

Waist-to-Height Ratio as a Low-Cost Tool for Identifying Cardiovascular Risk in Metabolically Dysfunctional-Associated Fatty Liver Disease

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Abstract

Background: Metabolic dysfunction-associated fatty liver disease (MAFLD), earlier referred to as non-alcoholic fatty liver disease (NAFLD), is a hepatic condition strongly linked with metabolic dysregulation and cardiovascular risk. Atherogenic dyslipidaemia is prevalent in MAFLD and significantly contributes to cardiovascular morbidity. In resource-limited settings, access to lipid testing is often restricted, highlighting the need for simple anthropometric tools to identify patients at increased cardiovascular disease (CVD) risk. This study aimed to evaluate the association between anthropometric indices and lipid parameters in MAFLD and identify the most predictive anthropometric measure of dyslipidaemia. **Material and Methods:** This cross-sectional study was carried out at the Himalayan Institute of Medical Sciences, Dehradun, India, over six months. A total of 350 adult patients with ultrasonography-confirmed MAFLD were recruited. Anthropometric measurements (BMI, WC, WHPR, WHTR) and fasting lipid profiles (total cholesterol, LDL-C, HDL-C, non-HDL-C, triglycerides) were obtained. Pearson correlation, linear regression, and ROC curve analysis were applied to determine associations and diagnostic utility. Data were analysed using SPSS v25 and Microsoft Excel. **Results:** The mean age of participants was 46.85 ± 12.1 years, with 63.71% being male. Participants exhibited a dyslipidaemia profile and high prevalence of central obesity (mean WHTR = 0.68 ± 0.08 ; BMI = 32.39 ± 5.01 kg/m²). WHTR showed strong positive correlations with triglycerides ($r = 0.77$), total cholesterol ($r = 0.82$), and non-HDL-C ($r = 0.81$) (all $p < 0.001$), and was the most significant predictor in regression analysis ($R^2 > 0.65$ for all parameters). ROC analysis identified a WHTR cut-off of 0.625 with excellent sensitivity (98.5%) and specificity (up to 100%) for detecting elevated lipid levels. **Conclusion:** This study confirms that waist-to-height ratio (WHTR) is a strong, non-invasive predictor of dyslipidaemia and cardiovascular disease (CVD) risk in patients with metabolic dysfunction-associated fatty liver disease (MAFLD), outperforming body mass index (BMI) and other anthropometric indices. Consistent with previous studies from Asian and Indian populations, WHTR demonstrated superior sensitivity to visceral fat, a key driver of metabolic risk. With its fixed cut-off, simplicity, and low cost, WHTR is particularly well-suited for use in primary care and resource-limited settings. A WHTR threshold of ≥ 0.625 may serve as a practical and reliable screening tool for identifying high-risk individuals, enabling early detection and timely intervention in environments where access to biochemical testing is limited.

Keywords: Anthropometry; Dyslipidaemias; Non-alcoholic fatty liver disease; Resource-Limited Settings; Risk Factors.

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INTRODUCTION

Metabolic dysfunction-associated fatty liver disease (MAFLD), formerly termed non-alcoholic fatty liver disease (NAFLD), denotes a redefined clinical entity that emphasizes the underlying metabolic dysfunction rather than exclusion of alcohol use or other liver diseases. According to the recent international consensus, the diagnosis of MAFLD requires evidence of hepatic steatosis accompanied by at least one of the following criteria: overweight or obesity, type 2 diabetes mellitus, or signs of metabolic dysfunction in individuals who are not obese.^[1] This inclusive definition aligns better with clinical practice and reflects the metabolic nature of the disease.^[2]

MAFLD has become a significant public health issue, impacting approximately 25–30% of people worldwide, with

even higher prevalence in South Asian countries, including India.^[3] In India, the prevalence of MAFLD ranges between 9% and 32% in different population groups, with increasing detection rates due to urbanization, sedentary lifestyle, and rising incidence of obesity and metabolic syndrome.^[4] MAFLD not

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only leads to progressive liver disease, such as steatohepatitis and cirrhosis, but also significantly escalates the risk of cardiovascular diseases (CVD), which remain the leading cause of mortality in these patients.^[5,6]

Atherogenic dyslipidemia—characterized by elevated triglycerides, increased levels of low-density lipoprotein cholesterol (LDL-C) and non-high-density lipoprotein cholesterol (non-HDL-C), along with reduced high-density lipoprotein cholesterol (HDL-C)—is highly prevalent in MAFLD and serves as a major contributor to cardiovascular morbidity and mortality.^[7,8] Monitoring lipid parameters is essential for risk stratification and timely intervention to reduce the cardiovascular burden in patients with MAFLD. However, in resource-constrained settings, access to advanced biochemical testing is often limited, necessitating the identification of simple, low-cost alternatives that can aid in risk prediction.

