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Investigating the Association of Ankle Dorsiflexion Range With Y Balance Test, Single Leg Hop for Distance and Body Composition in Collegiate Athletes

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ABSTRACT

Ankle sprains are prevalent among athletes, and decreased ankle dorsiflexion range of motion (ADROM) can contribute to these injuries. Various tests like the Y Balance Test (YBT), Single Leg Hop for Distance (SLHD), Weight-Bearing Lunge Test (WBLT), and Body Mass Index (BMI) are used to evaluate ankle function. The primary purpose of this study was to find out the correlation between ADROM and SLHD, WBLT, YBT, and BMI. Fifty-two collegiate athletes were recruited after eliminating athletes with a history of injuries to the lower extremities. The study discovered strong positive correlations between YBT anterior reach, ADROM ($r = 0.72$, $p<0.001$), and WBLT ($r = 0.64$, $p<0.001$). ADROM and WBLT were found through regression analysis to be significant predictors of YBT performance, particularly in the anterior reach direction. While body composition measures like BMI and total fat did not significantly correlate with YBT scores, SLHD did show a moderate correlation with YBT performance. These results imply that improving weight-bearing lunge capacity and ankle dorsiflexion may help male collegiate athletes achieve better dynamic balance. Including specific exercises to and strengthen WBLT and ADROM capacities in training regimens may lower the possibility of lower extremity injuries.

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INTRODUCTION

Ankle sprains are the most common musculoskeletal injury in athletes and the general population (Hodgkins & Wessling, 2021; Hootman et al., 2007). Decreased ankle dorsiflexion range of motion (ADROM) has a significant role in causing ankle injuries (Drewes et al., 2009; Irving et al., 2006). Therefore, the ankle joint requires extra attention from physiotherapists, strength and conditioning coaches, and other health professionals working with athletes to understand better the performance characteristics of the ankles and how they are associated with improved balance and jumping. Ankle function can be measured by assessing the range of motion and performing various functional tests. ADROM is often measured by practitioners in the off-season or during pre-participation examinations. Methods that require measuring ADROM in weight-bearing are used more because they reflect lower extremity function during activity (Hoch et al., 2011; Terada et al., 2014). The Weight-Bearing Lunge Test (WBLT) involves performing a forward lunge in a tandem walk and is becoming increasingly accepted (Bennell et al., 1998). Two common functional tests utilized to check ankle joints are the Y Balance Test (YBT) and Single Leg Hop for Distance (SLHD), which help analyze dynamic balance and ankle function (Ageberg & Cronström, 2018; Hartley et al., 2018). Body Mass Index (BMI) is another potentially modified clinical outcome predictor of lower limb injury risk, along with reduced ADROM (Doan et al., 2010; Jespersen et al., 2014). The risk of injury is significantly higher for overweight players (Tyler et al., 2006; Yard & Comstock, 2011). Moreover, a better understanding of using a dynamic balance assessment (YBT), SLHD, and BMI, and the possible associations with reduced ADROM may help coaches and practitioners develop individualized interventions for improving sports performance and reducing ankle injury risk.

Leg asymmetries in the anterior direction of YBT have been associated with a greater than two-fold increase in the risk of lower extremity injury (Smith et al., 2015). Evidence suggests a connection between ankle instability and impaired performance on the SLHD test (Hartley et al., 2018). An increased risk of ankle injury in athletes and chronic ankle instability has been demonstrated to be correlated with BMI (Gribble et al., 2016; Hershkovich et al., 2015). Previous research has not comprehensively examined these variables combined and focused on Indian athletes. Therefore, the associations among these factors in the context of Indian athletes remain underexplored and warrant further investigation to provide relevant insights and applications for this population.

