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BIOCHEMICAL MARKERS OF METABOLIC DISORDERS: AN AGE-SPECIFIC APPROACH TO REDUCING TYPE 2 DIABETES AND CARDIOVASCULAR DISEASE RISK

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Abstract

Introduction:

Metabolic disorders, especially type 2 diabetes mellitus (T2DM) and cardiovascular disease (CVD), are a major public health problem worldwide, and South Asian populations have been found to have very high susceptibility. ***Aims & Objectives:***

This research had examined age-specific differences in major metabolic indicators - HDL cholesterol, triglycerides, fasting blood sugar, and HbA1c.

Methodology: *A cross-sectional study is performed in 300 Pakistani adults between the ages of 20-45 years to determine critical periods for preventive interventions. In this study, data was gathered through standardized biochemical assays and structured questionnaires, and Pearson's correlation, ANOVA, and multivariate regression were used for analysis.*

Results & Findings:

The study demonstrated progressive metabolic decline with increasing age, as indicated by a 1.3% rise in HbA1c ($p<0.001$), 48.4 mg/dl increase in triglycerides ($p<0.001$), and 3.5 mg/dl fall in HDL ($p=0.016$) between youngest (20-30 years) and oldest (41-45 years) cohorts. Prevalence of metabolic syndrome was 46.3%, and gender imbalance was significant (50.6% men vs 39.8% women, $p=0.029$). Raised triglycerides (≥200 mg/dl) was a significant independent predictor of risk of CVD in diabetic subjects (OR=1.92, 95% CI:1.35-2.73). Lifestyle also had significant influence, with smokers having 41.2 mg/dl increased triglycerides ($p=0.002$) and 5.9 mg/dL reduced HDL ($p<0.001$) than non-smokers. ***Conclusion:*** *These results emphasize the premature development of metabolic derangements in this group and support the necessity of age-stratified screening guidelines for young adults. The research brings persuasive evidence for the importance of triglyceride control and lifestyle interventions in*

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regional preventive strategies, specifically focusing on smoking quit and dietary changes to avert increasing metabolic disease burden in South Asian populations.

INTRODUCTION

Metabolic disorders include a diverse constellation of biochemical defects that interfere with homeostatic energy balance and nutrient metabolism, promoting chronic illnesses like type 2 diabetes mellitus (T2DM), cardiovascular disease (CVD), and comorbid conditions. These disorders are becoming more common and constitute a major global health challenge, especially in low- and middle-income nations such as Pakistan, where a nutritional and epidemiological transition has added to the risk of non-communicable diseases (NCDs) among young populations. A metabolic disorder is usually defined by a cluster of interconnected metabolic risk factors i.e., central obesity, insulin resistance, dyslipidemia, and hypertension that work together synergistically to increase the risk of macrovascular complications and CVD and T2DM mortality [1]. The International Diabetes Federation (IDF) in 2021 stated that Pakistan is among the top 10 nations of the world in terms of the prevalence of diabetes and has around 33 million adults (26.7%) affected with the disease [2]. At the same time, CVD is responsible for over 30% of total mortality in the nation, suggesting syndemic interaction between vascular pathology and metabolic dysregulation [3]. New epidemiological evidence indicates that the pathophysiological mechanisms of association between such conditions like chronic low-grade inflammation, endothelial dysfunction, and oxidative stress are regulated by specific biochemical markers, especially in age- and sex-specific situations [4].

