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Original Article

Association Between Spatial QRS-T Angle and Anthropometric/Lipid-Derived Indices

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ABSTRACT

Background: Estimating the spatial QRS-T angle (SA) serves as a valuable predictor of abnormal ventricular repolarization sequences, with a wider SA linked to an increased risk of cardiovascular events. SA can be derived from 12-lead ECGs. This study aimed to determine the factors influencing the magnitude of SA, including estimation methods, gender, anthropometric measures, and lipid profile–derived ratios and indices in healthy individuals.

Methods: This cross-sectional study involved 138 healthy participants. The primary outcome was the estimation of SA from 12-lead ECGs using 3 different modules: module 1 (aVF, V2, V5, and V6), module 2 (aVF, V2, and V6), and module 3 (I, aVF, and V5). Secondary outcomes involved ratios and indices derived from weight, height, waist circumference, serum triglycerides, and high-density lipoprotein levels.

Results: Significant variability in estimating the SA degree and detecting abnormal widening of the SA (> 135°) was found to be related to the measurement modules used. Women exhibited significantly lower SA degrees than men. Estimated total body mass and relative fat mass were important confounding factors contributing to the differences between modules in SA estimation. Among the modules, module 1 demonstrated greater accuracy than the others.

Conclusions: An accurate estimation of SA depends on the selected ECG leads, as well as adjustments for anthropometric measurements and gender. ***(Iranian Heart Journal 2025; 26(3): 59-68)***

KEYWORDS: Spatial QRS-T angle, Modules, Gender, Anthropometric measurements, Lipid profile

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Electrophysiological studies serve as a valuable tool for diagnosing and predicting disease outcomes. ECG recordings are clinically useful for detecting cardiovascular diseases and evaluating risk factor predictors. [1] The spatial QRS-T angle (SA) can be derived from either ECG or vector cardiography. Multiple studies emphasize the significance of SA assessment in pathological conditions such as myocardial ischemia, as an increased SA reflects abnormal ventricular repolarization. [2, 3] In addition, SA serves as a predictor of sudden cardiac death in the general population. [4] The magnitude of SA is influenced by various factors, including genetics, environmental influences, and cardiac events. For instance, healthy women exhibit a smaller QRS-T angle (−12°) than those with cardiovascular events (+15°). [5] Stabenau et al. [6] observed that men exhibited a larger SA than women, even after adjusting for confounding factors such as age, race, body mass index (BMI), and sinus heart rate.

SA shows a positive correlation with key components of metabolic syndrome, including overweight/obesity, dyslipidemia, and elevated glycemic index, after accounting for covariates like age, smoking, heart rate, and ECG conduction parameters. [7] Furthermore, the methodology used to measure SA influences the detection of abnormally widened angles in clinical practice. [8] Nonetheless, the limitations of lipid profiles and anthropometric indices in assessing SA remain understudied, and there is no conclusive evidence linking these factors to SA magnitude in healthy, asymptomatic individuals.

The present study sought to investigate the association between SA magnitude, determined through various 12-lead ECG methods, and anthropometric/lipid-derived indices and ratios in healthy individuals. The study also aimed to minimize potential biases in SA calculation procedures.

METHODS

Study Design and Population

This cross-sectional study involved 138 healthy participants (36 men and 102 women, average age: 41.7 ± 14.3 years) randomly recruited from healthcare centers. All participants were informed about the study's objectives, and informed consent was obtained from each individual. The study received approval from the institutional Scientific and Ethics Committees (No. 893, Date: 9/12/2024) at the College of Medicine, University of Diyala.

The sample size was calculated using the following formula: $3 + [(Z_1\text{-}\alpha/2 + Z_1\text{-}\beta)/C]^2$ and $C = 0.5 \times \text{Ln}\,[(1+r)/(1-r)]$,

where $z = 1.96$, $\alpha = 0.01$, $\beta = 0.1$, and $r = \pm 0.25$. [9]

Electrocardiography Measurements and Definition of the SA Degree

Twelve-lead ECG recordings (at 25 mm/second and 10 mm/mV) were obtained by assistant medics. Any ECGs missing due to technical errors were excluded from the study. The researchers performed all measurements manually. Each ECG record was scanned, coded, and presented to the investigators, who were blinded to the participants' anthropometric and biochemical data.