Anthropometric indices such as body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), and waist-to-height ratio (WHTR) have been widely studied for their associations with metabolic syndrome and cardiovascular risk. Among these, WHTR has attracted significant interest due to its ability to reflect central adiposity, which is more strongly linked to metabolic complications than overall obesity.^[9] Unlike BMI, which does not differentiate between fat and lean mass, WHTR offers a more accurate and practical estimate of visceral fat accumulation, especially relevant in South Asian populations known to have higher abdominal fat at lower BMI thresholds.^[10,11]

Recent evidence suggests that WHTR predicts cardiometabolic risk better than BMI or WC alone.^[12,13] Moreover, it is an inexpensive, noninvasive tool that can be easily applied in primary care settings without needing age— or sex-specific reference values, making it particularly valuable in rural and low-resource environments.

Despite growing interest in the clinical use of anthropometric measures, data on their validity and predictive value in MAFLD populations, particularly in India, remain scarce. Therefore, the present study evaluated the relationship between anthropometric parameters and lipid profiles in patients with MAFLD and identified the most useful anthropometric marker for predicting cardiovascular risk in a resource-limited setting. This study seeks to contribute to cost-effective risk-stratification strategies for MAFLD patients in resource-limited environments by identifying simple and reliable predictors of dyslipidemia.

MATERIALS AND METHODS

Study Design and Setting: This study employed a cross-sectional design and was conducted in a hospital setting in the Departments of Biochemistry and Medicine at the Himalayan Institute of Medical Sciences, Swami Rama Himalayan University, Jolly Grant, Dehradun, India. It lasted five months (Dec 2024 to April 2025).

Study Participants: Three hundred fifty adult individuals aged 18 years and above, diagnosed with non-alcoholic fatty liver disease (NAFLD) based on ultrasonographic findings,

were enrolled consecutively from the inpatient and outpatient departments of General Medicine. Patients with a history of alcohol consumption, known chronic liver disease of other etiologies (e.g., viral hepatitis, autoimmune hepatitis), or use of hepatotoxic drugs were excluded.

Ethical Considerations: Ethical clearance was obtained from the Institutional Ethics Committee via letter no. HIMS/RC/2024/284 dated 30/11/2024. Before data collection commenced, written informed consent was obtained from all participants.

Data Collection: Anthropometric Parameters: All participants underwent anthropometric assessments using standardized procedures. Body weight (in kilograms) was measured using a calibrated digital scale with a precision of 0.1 kg. Height (in centimetres) was measured using a stadiometer, accurate to the nearest 0.1 cm. Waist circumference (WC, in cm) was recorded midpoint between the lower margin of the last palpable rib and the top of the iliac crest. In contrast, hip circumference (HC, in cm) was measured at the widest part of the buttocks. Waist-to-hip ratio (WHR) was calculated by dividing WC by HC, and waist-to-height ratio (WHTR) was derived by dividing WC by height. Body mass

The body mass index (BMI, in kg/m²) was calculated by dividing body weight in kilograms by the square of height in meters.