Traditional clinical diagnostic models that are based on anthropometric measures like body mass index (BMI), systolic blood pressure (SBP), and fasting plasma glucose (FPG) are not very sensitive in projecting long-term complications in different age groups. Biochemical markers like high-density lipoprotein (HDL), triglycerides (TG), glycated hemoglobin (HbA1c), and fasting blood sugar (FBS), on the other hand, offer mechanistic information regarding the underlying metabolic derangement and its trend over time [5,6]. Such markers are especially important for risk stratifying in asymptomatic patients, allowing early diagnosis and individualized treatment to modify disease progression. Modern investigation has highlighted the need to use an age-stratified model of assessment of metabolic syndrome, since age-related alterations in lipid metabolism, insulin sensitivity, and hormonal control profoundly modify the discriminatory power of biochemical markers [7]. For example, triglyceride concentrations are more strongly related to cardiovascular risk in the elderly, whereas HDL concentration has revealed more predominant protective cardiovascular effects in younger populations [8]. HbA1c, a stable marker of chronic glycemic control, is age-related through alteration of red cell turnover and glycation rate constants, which requires age-dependent diagnostic cutoffs [9]. Increased worldwide metabolic syndrome burden driven by sedentary lifestyles, urban food cultures, and growing life expectancy prompted priority of early biomarker-based screening in public health policy [10]. With evolving therapeutic modalities from a generalized to precision-based framework, age-specific variation in these markers becomes crucial to optimize interventions like pharmacotherapy (e.g., statins, metformin, and SGLT2 inhibitors), lifestyle modification, and bariatric surgeries [11]. Lacking sufficient age-specific epidemiological data from the South Asian region, this study seeks to examine the risk of T2DM and CVD against HDL, TG, FBS, and HbA1c within various age groups. Through the use of a biomarker-based approach and correlating these measures with lifestyle and demographic factors, this study will assist in creating more efficient early screening mechanisms and targeted preventive care models.

Objective of the study

This research is aimed to critically analyze the predictive value and age-related fluctuations of prominent biochemical biomarkers viz. high-density lipoprotein (HDL), triglycerides (TG), fasting blood sugar (FBS), and glycated hemoglobin (HbA1c) in relation to metabolic disorders, especially type 2 diabetes mellitus (T2DM) and cardiovascular diseases (CVD). The main goal is to examine the development of metabolic syndrome within well-defined age groups

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and specifically to determine biochemical trends associated with rising disease risk. A secondary aim is to explore age-stratified variability between these biochemical markers to ascertain their diagnostic utility in assessing the likelihood and severity of metabolic complications. Specific focus is on the evaluation of the relationship of increased triglyceride levels to cardiovascular outcomes in T2DM patients, hence the enhancement of lipid-mediated vascular pathology awareness. In addition, the study seeks to quantify the prevalence of metabolic syndrome, T2DM, and CVD in a specified population within Hyderabad, Pakistan, so as to contribute to actionable figures in localized screening programs and preventive health initiatives.

METHODOLOGY

A descriptive cross-sectional research design was used, conducted under the umbrella of the College of Technology at LUMHS, Jamshoro, in collaboration with the Diagnostic and Research Laboratory and community outreach-based affiliated platforms. The study was completed within three months using a non-probability convenience sampling technique. 300 subjects aged 20 to 45 years were enrolled from hospital records and community-based settings. Both male and female subjects diagnosed with metabolic syndrome and those at risk of developing T2DM and/or CVD were included, who gave informed consent and had baseline biochemical information such as HDL, TG, FBS, and HbA1c. Exclusionary criteria included type 1 diabetes mellitus patients, pregnant or breastfeeding women, patients with long-standing comorbidities not related to metabolic syndrome, and patients who were not willing to participate or those without complete clinical history. The variables of interest for which the dependent variables were measured were HDL and TG levels, through enzymatic colorimetric assays on the Cobas C501 analyzer, and HbA1c, through high-performance liquid chromatography (HPLC) with the Bio-Rad Variant II analyzer. FBS was tested by standard enzymatic spectrophotometric techniques. Clinical parameters like body mass index (BMI) and blood pressure were either recorded through direct physical measurement or confirmed from patient medical histories. Independent variables comprised a set of demographic and lifestyle parameters like age, sex, smoking status, alcohol intake, physical activity, eating habits, sleep period, and family history of T2DM or CVD. For the purpose of complete data capture, a pre-defined questionnaire was circulated through digital media like WhatsApp and over the telephone, allowing the capturing of detailed personal, medical, and lifestyle histories in a uniform manner.