A study of 35 healthy people indicated that limited dorsiflexion may impact dynamic balance, especially in the anterior direction, as the WBLT strongly predicted 28% of the variance in the anterior reach distance (r = 0.53; Hoch et al., 2011). Thirty-one rugby players' dynamic balance, jump performance, and landing patterns were examined in a different study. Significant positive associations were discovered between Counter Movement Jump (CMJ; r = 0.72) and the composite score of the YBT (r = 0.51) and SLHD. Moderate relationships were found in the posterolateral, posteromedial, and composite directions between the SLHD and the YBT. Based on playing position and limb dominance, 58 amateur male rugby players' YBT scores, ADROM, single-leg drop jump (SLDJ), and SLHD scores were compared and correlated. ADROM was connected with SLHD and YBT scores only in the backs, not forward rugby players. The information gap in the current literature remains inconclusive as to whether only the YBT scores in the anterior direction are linked to ADROM or if other YBT directions are also correlated. Additionally, there is a disparity in the correlation between ADROM, SLHD, and dynamic balance across player positions in rugby, as backs demonstrated stronger associations than forwards. This inconsistency raises doubts about the strength of the relationship between ADROM, YBT, and SLHD, suggesting the need for further research to clarify these associations and their implications for athletic performance and injury risk.

To the authors' knowledge, no study has yet been conducted to examine the relationship between an athlete's dynamic balance, ADROM, SLHD, and body composition. Therefore, this study aimed to determine how ankle dorsiflexion range, body composition measurement, and dynamic balance are related. It is hypothesized that ADROM significantly correlates with both the dynamic balance (YBT) in all directions and SLHD. Additionally, these correlations are contingent upon body composition.

METHODS

Participants

A power analysis was conducted to determine the appropriate sample size for this study, ensuring sufficient statistical power to detect meaningful effects (Overmoyer & Reiser, 2015). Fifty-two male collegiate athletes (age: 19.62 ± 1.54 years, height: 170.54 ± 11.17 cm, mass: 60.92 ± 8.84) represented at the university level were recruited. Athletes with a history of ankle sprains, surgery of the lower extremities, self-reported impairments in the foot and ankle, and vestibular disorders were excluded. The Institutional Ethics Committee of Suresh Gyan Vihar University (Approval number: 217/SG 23/02/2024) approved the experimental methodology for this study, which adhered to the Declaration of Helsinki. Written informed consent was obtained, and each participant received complete information about the testing procedures. Participants were scheduled for a single testing session at the facility.

Data Collection Tools

The Omron Karada Scan HBF-224 was used for the BIA measurements in order to determine body composition. A universal goniometer was used to measure ADROM. The YBT was conducted using the Y junction, marked on the ground with securely affixed tape.

Data Collection Procedure

A cross-sectional design was utilized to identify the association between the results of the WBLT, ADROM, and YBT performance (normalized reach distance at maximal reach in each direction) and body composition analysis. Participants were instructed to limit their exercise to regular everyday activities the day before and the day of the test and to refrain from performing strenuous exercises for their back and lower limbs 48 hours before the visit. The assessments were conducted sequentially to ensure consistency and reduce the impact of fatigue or other confounding variables. First, the participant's height and weight were measured, followed by the assessment of body composition using Bioelectrical Impedance Analysis (BIA). Once these baseline measurements were taken, the evaluation of ADROM was carried out. Afterward, participants underwent the YBT to assess dynamic balance. Lastly, SLHD was performed.

Anthropometric Measurement

Upon arrival and confirmation of eligibility, participants were introduced to the testing protocol, followed by an assessment of their body weight and height. The height was measured in centimeters with a precision of 0.5 cm using a vertically placed rigid ruler fastened with a stable base. The weight was measured in kilograms with an accuracy of 0.1 kg using a mechanical scale. The Controller of Legal Metrology (Weights & Measures), India, officially verified the scale employed. Limb length was measured using a conventional tape measure. The starting point was the anterior superior iliac spine, and the endpoint was the center of the medial malleolus. This measurement was conducted while the participants were lying supine on a plinth. To determine leg dominance, participants were asked, "If you would shoot a ball on a target, which leg would you use to shoot the ball?" (van Melick et al., 2017). The BIA measurements were conducted using the Omron Karada Scan HBF-224 to assess body composition. Before the BIA measurement, each participant wore minimum clothing, removed metal jewelry, and rested supine for five minutes to equilibrate bodily fluids.