Any ECG records showing evidence of conduction defects, bundle branch blocks, or myocardial ischemia, diagnosed by consultant cardiologists, were excluded from the study.

SA represents the angle between the mean QRS and T vectors. It is calculated using quasi-orthogonal X, Y, and Z leads derived from sinus rhythm 12-lead ECGs. [10]

The matrix transformation process was implemented using 3 modules with distinct

configurations. Module 1 utilized standard leads aVF, V2, and V6 for QRS wave analysis, while employing aVF, V2, and V5 for T wave assessment. Module 2 applied standard leads aVF, V2, and V6 for both QRS and T waves, with quasi-orthogonal transformations calculated as X = 1.06 × V6, Y = 1.25 × aVF, and Z = (0.043 × V6) − (0.532 × V2). Module 3 incorporated standard leads I, aVF, and V2 for both QRS and T waves, with quasi-orthogonal transformations defined as X = I, Y = aVF, and Z = (-0.8 × V1) + (V2/2).
Based on established criteria, [11] SA values were categorized as normal (0–105°), borderline (105–135°), or abnormal (135–180°).

Anthropometric Measurements
Body weight (kg), height (m), waist circumference (cm), and hip circumference (cm) were measured to one decimal place by trained operators at the teaching hospital. Weight and height were measured using a stadiometer, while waist circumference was measured at the umbilical level and hip circumference at the midpoint between the lower rib and iliac crest, both using a metallic tape.

Blood Biochemistry Measurement
Venous blood samples were collected from participants after an overnight fast, then centrifuged to separate the serum for measurement of triglycerides (TG) and high-density lipoprotein (HDL) in the teaching hospital's laboratories.

Anthropometric/Lipid-Derived Ratios and Indices

BMI (kg/m^2) = $\frac{Weight\ (kg)}{Height\ (m)^2}$

Conicity index [12] = WC/(0.109 × (Wt/Ht)$^{0.5}$)

Waist-to-height ratio (WHtR) = $\frac{WC\ (cm)}{Ht\ (cm)}$

A body shape index (ABSI) [13] = WC (m) /$BMI^{2/3} \times Ht\ (m)^{1/2}$.

Abdominal volume index (AVI) [14] = (2 × (WC × 100)^2 + 0.7 × (WC × 100- HC ×100)^2 /11,000

Body roundness index (BRI) [15] = 364.2 – 365.5 × (1- ((0.5 × $\frac{WC}{\pi}$)^2 / (0.5 × Ht)^2))$^{0.5}$

Estimated total body fat (eTBF) [16] = 100 × (–Z + A − B)/C, where A = (4.15 × WC × 39.3701), B = (0.082 × Wt × 2.20462), C= (Wt × 2.20462), Z = 98.42 (men), Z = 76.76 (women)

Relative fat mass (RFM) [17] = 64−(20 × Ht/WC) + (12 × S), where S = 0 (men), S = 1 (women)

Adult body fat (%) [18] = BFI (in %) = (1.20 × BMI) + (0.23 × age) - (10.8 × gender) 5.4. with gender: 0 for a woman and 1 for a man

Adult body fat (ABF %) [19] = (1.20 × BMI) + (0.23 × age) – S, where S = 16.2 (men). S = 5.4 (women) Lipid accumulation product (LAP) = (WC –65) × TG (mmoL/L) for men, and (WC –58) × TG (mmoL/L) for women

Visceral adiposity index (VAI) [20] = (WC / 39.68 + 1.88 × BMI) × (TG/1.03) × (1.31/HDL) for men, and (WC / 36.58 + 1.89 × BMI) × (TG/0.81) × (1.52/HDL) for women

Statistical Analysis
Data are presented as percentages for categorical variables, medians with interquartile ranges for non-normally distributed data, and means ± standard deviation (SD) for continuous variables. Gender-based differences were assessed using a 2-tailed one-way ANOVA for continuous variables, the independent samples Kruskal-Wallis test for median comparisons, and the Chi-square test for categorical variables.

Spearman's correlation analysis was employed to examine relationships between SA (dependent variable) and participant characteristics (independent variables). Methodological comparisons were performed using Bland-Altman analysis to evaluate agreement between measurement techniques and multivariate ANOVA (MANOVA), adjusted for participant characteristics, to assess significant differences in QRS-T angle calculation methods.