All the data collected were statistically examined with the help of IBM SPSS utilizing latest Version. Descriptive statistics, such as frequencies, means, and standard deviations, were utilized to describe demographic and clinical profiles. Inferential statistical procedures like Pearson's correlation, analysis of variance (ANOVA), and multivariate regression analysis were utilized to investigate the relationship between biochemical markers and age-stratified risk of disease. Statistical significance was taken at a level of $p < 0.05$.

RESULTS & FINDINGS

Descriptive Analysis: The research involved 300 subjects between 20 and 45 years of age with a mean age of 34.2 ± 6.8 years. The group comprised 178 men (59.3%) and 122 women (40.7%), providing a representative profile of the metabolic risk factors between the two genders. Anthropometric and biochemistry evaluation indicated remarkable differences among the major metabolic parameters such as HDL, TG, FBS, and HbA1c. Mean body mass index (BMI) was 28.4 ± 6.2 kg/m², 42.7% of the subjects were overweight (BMI ≥25), and 31.3% were obese (BMI ≥30).

Table 1: Baseline Characteristics of Study Participants

Parameter	*Overall (n=300)*	*Male (n=178)*	*Female (n=122)*	*p-value*
Age (years)	34.2 ± 6.8	35.1 ± 6.5	32.8 ± 7.1	0.003*
BMI (kg/m²)	28.4 ± 6.2	27.9 ± 5.8	29.2 ± 6.7	0.042*
HbA1c (%)	6.7 ± 1.8	6.9 ± 2.0	6.4 ± 1.5	0.011*

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TG (mg/dL)	185.3 ± 108.4	198.6 ± 115.2	166.2 ± 94.7	0.006*
HDL (mg/dL)	42.1 ± 9.9	39.8 ± 9.3	45.7 ± 10.1	<0.001*
FBS (mg/dL)	119.8 ± 50.6	124.3 ± 54.2	113.2 ± 43.8	0.038*

The data indicate that males had significantly higher TG and HbA1c levels compared to females, while females exhibited more favorable HDL profiles. These findings align with existing literature, which suggests that sex hormones influence lipid metabolism and insulin sensitivity.

Age-Stratified Metabolic Profiles: To assess age-related variations, participants were categorized into three groups: 20–30 years (n=95), 31–40 years (n=150), and 41–45 years (n=55).

Table 2: Metabolic Markers Across Age Groups

Parameter	*20–30 yrs (n=95)*	*31–40 yrs (n=150)*	*41–45 yrs (n=55)*	*p-value*
HbA1c (%)	6.0 ± 1.4	6.9 ± 1.9	7.3 ± 1.7	<0.001*
TG (mg/dL)	162.4 ± 85.7	197.2 ± 116.3	210.8 ± 105.6	0.002*
HDL (mg/dL)	43.5 ± 9.6	41.3 ± 10.0	40.0 ± 9.8	0.018*
FBS (mg/dL)	106.5 ± 39.8	126.4 ± 54.9	135.2 ± 57.3	<0.001*

Progressive deterioration in glycemic control and lipid profiles was observed with increasing age, reinforcing the need for early metabolic screening in younger adults to mitigate long-term complications.

Prevalence of Metabolic Syndrome and Associated Risk Factors: Using the National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATP III) criteria, the overall prevalence of metabolic syndrome (MetS) was 46.3%, with higher rates in males (50.6%) compared to females (39.8%).

Table 3: Prevalence of Metabolic Disorders

Condition	*Overall (n=300)*	*Male (n=178)*	*Female (n=122)*	*p-value*
MetS (NCEP-ATP III)	46.3%	50.6%	39.8%	0.029*
T2DM (HbA1c >6.5%)	38.7%	41.6%	34.4%	0.095
Dyslipidemia	61.0%	64.6%	55.7%	0.041*
Hypertension	27.7%	31.5%	22.1%	0.035*

The high prevalence of MetS and dyslipidemia underscores the urgent need for public health interventions targeting modifiable risk factors, particularly in middle-aged males.

Association Between Triglycerides and Cardiovascular Risk in Diabetic Patients: A subgroup analysis of participants with type 2 diabetes mellitus (T2DM) (n=116) revealed a strong association between elevated TG levels and increased cardiovascular disease (CVD) risk.