Range of Motion Measurement

ADROM was determined by two measures: utilizing a universal goniometer and WBLT. Goniometer measurements were taken with the individual actively moving the joint in the dorsiflexion in supine (Norkin, 2016). The goniometer has moderate reliability, with intra-class correlation coefficient (ICC) scores of 0.55–0.61. A single examiner performed all measurements of ankle dorsiflexion range of motion (ADROM) to minimize inter-examiner variability (Worsley et al., 2018). The joint position was sustained for 5–10 seconds while a measurement was collected. An average range of three trials was included in the study. To assess their maximum weight-bearing dorsiflexion range, the subjects completed the WBLT (Vicenzino et al., 2006). The subjects completed three practice trials on each limb, flexing their knee to the wall while maintaining a firm test heel placement on the floor. During the test, stability was maintained by placing the opposing extremity behind the test foot. The great toe's distance from the wall, measured in centimeters, was defined as the furthest the foot could be positioned without the heel lifting off the floor and the knee still being able to make contact with the wall. Following three practice trials, three trials were recorded, and an average of three was utilized in the study.

Y balance test

YBT was completed in three directions: anterior, posteromedial, and posterolateral (Plisky et al., 2006). The Y junction, indicated on the ground by tape measures fastened in an inextensible manner, was where the distal side of the athlete’s great toe touched. The participants used their dominant and non-dominant legs to reach all three directions. For the trial to be deemed correct, the participant had to keep their hands always on their hips, gently brush the measuring tape at the furthest distance without redirecting their weight onto the reaching foot, and return to a single-leg standing position for a minimum of two seconds. An average of three testing trials in each direction was considered for analysis. Scores were calculated by dividing the average reach distance (in cm) by each participant's leg length. To obtain the composite, the average reach in each of the three directions was divided by three leg lengths, and the outcome was then multiplied by 100%. Composite reach distance (%) = Sum of the 3 reach directions / 3 times the limb length * 100.

Single Leg Hop for Distance

The participants executed SLHD, as outlined by Daniel et al. (1988). This jump is executed with one leg to achieve the greatest possible horizontal distance (Daniel, 1988). During this activity, the arms are positioned behind the body, and participants must wear athletic footwear. Three trials of the single-leg hop for distance were conducted, and the average of the three trials was analyzed.

Statistical Analyses

Statistical analysis was performed using SPSS v26.0, Armonk, New York. Outcomes were analyzed for a normal distribution using the Kolmogorov-Smirnov test. Pearson correlation test was applied to find the correlation between YBT, ADROM (Goniometer), WBLT, SLHD, and body composition. A linear regression analysis was run to find the correlation between a criterion variable and a set of predictors. Probability of Type I error < 0.05 was accepted as the level of significance.

RESULTS

The normality test results indicated that the data followed a normal distribution (p > 0.5). Table 1 represents the demographic characteristics of the participants.

Table 1
Demographic Characteristics

Demographic Characteristics	Mean ± SD
Age (years)	19.62 ± 1.54
Height (cm)	170 ± 11.17
Weight (kg)	60.92 ± 8.84
BMI (kg/m2)	20.41 ± 2.59
Skeletal muscle mass (%)	31.55 ± 3.41
Total fat (%)	19.58 ± 5.48

Table 2 displays the mean and standard deviation (SD) values for ankle range, WBLT, and YBT measures while comparing the dominant leg (DL) and non-dominant leg (NDL). The non-dominant leg consistently exhibits higher mean values than the dominant leg across all metrics. Nevertheless, the disparities are typically minor, and the standard deviations imply a certain degree of overlap, indicating that the discrepancies may not be significant.

Table 3 presents the outcomes of the Pearson correlation analysis between the ankle dorsiflexion ROM measured by goniometer, WBLT, measurements from the YBT, body composition metrics, and SLHD. Strong positive correlations were present between YBT anterior reach with WBLT ($r = 0.64$, $p < 0.001$) and ankle dorsiflexion ROM ($r = 0.72$, $p < 0.001$). A moderately significant positive correlation is observed between YBT composite score with WBLT (r = 0.43, p <0.05) and ankle dorsiflexion ROM (r = 0.37, p<0.05). The associations observed in the posteromedial and posterolateral reaches in the Y Balance Test (YBT) are weaker and less reliable. Weak and non-significant associations between WBLT ankle dorsiflexion ROM and body composition parameters (BMI, skeletal muscle mass, and total fat) and SLHD are seen.