All statistical tests used a significance threshold of a *P*-value < 0.05.

RESULTS

Characteristics of the participants

Table 1 summarizes the baseline characteristics of study participants. No significant gender differences were observed in age, conicity index, ABSI, AVI, LAP, or VAI (all *P*s > 0.05). Nevertheless, women demonstrated significantly higher values than men in several anthropometric indices: BMI, WHtR, BRI, eTBF, RFM, and ABF (all *P*s < 0.05).

In terms of SA variations by gender, our analysis revealed the following method-dependent gender differences in SA magnitude. In module 2, men showed significantly wider SA than women (median 72.3° vs. 39.3°; *P* < 0.001). In module 3, a nonsignificant trend toward wider SA was observed in men (69.7° vs. 57.1°; *P* = 0.063). Additionally, in module 1, women exhibited slightly, albeit nonsignificantly, wider SA than men (52.4° vs. 44.4°; *P* = 0.491).

Table 1. The baseline descriptive data of the participants included in the present study

Variables	Women (N=102)	Men (N=36)	Total (N=138)	*P*-value
Age, year	41.6±13.2	42.0±17.2	41.7±14.3	0.899
BMI	30.2±5.7	26.9±4.9	29.4±5.7	<0.001
Conicity index	1.3±0.13	1.3±0.1	1.3±0.12	0.940
Waist-to-height ratio	0.619±0.1	0.557±0.07	0.603±0.097	<0.001
A body shape index	0.080±0.007	0.082±0.006	0.081±0.007	0.219
Abdominal volume index	19.7±6.21	18.8±4.4	19.5±5.8	0.346
Body roundness index	47.8±9.2	38.5±5.6	45.4±9.3	<0.001
Estimated total body fat	41.2±10.2	24.24±8.30	36.8±12.28.6	<0.001
Relative fat mass	42.8±5.7	27.5±5.1	38.8±8.7	<0.001
Adult body fat	45.9±8.6	41.9±8.1	44.8±8.6	0.016
Lipid accumulation product	42.1 (26.1, 84.7)	56.7 (22.8, 92.5)	44.7 (26.1, 84.7)	0.567
Visceral adiposity index	0.571 (0.378, 0.734)	0.682 (0.360, 0.915)	0.616 (0.378, 0.806)	0.122
Spatial QRS-T angle				
Module 1	52.4° (29.9, 78.7)	44.4° (23.8, 87.5)	50.8 (29.3, 78.7)	0.491
Module 2	39.3° (26.6, 61.1)	72.3° (42.5, 83.8)	45.1 (30.0, 72.3)	<0.001
Module 3	57.1° (39.0, 77.6)	69.7° (46.3, 87.6)	60.1 (39.5, 80.4)	0.063

The results are expressed as mean ± SD for continuous data, and as median (interquartile range). *P*-values were calculated using an independent 2-sample *t*-test for continuous data and one-way ANOVA (independent samples) or the Kruskal-Wallis test for categorical data.