Biochemical Parameters: After an overnight fast, venous blood samples were collected from all participants and analyzed for lipid profile parameters using the Beckman Coulter DxC 700 AU analyzer. Total cholesterol (Chol), triglycerides (TG), and high-density lipoprotein cholesterol (HDL-C) were measured using enzymatic methods. Non-HDL cholesterol was calculated by subtracting HDL-C from total cholesterol. Very low-density lipoprotein cholesterol (VLDL-C) and low-density lipoprotein cholesterol (LDL-C) were calculated using the Friedewald formula.^[14]

Statistical Analysis: Data were entered and analysed using SPSS (version 25.0) and Microsoft Excel. Descriptive statistics were calculated as mean \pm standard deviation (SD) for continuous variables, and frequency with percentage for categorical variables. The Shapiro-Wilk test was applied to assess the normality of data distribution. Pearson's correlation coefficient was used to evaluate the linear relationships between anthropometric indices and lipid parameters, with a two-tailed p-value of <0.05 considered statistically significant. Simple linear regression analysis was conducted to determine the predictive value of anthropometric indices for lipid parameters, with R² and adjusted R² values reported to indicate the model's strength. Receiver Operating Characteristic (ROC) curve analysis was performed to evaluate the waist-to-height ratio (WHTR) diagnostic ability in identifying elevated lipid values, including triglycerides, total cholesterol, and non-HDL cholesterol. The optimal WHTR cut-off was determined using the Youden Index (sensitivity + specificity – 1), and area under the curve (AUC), sensitivity, specificity, and corresponding cut-off values were reported.

RESULTS

The study included 350 participants diagnosed with MAFLD. The mean age of the study participants was 46.85 ± 12.1 years,

with a median age of 47 years, indicating a middle-aged population. Regarding gender distribution, the study population comprised 223 males (63.71%) and 127 females (36.29%), showing a higher prevalence of MAFLD among males in this cross-sectional study.

[Table 1] shows the mean and standard deviation of age, anthropometric parameters, and lipid profiles of participants. The results indicate a generally dyslipidaemic profile among the study participants, with a mean LDL-C of 180.89 ± 52.1 mg/dL and a mean non-HDL-C of 223.1 ± 84.99 mg/dL. This is consistent with an elevated risk of cardiovascular disease in individuals with MAFLD.

Additionally, the anthropometric measurements reveal a significant prevalence of central and overall obesity. The mean BMI falls within the obese range (32.39 ± 5.01 kg/m²), while the mean Waist-to-Height Ratio (WHTR > 0.6) and Waist-to-Hip Ratio (WHPR > 0.9) further support the presence of increased cardiovascular risk in this population. Correlation analysis demonstrated statistically significant associations between anthropometric indices and lipid parameters. WHTR showed a strong and positive correlation with triglycerides ($r = 0.77$, $p < 0.001$), total cholesterol ($r = 0.82$, $p < 0.001$), and non-HDL cholesterol ($r = 0.81$, $p < 0.001$). Similarly, waist circumference also correlated significantly with TG ($r = 0.63$, $p < 0.001$), total cholesterol ($r = 0.66$, $p < 0.001$), and non-HDL cholesterol ($r = 0.66$, $p < 0.001$). While BMI demonstrated a moderate correlation with these lipid parameters ($r \approx 0.49-0.5$, $p < 0.001$), the waist-to-hip ratio (WHR) showed weaker associations. WHTR consistently exhibited the highest correlation values across all lipid fractions, as depicted in [Table 2 and Figure 1-3], among all anthropometric measures. Non-HDL cholesterol showed a strong positive correlation with WHTR, unlike LDL-C ($r = 0.22$, $p < 0.001$), which had a weak association. This highlights non-HDL-C as a more comprehensive indicator of atherogenicity linked to central obesity in MAFLD patients.

A statistically significant negative correlation was observed between WHTR and HDL-C levels ($r = -0.35$, $p < 0.001$), indicating that HDL-C tends to decrease as the waist-to-height ratio increases, as shown in Figure 4. This inverse relationship reinforces the role of central obesity in contributing to atherogenic dyslipidaemia among patients with MAFLD.

Linear regression analyses were conducted with WHTR as the independent variable to assess predictive strength further. WHTR emerged as a significant linear predictor of triglycerides ($R = 0.77$, $R^2 = 0.59$, $F = 28.29$, $p < 0.001$), total cholesterol ($R = 0.82$, $R^2 = 0.67$, $F = 694.75$, $p < 0.001$), and non-HDL cholesterol ($R = 0.81$, $R^2 = 0.66$, $F = 661.34$, $p < 0.001$). These models confirmed that WHTR accounted for over 65% of the variance in total and non-HDL cholesterol levels, reinforcing its role as a key predictor of cardiovascular risk among MAFLD patients.

