable Marker to Predict Non-Alcoholic Fatty Liver Disease. *Biomedicines*, *10*(9), 2251. https://doi.org/10.3390/biomedicines10092251

[17] Li, S., An, L., Fu, Z., Zhang, W., & Liu, H. (2024). Association Between Triglyceride-Glucose Related Indices and All-Cause and Cause-Specific Mortality in the General Population: A Cohort Study. *Cardiovascular Diabetology*, *23*(1). https://doi.org/10.1186/s12933-024-02390-0

[18] Zheng, S., Shi, S., Ren, X., Tingting, H., Li, Y., Chen, Y., Liu, W., Hou, P. C., & Hu, Y. (2016). Triglyceride Glucose-Waist Circumference, a Novel and Effective Predictor of Diabetes in First-Degree Relatives of Type 2 Diabetes Patients: Cross-Sectional and Prospective Cohort Study. *Journal of Translational Medicine*, *14*(1). https://doi.org/10.1186/s12967-016-1020-8

[19] Ross, R., Neeland, I. J., Yamashita, S., Shai, I., Seidell, J., Magni, P., Santos, R. D., Arsenault, B., Cuevas, A., Hu, F. B., Griffin, B. A., Zambon, A., Barter, P., Fruchart, J. C., Eckel, R. H., Matsuzawa, Y., & Després, J. P. (2020). Waist circumference as a vital sign in clinical practice: a Consensus Statement from the IAS and ICCR Working Group on Visceral Obesity. *Nature Reviews Endocrinology*, *16*(3), 177–189. https://doi.org/10.1038/s41574-019-0310-7

[20] Xi, B., Zong, X., Kelishadi, R., Litwin, M., Hong, Y. M., Poh, B. K., Steffen, L. M., Galcheva, S. V, Herter-Aeberli, I., Nawarycz, T., Krzywińska-Wiewiorowska, M., Khadilkar, A., Schmidt, M. D., Neuhauser, H., Schienkiewitz, A., Kułaga, Z., Kim, H. S., Stawińska-Witoszyńska, B., Motlagh, M. E., Ruzita, A. T., Iotova, V. M., Grajda, A., Ismail, M. N., Krzyżaniak, A., Heshmat, R., Stratev, V., Różdżyńska-Świątkowska, A., Ardalan, G., Qorbani, M., Świąder-Leśniak, A., Ostrowska-Nawarycz, L., Yotov,

Y., Ekbote, V., Khadilkar, V., Venn, A. J., Dwyer, T., Zhao, M., Magnussen, C. G., & Bovet, P. (2020). International Waist Circumference Percentile Cutoffs for Central Obesity in Children and Adolescents Aged 6 to 18 Years. *The Journal of Clinical Endocrinology & Metabolism*, *105*(4), e1569–e1583. https://doi.org/10.1210/clinem/dgz195

[21] Priego-Parra, B. A., Román-Calleja, B. M., Gallego-Duran, R., Gracia-Sancho, J., Velarde Ruiz-Velasco, J. A., & Remes-Troche, J. M. (2025). Triglyceride-glucose-waist circumference index: A powerful tool for metabolic dysfunction-associated steatotic liver disease. *World Journal of Hepatology*, *17*(7), 107668. https://doi.org/10.4254/wjh.v17.i7.107668

[22] Dou, J., Guo, F., Guo, C., Wu, R.-Y., Hu, Y.-W., Sun, X.-L., & Wei, J. (2025). Triglyceride glucose-waist height ratio index is a promising and robust glucose and lipid metabolism indicator for predicting long-term type 2 diabetes: insights from a Japanese prospective cohort data from 12 years. *Diabetes Research and Clinical Practice*, *227*, 112398. https://doi.org/https://doi.org/10.1016/j.diabres.2025.112398

[23] Qiao, Y., Wang, Y., Chen, C., Huang, Y., & Zhao, C. (2025). Association between triglyceride-glucose (TyG) related indices and cardiovascular diseases and mortality among individuals with metabolic dysfunction-associated steatotic liver disease: a cohort study of UK Biobank. *Cardiovascular Diabetology*, *24*(1), 12. https://doi.org/10.1186/s12933-024-02572-w

[24] Chen Q Liu W, Zhou X, H. Q. (2022). Advanced glycation end products via skin autofluorescence as a new biomarker for major adverse cardiovascular events: A meta-analysis of prospective studies. *Nutrition, Metabolism and Cardiovascular Diseases*, *32*(5), 1083–92.

[25] Ashwell, M., Gunn, P. J., & Gibson, S. (2011). Waist-to-height Ratio Is a Better Screening Tool Than Waist Circumference and BMI for Adult Cardiometabolic Risk Factors: Systematic Review and Meta-analysis. *Obesity Reviews*, *13*(3), 275–286. https://doi.org/10.1111/j.1467-789x.2011.00952.x

[26] Jiang, C., Lin, N., Liu, Y., Hou, B., & Xie, A. (2024). *Association of Adiposity-and Lipid-Related Indices With Metabolic Syndrome Among Older Adults in the Coastal City of China: A Population-Based Study*. https://doi.org/10.21203/rs.3.rs-4381017/v1

[27] Yang, S. (2025). *Association of Triglyceride-Glucose Index (TyG) and a Body Shape Index (ABSI) With Cognitive Decline and Dementia Risk*. https://doi.org/10.21203/rs.3.rs-7414213/v1

[28] Du, T., Yuan, G., Zhang, M., Zhou, X., Sun, X., & Yu, X. (2014). Clinical Usefulness of Lipid Ratios, Visceral Adiposity Indicators, and the Triglycerides and Glucose Index as Risk Markers of Insulin Resistance. *Cardiovascular Diabetology*, *13*(1). https://doi.org/10.1186/s12933-014-0146-3