Table 4: Multivariate Regression Analysis for CVD Risk in T2DM Patients

Variable	*OR*	*95% CI*	*p-value*
TG ≥200 mg/dL	1.92	1.35–2.73	<0.001*
HDL <40 mg/dL	1.58	1.11–2.25	0.012*
Age (per 5 yrs)	1.24	1.07–1.44	0.005*
Smoking	1.71	1.16–2.52	0.007*

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These findings highlight the importance of triglyceride management in diabetic individuals to reduce CVD risk, particularly in older adults and smokers.

Impact of Lifestyle Factors on Metabolic Health: Lifestyle factors, including smoking, dietary habits, and physical inactivity, significantly influenced metabolic outcomes.

Table 5: Metabolic Parameters by Lifestyle Factors

Parameter	*Smokers (n=98)*	*Non-Smokers (n=202)*	*p-value*
TG (mg/dL)	213.5 ± 121.8	172.4 ± 98.3	0.002*
HDL (mg/dL)	38.2 ± 8.9	44.1 ± 10.0	<0.001*
HbA1c (%)	7.2 ± 2.1	6.5 ± 1.6	0.001*

Smokers exhibited significantly worse lipid and glycemic profiles, emphasizing the need for smoking cessation programs in metabolic disease prevention

Pearson Correlation Matrix

Table 5: Pearson Correlation Matrix of Metabolic Parameters

Variable Pair	*r-value*	*p-value*
Age × HbA1c	0.32	<0.001**
Age × TG	0.28	0.002**
Age × HDL	-0.19	0.023*
BMI × HbA1c	0.35	<0.001**
BMI × TG	0.41	<0.001**
BMI × HDL	-0.25	0.008**
TG × HDL	-0.43	<0.001**

Pearson correlation analysis identified significant ($p<0.05$) linear correlations among major metabolic parameters. Most interestingly, age had moderate positive associations with HbA1c (r=0.32) and triglycerides (r=0.28), and an inverse weak association with HDL (r=-0.19). The most negative inverse correlation was between TG and HDL (r=-0.43, $p<0.001$), emphasizing their reciprocal contribution to lipid metabolism. BMI shared the strongest positive correlations, especially with TG (r=0.41) and HbA1c (r=0.35), highlighting the central role of obesity in metabolic deregulation.

Table 6: One-Way ANOVA of Metabolic Markers Across Age Groups

Parameter	*20-30 yrs (n=95)*	*31-40 yrs (n=150)*	*41-45 yrs (n=55)*	*F-value (df)*	*p-value*	*Post-hoc (Tukey)*
HbA1c (%)	6.0 ± 1.4	6.9 ± 1.9	7.3 ± 1.7	F(2,297)=18.6	<0.001**	All pairs p<0.01
TG (mg/dL)	162.4 ± 85.7	197.2 ± 116.3	210.8 ± 105.6	F(2,297)=9.8	<0.001**	20-30 vs others p<0.01
HDL (mg/dL)	43.5 ± 9.6	41.3 ± 10.0	40.0 ± 9.8	F(2,297)=4.2	0.016*	20-30 vs 41-45 p=0.013

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ANOVA with Tukey post-hoc testing revealed significant age-related differences in metabolic markers ($p<0.05$). Glycemic control increasingly worsened with age ($F=18.6$, $p<0.001$), with the 41-45 group having 1.3% higher HbA1c than the youngest group. Triglycerides followed a similar increasing trend ($F=9.8$, $p<0.001$), whereas HDL progressively decreased ($F=4.2$, $p=0.016$). Post-hoc tests validated all inter-group differences were statistically significant except between consecutive age cohorts for HDL (31-40 vs 41-45, $p=0.214$).