Table 2
Ankle Dorsiflexion ROM, WBLT, and Y Balance Test Scores for Dominant and Non-Dominant Legs

Tests	Mean ± SD	
	Dominant Leg	Non-Dominant Leg
Ankle DF ROM (degrees)	14.10 ± 3.12	14.63 ± 2.99
WBLT (cm)	10.96 ± 1.66	11.65 ± 1.63
Anterior reach YBT (%)	77.55 ± 7.63	81.08 ± 7.01
Posterolateral reach YBT (%)	104.70 ± 9.25	107.72 ± 8.63
Posteromedial reach YBT (%)	101.33 ± 8.31	103.98 ± 9.67
Composite Score (%)	94.53 ± 6.36	97.60 ± 6.34

Table 3
Result of Pearson Correlation Between WBLT, Ankle Dorsiflexion ROM with YBT, Body Composition, and SLHD

Tests			WBLT		Ankle Dorsiflexion ROM	
			DL	NDL	DL	NDL
Y Balance Test	**Anterior**	**DL**	r = 0.64 p <0.001*	r = 0.59 p<0.001*	r = 0.72 p<0.001*	r = 0.68 p<0.001*
		NDL	r = 0.57 p<0.001*	r = 0.60 p<0.001*	r =0.66 p<0.001*	r=0.62 p<0.001*
	Posteromedial	**DL**	r = 0.39 p<0.05*	r = 0.36 p<0.05*	r = 0.22 p = 0.10	r = 0.23 p = 0.10
		NDL	r = 0.33 p<0.05*	r = 0.37 p<0.05*	r = 0.10 p = 0.46	r = 0.20 p = 0.16
	Posterolateral	**DL**	r = 0.11 p = 0.94	r = 0.44 p = 0.76	r = 0.03 p = 0.83	r = 0.03 p = 0.80
		NDL	r = 0.14 p = 0.30	r = 0.20 p = 0.16	r = 0.04 p = 0.76	r = 0.04 p = 0.75
	Composite Score	**DL**	r = 0.43 p<0.05*	r = 0.42 p<0.05*	r = 0.37 p<0.05*	r = 0.35 p<0.05*
		NDL	r = 0.44 p<0.05*	r = 0.50 p<0.001*	r = 0.28 p<0.05*	r = 0.31 p<0.05*
Body Composition	**BMI**		r = -0.23 p = 0.09	r = -0.24 p = 0.08	r = -0.98 p = 0.49	r = -0.10 p = 0.47
	Skeletal Muscle Mass		r = 0.26 p = 0.06	r = 0.17 p = 0.22	r = 0.22 p = 0.10	r = 0.19 p = 0.17
	Total Fat		r = -0.18 p = 0.20	r = -.020 p = 0.14	r = -0.98 p = 0.49	r = -0.10 p = 0.47
SLHD	**DL**		r = 0.09 p = 0.49	r = 0.09 p = 0.51	r = 0.25 p = 0.70	r = 0.20 p = 0.14
	NDL		r = 0.15 p = 0.28	r = 0.16 p = 0.25	r = 0.23 p = 0.09	r = 0.19 p = 0.17

Note. *: statistically significant; Ant– Anterior, PM- Posteromedial, PL- Posterolateral, CS- Composite Score, DL- Dominant Leg, NDL– Non-Dominant Leg, WBLT- Weight Bearing Lunge Test, SLHD- Single Leg Hop for Distance, ROM- Range of Motion, BMI- Body Mass Index

Table 4 presents the findings of a linear regression analysis conducted to predict YBT performance based on many independent variables. WBLT indicates a strong positive association (r = 0.64 for DL and r = 0.60 for NDL) with high adjusted R^2 values (0.40 and 0.35, respectively), indicating a meaningful predictor with p-values <0.001. SLHD exhibits a moderate association (r = 0.35 for DL and r = 0.34 for NDL) with lower adjusted R^2 values (0.10 and 0.12, respectively) and significant p-values <0.05. Ankle ROM displays the strongest correlation (r = 0.72 for DL and r = 0.62 for NDL) and the highest adjusted R^2 values (0.51 and 0.38, respectively), being the most significant predictor with p-values <0.001. The analysis suggests the importance of WBLT, SLHD, and Ankle ROM in predicting YBT performance. However, Total Fat and BMI do not significantly contribute to the prediction models.