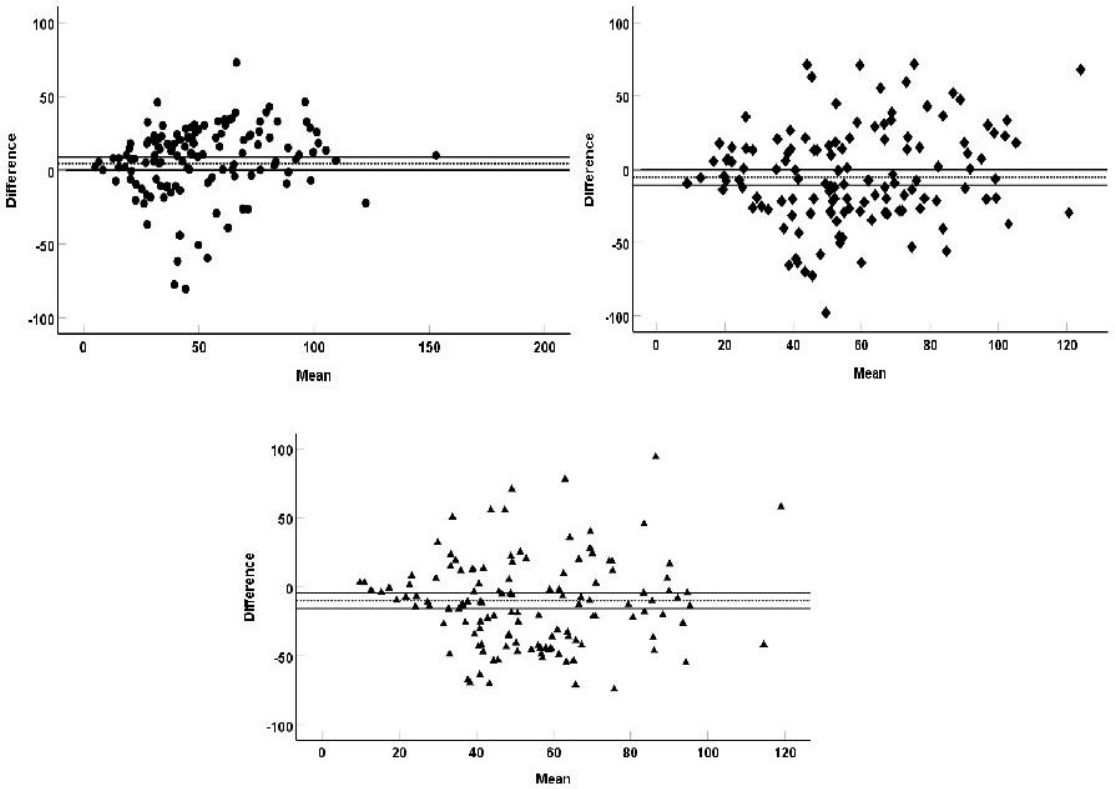

Figure 1. Bland-Altman plots show significant disagreement in the QRS-T angle measurement differences between modules 1 and 2 (upper left; $P < 0.047$), modules 1 and 3 (upper right; $P = 0.043$), and modules 2 and 3 (lower; $P < 0.001$).

Method-dependent variations in SA measurements

Figure 1 presents Bland-Altman plots demonstrating significant inter-method differences in SA degree calculations, as follows:

Comparison between Modules 1 and 2 showed a mean difference of 4.48° (95% CI, 0.07 to 0.89; $P = 0.047$). The mean difference in the comparison between Modules 1 and 3 was 5.56° (95% CI, −10.94 to −0.17; $P = 0.043$). Additionally, in the comparison between Modules 2 and 3, the mean difference was −10.04° (95% CI, −15.58 to −4.51; $P < 0.001$).

Figure 2 shows a significant ($\chi^2 = 9.794$; $P = 0.044$) difference between the modules in detecting the distribution of SA degrees according to their normality. The number and percentage of participants who had QRS-T of 0–105º were 126 (93.1%), 135 (97.8%), and 131 (94.8%) using Modules 1, 2, and 3, respectively.

Further analysis using MANOVA revealed significant differences between QRS-T measurement procedures after adjusting for specific adiposity indices. When controlling for eTBF, we observed significant methodological variation (Wilk's $\lambda = 0.848$, $F = 7.209$; $P < 0.001$). Similarly, adjustments for RFM showed significant differences between methods (Wilk's $\lambda = 0.895$, $F = 4.732$; $P < 0.001$). Still, no significant inter-procedural differences were detected when adjusting for other covariates in the model.

Correlations between anthropometric/lipid-derived indices and SA

As shown in Table 2, Module 2 revealed significant correlations between SA degrees and anthropometric/lipid-derived indices. Positive correlations were observed for

height (r = 0.318; P < 0.001) and VA (r = 0.250; P = 0.003). Conversely, inverse correlations emerged with BMI (r = −0.324; P < 0.001), WHtR (r = −0.281; P < 0.001), AVI (r = −0.168; P < 0.001), BRI (r = −0.331; P < 0.001), eTBF (r = −0.263; P = 0.002), RFM (r = −0.323; P < 0.001), ABF, and LAP (r = −0.313; P < 0.001).