A receiver operating characteristic (ROC) curve analysis was conducted to identify the optimal cut-off value of WHTR and predict dyslipidaemia. For all three lipid parameters—triglycerides, total cholesterol, and non-HDL cholesterol—a WHTR threshold of 0.625 demonstrated the highest

diagnostic accuracy. At this cut-off, the sensitivity was 98.5% and the specificity was 100% for total and non-HDL cholesterol, with a slightly lower but still high specificity for triglycerides. The area under the ROC curve (AUC) approached 0.99 for total cholesterol (Figure 5), and approximately 0.985 for triglycerides and non-HDL cholesterol, indicating excellent predictive performance. The Youden Index was maximized at the 0.625 cut-off across all analyses, confirming this threshold as the most effective discriminator of abnormal lipid values.

In summary, this study's results highlight the utility of WHTR as a superior anthropometric indicator of cardiovascular disease risk in individuals with MAFLD. Its strong correlation with key lipid parameters, excellent predictive accuracy, and ease of measurement suggest that $WHTR \geq 0.625$ could serve as an easy and reliable tool for screening and early identification of individuals at high cardiometabolic risk, particularly in resource-limited clinical settings.

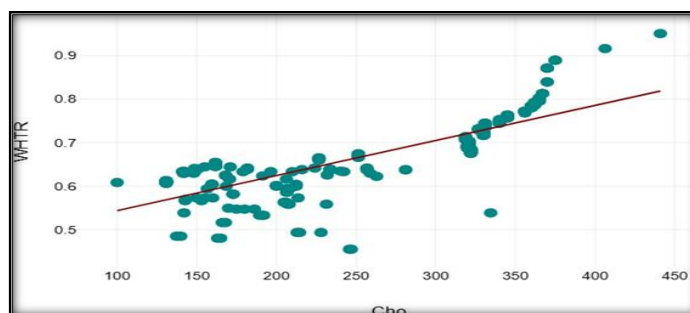


Figure 1: Scatter Diagram between Serum Cholesterol and Waist to height ratio. WHTR showed a strong and positive correlation with total cholesterol ($r = 0.82$, $p < 0.001$).

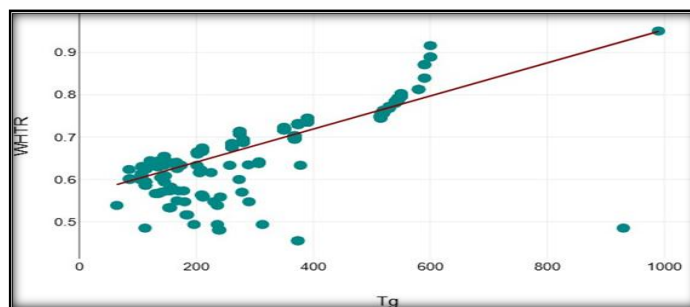


Figure 2: Scatter diagram between Serum Triglycerides and Weight to height ratio. WHTR showed a strong and positive correlation with triglycerides ($r = 0.77$, $p < 0.001$).

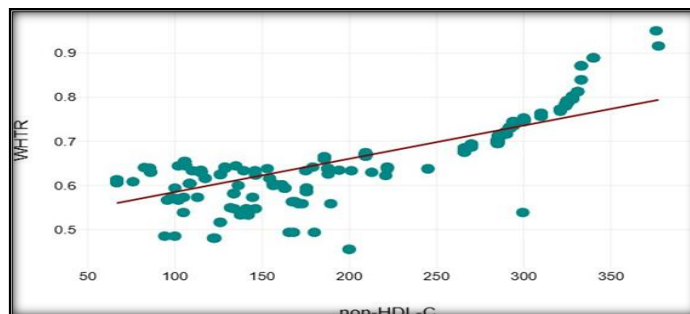


Figure 3: Scatter diagram between non-HDL-C and waist to height ratio. WHTR showed a strong and positive correlation with non-HDL cholesterol ($R = 0.81$, $R^2 = 0.66$, $F = 661.34$, $p < 0.001$).