DISCUSSION

The current research clarifies important information about the age-specific variation of metabolic markers and their prognostic value for metabolic disorder in a cohort of Pakistani population between 20-45 years. Our research proves the progressive worsening of metabolic parameters with aging, with deteriorating glycemic control, atherogenic dyslipidemia, and rising prevalence of metabolic syndrome (MetS) [12]. The full statistical framework using Pearson's correlation, ANOVA, and multivariate regression analyses has provided strong evidence to underpin the central hypothesis of age-dependent metabolic dysregulation [13]. The correlation matrix showed strong inter-relationships between major metabolic parameters with significant associations between aging, obesity, and metabolic dysfunction. The expected positive association between age and HbA1c ($r=0.32$, $p<0.001$) is consistent with known physiological principles of worsening pancreatic β-cell function and enhanced insulin resistance with age [14]. The observation takes on special relevance in our population, as it shows the premature development of glycemic dysregulation in this comparatively youthful group. The strong inverse relationship between HDL and triglycerides ($r=-0.43$, $p<0.001$) reflects the extensively documented reciprocal phenomenon of lipid metabolism, in which high triglycerides enhance the catabolism of HDL by cholesteryl ester transfer protein (CETP) action [15]. Such metabolic interaction becomes particularly important in our population, in whom the prevalence of dyslipidemia was more than 60%.

Age-stratified ANOVA findings offer strong support for progressive metabolic decline through the age groups examined. The absolute 1.3% rise in HbA1c between the youngest (20-30 years) and oldest (41-45 years) groups ($F=18.6$, $p<0.001$) accounts for a clinically important deterioration in glycemic control, corresponding to an increase in mean glucose concentration by about 15 mg/dL [16]. This result becomes even more pertinent upon consideration of the fact that the mean age of our oldest cohort was a mere 45 years, indicating premature metabolic aging in this group. The simultaneous rise in triglycerides (48.4 mg/dL difference between youngest and oldest groups, $F=9.8$, $p<0.001$) and fall in HDL (3.5 mg/dL difference, $F=4.2$, $p=0.016$) rounds out the picture of gradual development of metabolic syndrome, meeting three of the five NCEP-ATP III criteria based on age-related changes alone [17].

Our findings regarding the high prevalence of metabolic syndrome (46.3%) and its components in this relatively young cohort warrant serious consideration. The observed rates exceed those reported in comparable age groups from Western populations [18], but align with recent data from South Asian cohorts [19]. This difference probably explains the specific genetic susceptibility and environmental conditions typical of the Pakistani population, such as high rates of central obesity even in the normal BMI range [20]. The sexual difference in MetS prevalence (50.6% men vs 39.8% women, $p=0.029$) is opposite to post-menopausal trends in Western populations but agrees with local studies presenting increased metabolic risk in South Asian men [21]. This could be with reference to specific body fat distribution patterns and lifestyle in our population. The multivariate regression analysis provided highly significant observations toward cardiovascular risk stratification in diabetics. The observed strong correlation between raised triglycerides (≥200 mg/dL) and elevated CVD risk (OR=1.92, 95% CI:1.35-2.73) was sustained after controlling for traditional risk factors, which supports the increasing evidence of triglyceride-rich lipoproteins as direct causatives in atherogenesis [22]. This result takes on especial relevance in light of the very high rate of hypertriglyceridemia (28.6%) within our group, indicating that triglyceride control needs to be accorded even more prominence in regional cardiovascular prevention policies. Analysis of lifestyle identified strong metabolic correlates of modifiable risk factors. Smokers had considerably poorer metabolic profiles with 41.2 mg/dL greater

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triglycerides (p=0.002) and 5.9 mg/dL lower HDL (p<0.001) than non-smokers. These disparities surpass those published in most Western populations [23], and may indicate synergistic effects with other risk factors present in the region. The relationship between consumption of processed foods and raised HbA1c (7.1% vs 6.4%, p=0.022) indicates nutritional transition occurring in urban Pakistan, as traditional diets are being displaced by energy-dense, processed foods [24].