Table 2. The correlations between QRS-T angles determined by 3 modules and the anthropometric/lipid-derived ratios and indices

Variables	Module 1	Module 2	Module 3
Age, years	-0.007 (0.937)	-0.040 (0.645)	-0.019 (0.826)
Weight, kg	0.035 (0.687)	-0.143 (0.094)	-0.022 (0.796)
Height, m	-0.106 (0.215)	**0.318 (<0.001)**	0.044 (0.612)
Waist, cm	0.035 (0.680)	-0.163 (0.057)	0.025 (0.775)
Body mass index	0.108 (0.207)	**-0.324 (<0.001)**	-0.068 (0.429)
Conicity index	-0.038 (0.659)	-0.032 (0.713)	0.065 (0.450)
Waist-to-height ratio	0.061 (0.477)	**-0.281 (0.001)**	-0.024 (0.780)
A body shape index	-0.093 (0.280)	0.074 (0.389)	0.084 (0.330)
Abdominal volume index	0.035 (0.680)	**-0.168 (0.050)**	0.024 (0.777)
Body roundness index	0.088 (0.302)	**-0.331 (<0.001)**	-0.034 (0.690)
Estimated total body fat	0.009 (0.914)	**-0.263 (0.002)**	-0.037 (0.665)
Relative fat mass	0.087 (0.390)	**-0.323 (<0.001)**	-0.075 (0.382)
Adult body fat	0.046 (0.589)	**-0.313 (<0.001)**	-0.060 (0.484)
Lipid accumulation product	-0.123 (0.152)	**-0.176 (0.039)**	-0.035 (0.687)
Lipid accumulation product	0.165 (0.053)	**0.250 (0.003)**	0.095 (0.265)

The results are expressed as Spearman's correlation coefficients (probability).

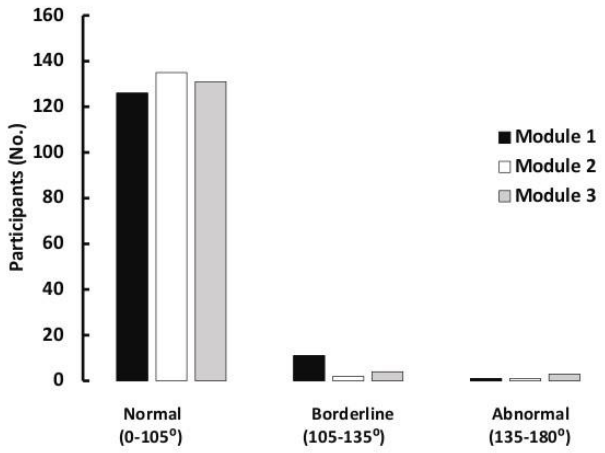

Figure 2. The image illustrates significant differences between modules used in calculating the degrees of the QRS-T angle according to their normality range.

The SA degrees range among healthy participants according to BMI

Figure 3 demonstrates BMI-dependent variations in SA measurements across calculation methods. Among normal-weight participants (BMI: 18–24.99 kg/m²), the mean SA showed no significant inter-method differences (Module 1: 53.2°; Module 2: 68.5°; and Module 3: 56.4°). However, overweight participants (BMI: 25.0–29.99 kg/m²) exhibited method-specific deviations: compared to normal-weight individuals, SA values were significantly narrower when calculated via Module 2 (43.4° vs. 68.5°; P < 0.001) but wider via Module 3 (73.5° vs. 56.4°; P =

0.006). Notably, obese participants demonstrated significantly reduced SA compared to overweight participants according to Module 3 (53.0° vs. 73.5°).