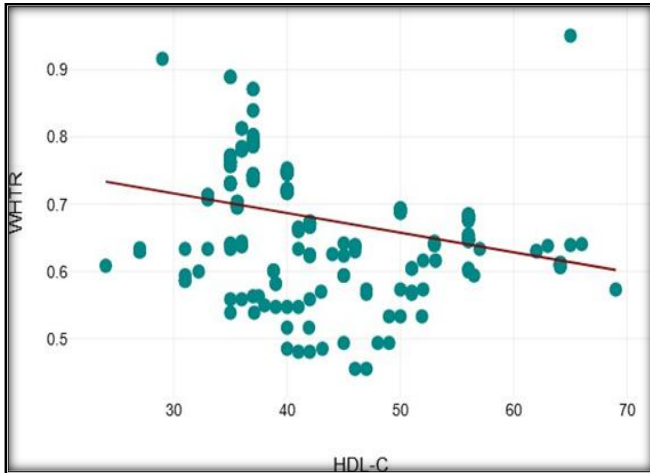


Figure 4: Scatter diagram between HDL-C and Waist to height ratio. A statistically significant negative correlation was observed between WHTR and HDL-C levels ($r = -0.35$, $p < 0.001$).

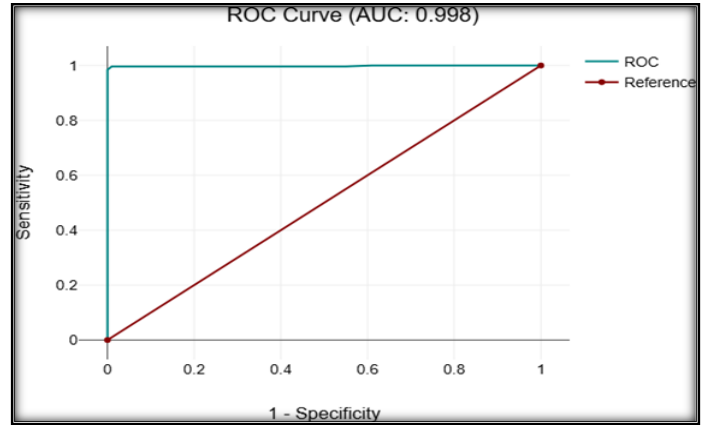


Figure 5: The area under the ROC curve (AUC) approached 0.99 for total cholesterol and approximately 0.985 for triglycerides and non-HDL cholesterol, indicating excellent predictive performance. The Youden Index was maximized at the 0.625 cut-off across all analyses. At this cut-off, the sensitivity was 98.5% and the specificity was 100% for total and non-HDL cholesterol.

Table 1: Mean and Standard Deviation of Age, Anthropometric Parameters, and Lipid Profile of Study Participants.

Parameters	Mean \pm SD (n=350)
Age	46.85 \pm 12.1
Men	63.71%
Women	36.29%
Body Mass Index (kg/m ²)	32.39 \pm 5.01
Waist Circumference (cm)	106.02 \pm 10.48
Hip Circumference (cm)	113.25 \pm 9.86
Waist to Height Ratio (WHTR)	0.68 \pm 0.08
Waist to Hip Ratio (WHPR)	0.94 \pm 0.05
LDL-C (mg/dl)	180.89 \pm 52.1
TG (mg/dl)	293.74 \pm 156.94
Total cholesterol (mg/dl)	266.17 \pm 80.14
HDL-C (mg/dl)	43.08 \pm 9.57
Non-HDL-C (mg/dl)	223.1 \pm 84.99

Table 2: Correlation analysis of WHTR with Lipid Parameters

Lipid Parameter		Correlation with WHTR
TG	Correlation	0.77
	p	<.001
Chol	Correlation	0.82
	p	<.001
LDL-C	Correlation	0.22
	p	<.001
VLDL-C	Correlation	0.77
	p	<.001
HDL-C	Correlation	-0.35
	p	<.001
Non-HDL-C	Correlation	0.81
	p	<.001

DISCUSSION

This cross-sectional study demonstrated a strong association between the waist-to-height ratio (WHTR) and dyslipidaemia in patients with MAFLD. Among the anthropometric indices evaluated, WHTR exhibited the strongest positive correlations with triglycerides, total cholesterol, and non-HDL cholesterol, all with high statistical significance ($p < 0.001$). Linear regression models confirmed WHTR as a robust predictor of lipid parameters, accounting for over 65% of the variance in total and non-HDL cholesterol levels. Receiver operating characteristic

(ROC) analysis revealed a WHTR cut-off of 0.625 as optimal for predicting dyslipidaemia, offering excellent sensitivity and specificity. These findings support the use of WHTR as a reliable marker for cardiovascular disease (CVD) risk in MAFLD patients.