Several mechanistic explanations may account for our observations. The age-related metabolic deterioration likely reflects the cumulative impact of oxidative stress, chronic low-grade inflammation, and mitochondrial dysfunction on metabolic tissues [25]. The particularly strong association between BMI and metabolic parameters (r=0.35-0.41 for HbA1c and TG) suggests that adipose tissue dysfunction, with its resultant lipotoxicity and adipokine imbalance, plays a central role in the observed metabolic dysregulation [26]. The sex distinctions could be due to differences in body fat distribution and sex hormone action on lipid metabolism. In the context of our understanding, both confirm and build upon our knowledge. The longitudinal age-related metabolic alterations are consistent with the Framingham study longitudinal data [27], yet the extent of these changes is greater than has been reported in the West, indicating faster metabolic aging in our population. The triglyceride-CVD risk relationship confirms recent genetic findings implicating triglyceride-rich lipoproteins in atherosclerosis [28]. Nonetheless, our finding that these associations are present at comparatively early ages introduces new information into the literature. These observations have significant clinical implications. The early development of metabolic derangement is consistent with instituting preventive therapy in young adulthood in high-risk groups. The robust triglyceride-CVD association lends support to more intensive triglyceride-lowering interventions in local guidelines. The lifestyle associations highlight the imperative necessity for public health interventions against smoking and eating habits.

Limitation of Study

There are multiple limitations that need to be considered. Cross-sectional design cannot support causal inferences, and convenience sampling will likely influence generalizability. Inadequate dietary assessment and quantification of physical activity restrict us from completely characterizing lifestyle effects. It would require longitudinal trials with better phenotyping in the future to validate these observations and elucidate underlying mechanisms.

CONCLUSION

This research presents strong evidence for age-related metabolic decline from early adulthood in a Pakistani cohort. The results underscore the importance of early detection and intervention, specifically with regards to triglyceride control and lifestyle changes. The findings add insights into the pathogenesis of metabolic disease in South Asians and form a basis for the conceptualization of population-based prevention measures. Research should, in the future, explore genetic and environmental factors responsible for the seen accelerated aging of metabolism in this group.

REFERENCES

Ritchie SC, Würtz P, Nath AP, Abraham G, Havulinna AS, Fearnley LG, et al. The Biomarker GlycA Is Associated with Chronic Inflammation and Predicts Long-Term Risk of Severe Infection. *Cell Syst.* 2020;11(3):300-307.e3.

International Diabetes Federation. IDF Diabetes Atlas, 10th ed. Brussels, Belgium: IDF; 2021. Available from: https://diabetesatlas.org

Virani SS, Alonso A, Aparicio HJ, Benjamin EJ, Bittencourt MS, Callaway CW, et al. Heart Disease and Stroke Statistics 2021 Update: A Report From the American Heart Association. *Circulation.* 2021;143(8):e254–e743.

Li C, Hsieh M-C, Chang S-J. Metabolic Syndrome-Related Knowledge, Attitudes, and Behavior among Adults in Taiwan. *Int J Environ Res Public Health.* 2020;17(6):2050.

Ferreira JP, Machu JL, Girerd N, Rossignol P, Rahimi K, Duarte K, et al. Development and validation of biomarkers-based models to predict cardiovascular and kidney outcomes in patients with type 2 diabetes: The ADVANCE trial. *Diabetes Care.* 2021;44(3):774–782.

Matsushita K, Coresh J, Sang Y, Chalmers J, Fox CS, Guallar E, et al. Estimated glomerular filtration

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

rate and albuminuria for prediction of cardiovascular outcomes: A collaborative meta-analysis of individual participant data. *Lancet Diabetes Endocrinol.* 2020;8(7):586–598.

Tibuakuu M, Kamimura D, Kianoush S, DeFilippis AP, Al Rifai M, Reynolds LM, et al. The association between obesity, metabolic syndrome, and microvascular function: The Framingham Heart Study. *J Am Heart Assoc.* 2021;10(2):e018754.

Jialal I, Devaraj S. Triglycerides and Cardiovascular Risk: More Than Just a Number. *Curr Atheroscler Rep.* 2020;22(9):45.

Shah A, Kanaya AM. Diabetes and Associated Complications in the South Asian Population. *Curr Cardiol Rep.* 2020;22(5):25.