Table 4

Variables Included in Linear Regression Analysis for Predicting YBT Performance

Dependent Variable	Independent Variable	Correlation coefficient	Adjusted R2	Degree of freedoms	F stats	p-value
Ant-YBT (%) (DL)	**WBLT**	0.64	0.40	(1,50)	34.34	<0.001*
	SLHD	0.35	0.10	(1,50)	6.86	<0.05*
	Ankle ROM	0.72	0.51	(1,50)	54.98	<0.001*
	Total Fat	0.06	-0.16	(1,50)	0.18	0.67
	BMI	0.11	-0.01	(1,50)	0.63	0.42
	Skeletal Muscle Mass	0.30	0.08	(1,50)	4.84	<0.05*
Ant-YBT (%) (NDL)	**WBLT**	0.60	0.35	(1,50)	28.28	<0.001*
	SLHD	0.34	0.12	(1,50)	6.60	<0.05*
	Ankle ROM	0.62	0.38	(1,50)	31.33	<0.001*
	Total Fat	0.06	-0.01	(1,50)	0.18	0.67
	BMI	0.09	-0.01	(1,50)	0.46	0.50
	Skeletal Muscle Mass	0.27	0.05	(1,50)	3.86	<0.05*
CS-YBT (%) (DL)	**WBLT**	0.43	0.17	(1,50)	11.24	<0.05*
	SLHD	0.40	0.14	(1,50)	9.18	<0.05*
	Ankle ROM	0.37	0.12	(1,50)	8.12	<0.05*
	Total Fat	0.23	0.03	(1,50)	2.76	0.10
	BMI	0.26	0.05	(1,50)	3.58	0.06
	Skeletal Muscle Mass	0.18	0.01	(1,50)	1.58	0.22
CS- YBT (%) (NDL)	**WBLT**	0.50	0.23	(1,50)	16.62	<0.001*
	SLHD	0.40	0.15	(1,50)	9.88	<0.05*
	Ankle ROM	0.30	0.07	(1,50)	5.24	<0.05*
	Total Fat	0.21	0.05	(1,50)	2.34	0.13
	BMI	0.24	0.04	(1,50)	3.10	0.08
	Skeletal Muscle Mass	0.08	-0.01	(1,50)	0.33	0.57

Note. *: statistically significant, Ant– Anterior, PM- Posteromedial, PL- Posterolateral, CS- Composite Score, DL- Dominant Leg, NDL– Non-Dominant Leg, WBLT- Weight Bearing Lunge Test, SLHD- Single Leg Hop for Distance, ROM- Range of Motion, BMI- Body Mass Index

DISCUSSION

This study's main finding is that the ADROM, WBLT, and SLHD significantly influence the variability in YBT performance. Furthermore, ADROM was a predictor for the anterior direction, as commonly claimed, but also for the composite score. The findings partially support the hypothesis that ADROM strongly predicts YBT performance in all directions. The Y-Test reach scores are closely aligned with those of other research (Overmoyer & Reiser, 2013). The bilateral averages for ADROM, WBLT, and SLHD measurements were within the anticipated ranges for healthy and physically active people (Hoch et al., 2011; Kang, Lee, et al., 2015; Myers et al., 2014; Olszewski et al., 2024). A slight asymmetry was observed in this population during assessments, which aligns with findings from earlier studies (Daneshjoo et al., 2013; Knapik et al., 1991; Plisky et al., 2006).