Compared to the weaker association with LDL-C, the strong correlation between WHTR and non-HDL cholesterol underscores the value of non-HDL-C as a more inclusive indicator of atherogenic lipid burden. Non-HDL-C includes all atherogenic lipoproteins—LDL, VLDL, IDL, and lipoprotein remnants—many of which are elevated in insulin-resistant and

centrally obese individuals. In contrast, LDL-C alone does not reflect the full spectrum of lipoprotein abnormalities seen in MAFLD, particularly in the presence of elevated triglycerides. Given the metabolic heterogeneity of MAFLD and the high prevalence of mixed dyslipidaemia, non-HDL-C offers a more reliable lipid parameter for cardiovascular risk stratification. Its strong association with WHTR further supports using simple anthropometric tools to predict clinically relevant lipid abnormalities in resource-limited settings.

Our findings are consistent with several studies conducted in Asian and Indian populations advocating WHTR as a superior anthropometric tool. For instance, in a study conducted among Chinese Han adolescents, WHTR was closely linked with increased metabolic risk factors, including triglyceride levels and fasting plasma glucose, even in individuals with a normal BMI.^[15] In an urban Indian cohort, research showed that WHTR ≥ 0.50 effectively identified individuals with central obesity and associated metabolic abnormalities, despite many having BMI within the normal range.^[15] These studies highlight the ability of WHTR to detect visceral adiposity, a key driver of metabolic dysfunction, which BMI often overlooks.

In the Indian context, a study in rural Telangana comparing different obesity indices concluded that WHTR was at least as effective as BMI and waist circumference in predicting cardiometabolic risk, with the added advantage of being simple and applicable across sexes and age groups.^[16] Similarly, a study from urban slums in Mumbai emphasized that WHTR detected cardiometabolic risk better than BMI in women with central obesity but normal weight.^[17] These findings parallel our results, strengthening the argument that WHTR is a practical and effective tool for identifying metabolic risk, especially in Asian populations who are more prone to central adiposity even at lower BMI thresholds.^[18] The superiority of WHTR over BMI lies in its ability to reflect central fat distribution, which is more closely linked to insulin resistance, dyslipidaemia, and cardiovascular morbidity than overall body mass.^[19] Unlike BMI, WHTR does not require age- and sex-specific cut-offs, making it easier to implement in clinical and community settings. Moreover, WHTR is not influenced by muscle mass or bone density, which can confound BMI interpretations, especially in specific populations like older people or those with sarcopenia.^[20]

Identifying a simple, cost-effective screening tool is essential in the context of MAFLD, where hepatic fat accumulation is often accompanied by visceral adiposity and metabolic derangements. WHTR fulfils this requirement, and our study reaffirms its predictive power. Given the rising burden of MAFLD and cardiovascular diseases in resource-constrained settings like India, the routine use of WHTR in clinical evaluations could significantly improve early detection and intervention strategies.

However, the current study has some limitations. It is cross-sectional in design and cannot establish temporal or causal relationships. Additionally, the study population was confined to a single centre and comprised only patients diagnosed with MAFLD, which may limit the

generalizability of findings to the broader population. Future longitudinal and multicentric studies are warranted to validate these findings and explore the prognostic value of WHTR in predicting long-term cardiovascular outcomes. Also, reliance on self-reported data, such as patient-reported alcohol intake, introduces potential inaccuracies and biases related to the honesty and precision of the data collection process.

CONCLUSION

In conclusion, WHTR emerged as a superior anthropometric index for predicting dyslipidaemia and cardiovascular risk in individuals with MAFLD. WHTR cut-off levels of 0.625 demonstrated excellent diagnostic accuracy and may be adopted as a practical screening threshold in routine clinical practice. Given its simplicity, low cost, and strong predictive ability, WHTR has the potential to replace or supplement BMI in both clinical and public health settings, particularly in Asian populations with high cardiometabolic vulnerability.

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Conflicts of interest

There are no conflicts of interest.

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