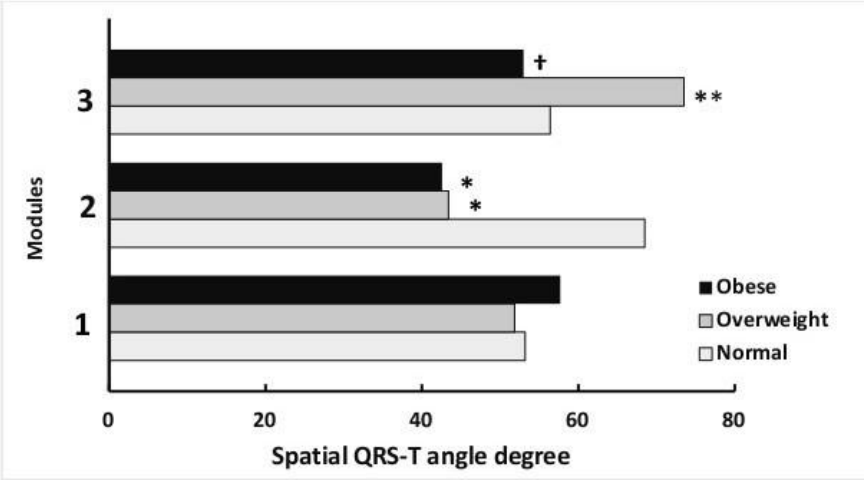

Figure 3. The image showcases the distribution of the means of the degrees of the QRST angle according to the body mass index.

*P < 0.001, **P = 0.006 in the comparison between overweight participants and those with normal weight and †P < 0.001 in the comparison between overweight participants and obese individuals

DISCUSSION

The present study identified several confounding factors affecting SA assessment in healthy individuals, underscoring the need to consider these characteristics when interpreting SA as a predictor of abnormal ventricular repolarization. [21] Notably, Module 3 produced atypically widened SA values, suggesting it may either offer superior accuracy or introduce measurement artifacts compared to other modules. This finding warrants further validation through vector cardiography. [21]

Consistent with previous research, [22] we observed gender-specific differences. Whereas women demonstrated significantly higher anthropometric values, men exhibited wider SA degrees. This dissociation between body composition metrics and electrophysiological patterns reinforces the multifactorial nature of ventricular repolarization dynamics.

Consistent with existing literature, our findings support the association between widened SA and metabolic dysfunction. We observed a significant positive correlation between SA and VAI, which chimes with reports linking abnormal SA to metabolic syndrome. [7] Remarkably, participants with abdominal obesity demonstrated a higher prevalence of aberrant SA values, further highlighting this relationship. [7] Be that as it may, in contrast to studies of hypertensive populations, [23] we found no significant association between SA and either BMI or conicity index in healthy individuals. This discrepancy may reflect fundamental differences in ventricular repolarization patterns between healthy subjects and patients with obesity-related hypertension, where prior research has identified SA degrees > 90° as clinically significant. [23]

Our analysis revealed method-dependent relationships between SA and anthropometric/lipid-derived parameters. While Modules 1 and 3 showed no significant correlations, Module 2 demonstrated both positive associations (height and VAI) and inverse relationships (BMI, WHtR, AVI, BRI, eTBF, RFM, ABF,

and LAP) with SA. These findings, combined with the Bland-Altman results in Figure 1, suggest that Module 2 may be suboptimal for SA calculation in clinical contexts. When employing more reliable calculation methods, it becomes essential to adjust for confounding factors that influence SA widening. Our MANOVA results identified eTBF and RFM as key sources of inter-method variability, which effectively explains the differences between the modules shown in Figure 1.

Multiple independent factors, including weight, height, waist circumference, gender, and race, significantly influence SA magnitude. [5,24-26] These parameters must be properly adjusted in SA calculations; failure to do so renders Modules 2 and 3 unsuitable for reliable SA assessment. Our findings suggest that Module 1 (utilizing leads aVF, V2, V5, and V6) demonstrates superior accuracy for SA determination. This finding is concordant with existing literature showing discrepancies in SA prediction when utilizing different lead combinations: while some studies report errors with leads I, II, V2, and V5, [27] others demonstrate reliable SA measurement using leads I, II, aVF, and V2 for detecting abnormal SA patterns. [28]

Study Strengths and Limitations

A key strength of this investigation is its comprehensive approach, employing 3 calculation modules while incorporating multiple anthropometric and adiposity indices as independent cardiovascular risk factors. Nonetheless, the sample size represents a significant limitation that should be addressed in future electrophysiological research.

CONCLUSIONS

Accurate estimation of SA from 12-lead ECGs requires multiple measurements and comparative analyses to identify aberrant widening. Critical to this process is proper adjustment for anthropometric confounders, including weight, height, waist circumference, and gender, which significantly improves both SA estimation precision and abnormal QRS-T angle detection. Our findings demonstrate that the lead combination of aVF, V2, V5, and V6 provides superior reliability for SA calculation compared to alternative configurations (aVF/V2/V6 or I/aVF/V2), offering optimal clinical utility for ventricular repolarization assessment.

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