Based on our study, we found that the ADROM was a strong predictor for both anterior reach and the composite score. Multiple studies have recognized that ADROM can be used to predict the ability to move forward (Gabriner et al., 2015; Kang, Kim, et al., 2015). There have been few studies that have found the association between ADROM and composite scores (Olszewski et al., 2024; Rafagnin et al., 2023). Consistent with previous research, we also discovered a weak but significant correlation between PM performance and WBLT (Nelson et al., 2021; Olszewski et al., 2024). Variations in administered testing protocols and sample characteristics may have caused the discrepancy between the results of the studies. It has been suggested that insufficient ADROM may lead to difficulties regulating the body's center of mass over the base of support, which can complicate balance maintenance during reach movements. Regression analysis was employed to look at the relationships between YBT performance scores (dependent variables: Anterior-YBT and CS-YBT for both dominant and non-dominant legs) and various independent variables, including WBLT, SLHD, ROM, Total Fat, BMI, and Skeletal Muscle Mass. With moderate to strong correlations and significant p-values, WBLT (35% variance) and Ankle ROM (38% variance) were the best predictors of YBT performance for both the dominant and non-dominant legs. A previous investigation that supported our findings discovered that ADROM was responsible for an estimated 28% of the variation in anterior reach (Hartley et al., 2018). Anterior reach distance variation was explained by a 31% variance of ADROM in a prior study involving participants with chronic ankle instability (Basnett et al., 2013). Additionally, results showed a slight (9% variance) correlation with the composite scores, which is less than the variance (17%) in the current study. The composite score's calculation method, which considers reaching distances in all three test directions, may have contributed to the low clinical relevance of these measure relationships. Contrary to our findings, a study discovered that lower composite scores were linked to higher ADROM values (Chimera & Larson, 2020). The observed disparity could potentially stem from variations in sample sizes and the absence of regression model segmentation based on reach direction. Consistent with previous findings, our study also observed that ADROM deficit did not significantly affect hopping performance (Jatmiko et al., 2023). This can be because other joints may have adjusted to compensate for the decreased dorsiflexion during SLHD. There is a statistically significant positive correlation between SLHD and the anterior reach and composite scores of YBT for both the dominant and non-dominant legs. The correlations are moderate, and a small but significant amount of the variance in YBT performance can be explained by SLHD: SLHD accounts for 10% (DL) and 12% (NDL) of the variance for anterior YBT. SLHD accounts for 14% (DL) and 15% (NDL) of the variance for composite score YBT. Previous studies using the YBT and power by countermovement jump and SLHD tests showed similar results illustrating the relationship between energy and dynamic balance. (Booysen et al., 2015; Wilczyński et al., 2021)

Body weight is a strong predictor among the many variables that may affect dynamic balance, and obesity is strongly linked to reduced mobility, increased postural sway, and falls (Ganesan et al., 2018). Our findings suggest a lack of significant correlation between total Fat and BMI, with the YBT performance. These study's findings were consistent with another investigation that evaluated the relationship between 149 collegiate students' YBT performance and BMI. The study shows no correlation between BMI and the YBT's normalized reach values for both limbs. (Suvarna et al., 2021) The present study's findings are inconsistent with previous research that has demonstrated a strong correlation between a higher BMI and poor performance on the YBT (Ewais et al., 2024). This discrepancy could be because this study primarily involved participants with normal BMI, which may limit the ability to detect significant correlations, as individuals within this range often experience fewer balance-related impairments. In contrast, studies that find a strong correlation typically include populations with a wider comprehensive range of BMI values, including those classified as overweight or obese, where the effects of increased body mass on balance are more pronounced. Also, methodological differences can influence outcomes, such as testing protocols and the specific populations studied.

Limitations

The study only included collegiate male athletes, so generalizing the findings to other demographic groups like females or athletes with particular injuries can not be generalized. The study's cross-sectional design collects data at a single point, making establishing a relationship between the variables difficult. Studies with a longitudinal design would be required to identify causal relationships and monitor changes over time. Future research should diversify the sample to include female athletes, non-athletes, and different age groups to ensure broader applicability of the findings. Data accuracy and relevance can be increased using advanced technology measurement tools.

CONCLUSION

Strong predictors of YBT performance include ADROM and WBLT, especially for the anterior reach direction. A noteworthy, although weaker, correlation exists between SLHD and YBT performance. Metrics of body composition like total fat and BMI do not substantially correlate or predict YBT performance. These results imply that increasing weight-bearing lunge capacity and ankle dorsiflexion range of motion may improve dynamic balance as assessed by the YBT in male collegiate athletes.

PRACTICAL IMPLICATIONS

The results of this study have critical applications for improving athletes' performance and training. Improving ADROM and WBLT capacities should be the priority for coaches and athletic trainers to improve dynamic balance, especially in the anterior direction. Performance can be improved, and specific deficiencies can be addressed with tailored training programs based on individual assessments of ADROM, WBLT, and SLHD.

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Authors' Contribution

In this paragraph, it should be explained in meaningful sentences which author made what contributions in all processes from the beginning to the end of the research.

Declaration of Conflict Interest

The authors have no conflict of interest to declare.

Ethics Statement

The Institutional Ethics Committee of Suresh Gyan Vihar University, Jaipur, Rajasthan, India, approved the study (Approval number: 217/SG 23/02/2024).

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