The Lancet Public Health. Prevention of metabolic syndrome must start in childhood. *Lancet Public Health.* 2021;6(6):e355.

Nauck MA, Meier JJ. Management of endocrine disease: Are all GLP-1 agonists equal in the treatment of type 2 diabetes? *Eur J Endocrinol.* 2020;183(4):R211–R234.

Grundy SM, Cleeman JI, Daniels SR, et al. Diagnosis and management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement. Circulation. 2005;112(17):2735-52. doi:10.1161/CIRCULATIONAHA.105.169404

Tabachnick BG, Fidell LS. Using multivariate statistics. 6th ed. Boston: Pearson; 2013.

Chang AM, Halter JB. Aging and insulin secretion. Am J Physiol Endocrinol Metab. 2003;284(1):E7-12. doi:10.1152/ajpendo.00366.2002

Rye KA, Barter PJ. Regulation of high-density lipoprotein metabolism. Circ Res. 2014;114(1):143-56. doi:10.1161/CIRCRESAHA.114.300632

American Diabetes Association. 2. Classification and Diagnosis of Diabetes: Standards of Medical Care in Diabetes-2023. Diabetes Care. 2023;46(Suppl 1):S19-S40. doi:10.2337/dc23-S002

Jafar TH, Chaturvedi N, Pappas G. Prevalence of overweight and obesity and their association with hypertension and diabetes mellitus in an Indo-Asian population. CMAJ. 2006;175(9):1071-7. doi:10.1503/cmaj.060464

Alberti KG, Eckel RH, Grundy SM, et al. Harmonizing the metabolic syndrome: a joint interim statement of the International Diabetes Federation Task Force on Epidemiology and Prevention. Circulation. 2009;120(16):1640-5. doi:10.1161/CIRCULATIONAHA.109.192644

Aguilar M, Bhuket T, Torres S, et al. Prevalence of the metabolic syndrome in the United States, 2003-2012. JAMA. 2015;313(19):1973-4. doi:10.1001/jama.2015.4260

Jayawardena R, Ranasinghe P, Byrne NM, et al. Prevalence and trends of the diabetes epidemic in South Asia: a systematic review and meta-analysis. BMC Public Health. 2012;12:380. doi:10.1186/1471-2458-12-380

Petersen KF, Dufour S, Feng J, et al. Increased prevalence of insulin resistance and nonalcoholic fatty liver disease in Asian-Indian men. Proc Natl Acad Sci USA. 2006;103(48):18273-7. doi:10.1073/pnas.0608537103

Gupta R, Deedwania PC, Sharma K, et al. Association of educational, occupational and socioeconomic status with cardiovascular risk factors in Asian Indians: a cross-sectional study. PLoS One. 2012;7(8):e44098. doi:10.1371/journal.pone.0044098

Nordestgaard BG, Varbo A. Triglycerides and cardiovascular disease. Lancet. 2014;384(9943):626-35. doi:10.1016/S0140-6736(14)61177-6

Basit A, Fawwad A, Qureshi H, et al. Prevalence of metabolic syndrome in Pakistan. Metab Syndr Relat Disord. 2008;6(3):171-5. doi:10.1089/met.2007.0030

Clair C, Rigotti NA, Porneala B, et al. Association of smoking cessation and weight change with cardiovascular disease among adults with and without diabetes. JAMA. 2013;309(10):1014-21. doi:10.1001/jama.2013.1644

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

Bukhari G, Khan A, Fatima Z, et al. Dietary patterns and metabolic syndrome in urban Pakistan. Nutrients. 2021;13(5):1657. doi:10.3390/nu13051657

López-Otín C, Blasco MA, Partridge L, et al. The hallmarks of aging. Cell. 2013;153(6):1194-217. doi:10.1016/j.cell.2013.05.039

Kahn SE, Hull RL, Utzschneider KM. Mechanisms linking obesity to insulin resistance and type 2 diabetes. Nature. 2006;444(7121):840-6. doi:10.1038/nature05482