

Square Stepping Exercise and Dynamic Balance in Older Adults: A Pre-Experimental Study

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Abstract

Background: Age-related declines in strength, sensory integration, and neuromuscular control can impair dynamic balance and functional mobility. Square Stepping Exercise (SSE) combines multidirectional stepping with postural and cognitive demands and may be relevant to community-based balance training.

Objective: To examine changes in dynamic balance after a four-week SSE program among older adults attending a community-based Posyandu in Bandung Regency.

Methods: This pre-experimental one-group pretest-posttest study included 15 of 17 older adults screened through purposive sampling in May 2026. Participants completed 12 SSE sessions over four weeks, three sessions per week. Dynamic balance was assessed using the Timed Up and Go Test (TUGT) before and after the program. Because the within-participant difference scores were not normally distributed, the Wilcoxon signed-rank test was used as the inferential analysis. Cohen's *d* was calculated as the mean within-participant change divided by the standard deviation of the difference scores.

Results: Mean TUGT time decreased from 14.60 ± 2.23 seconds at pretest to 11.60 ± 2.72 seconds at posttest. The mean reduction was 3.00 ± 0.85 seconds (95% CI, 2.53 to 3.47), with a large within-participant effect (Cohen's *d* = 3.55; 95% CI, 2.15 to 4.94). The Wilcoxon signed-rank test indicated a statistically significant reduction ($p < 0.001$).

Conclusion: TUGT performance improved after four weeks of SSE in this community-based sample. The observed change does not establish a causal effect of SSE because the study lacked a comparison group.

Keywords

Aged; Exercise Therapy; Postural Balance; Timed Up and Go Test

Introduction

Population aging has become an important global demographic phenomenon as life expectancy increases and the proportion of older adults continues to grow. The increasing number of people aged 60 years and older creates greater demands for strategies that preserve functional capacity, mobility, and independence in later life.¹ In Indonesia, the growing proportion of older adults similarly highlights the need for community based health interventions that address functional decline associated with aging.² Aging is accompanied by progressive changes in several systems involved in movement and postural control, including reductions in muscle strength and power, alterations in sensory integration, and declines in neuromuscular responsiveness.³ These changes may compromise the ability to maintain postural stability during activities that require continuous adjustments of body position and movement.³

Dynamic balance refers to the ability to maintain or regain postural stability while the body is moving or when the base of support changes.³ This ability depends on the coordinated integration of visual, vestibular, somatosensory, and neuromuscular information to generate appropriate postural responses.⁴ Age related deterioration in these systems may impair functional mobility during walking, turning, transferring, and negotiating environmental challenges.⁵ Impaired balance and mobility are clinically important because they are associated with an increased risk of falls, functional limitations, and loss of independence among older adults.⁶ Exercise programs targeting sensorimotor control, proprioception, strength, and functional movement have therefore been investigated as strategies to improve balance related outcomes in older populations.⁷ Evidence from systematic reviews suggests that sensorimotor based exercise can improve dynamic balance in older adults, although the magnitude and certainty of effects may vary according to intervention characteristics and participant populations.⁷

Square Stepping Exercise (SSE) is a structured physical and cognitive exercise involving multidirectional stepping patterns performed on a mat divided into squares. Participants reproduce progressively challenging step sequences that require coordinated lower limb movement, postural control, spatial orientation, attention, and memory.⁸ Unlike exercises that primarily emphasize repetitive movement in a single direction, SSE requires repeated adjustments of the center of mass and base of support while participants respond to changing spatial patterns.⁸ These characteristics provide a theoretical rationale for using SSE as an exercise approach relevant to dynamic balance and functional mobility in older adults.^{8,9} The combination of physical and cognitive demands may also provide a distinct training stimulus compared with exercise programs focused predominantly on strength or repetitive walking.^{8,9}

Current evidence regarding SSE indicates potential benefits across several domains of physical and cognitive function. A scoping review of 37 studies reported considerable variation in SSE delivery, including differences in intervention format, frequency, session duration, program length, and outcome measures, with physical and cognitive function representing the principal domains evaluated.⁸ A systematic review of 12 controlled studies involving 577 participants aged 60 years and older reported favorable findings following SSE based interventions for balance, lower limb strength and power, gait speed, flexibility, and selected cognitive outcomes.⁹ These findings indicate that SSE may provide a multidimensional training stimulus relevant to the maintenance of mobility

and balance in older adults.^{8,9} However, substantial variation in intervention protocols and study settings limits the extent to which findings from one population or service context can be directly generalized to another community setting.

Several individual studies have also reported improvements in balance related outcomes following SSE. Previous research involving older adults reported reductions in Timed Up and Go Test (TUGT) performance after four weeks of SSE administered three times per week.^{10,11} Other research using different balance measures has similarly reported improved postintervention performance after an SSE program.¹¹ Nevertheless, differences in participant characteristics, baseline functional status, outcome measures, intervention implementation, and progression may contribute to variation in the magnitude of observed changes.⁸ These differences indicate the importance of evaluating SSE within specific populations and service contexts rather than assuming that findings from previous studies will be reproduced uniformly across community based older adult populations. Further evidence from routine community settings may therefore contribute to a more contextually appropriate understanding of changes in functional balance following SSE.

The research gap addressed in the present study concerns the limited evidence describing the application of a structured SSE program among older adults attending a community based Posyandu in Indonesia using an objective measure of functional mobility. Previous reviews have demonstrated considerable variation in SSE protocols and implementation settings, while existing evidence has been generated across heterogeneous populations and research environments.^{8,9} Consequently, findings from other settings cannot automatically be assumed to represent the response of older adults participating in community based programs with different demographic and functional characteristics. The present study addresses this gap by examining changes in dynamic balance measured using the TUGT before and after a four-week SSE program delivered three times per week to older adults attending Posyandu RW 27 Cipariuk, Bandung Regency.

The present study does not aim to establish definitive causal effectiveness because it uses a pre-experimental one group pretest posttest design without a comparison group. Instead, it evaluates within participant changes following a structured community-based exercise program to provide preliminary evidence regarding the observed change in dynamic balance in this specific setting. The novelty of this study lies in the contextual application of a structured SSE program among older adults attending a community based Posyandu in Indonesia and the evaluation of pre intervention and post intervention changes using an objective functional mobility measure. This context specific evidence may provide a basis for the development of future controlled studies and more rigorously designed community-based exercise programs. Accordingly, this study aimed to examine changes in dynamic balance following four weeks of SSE among older adults attending Posyandu RW 27 Cipariuk, Bandung Regency.

Methods

This study used a pre-experimental one group pretest posttest design to examine within participant changes in dynamic balance following a four-week Square Stepping Exercise (SSE) program. The study was conducted among older adults attending Posyandu RW 27 Cipariuk, Bandung Regency. Participant recruitment and initial screening were conducted in May 2026. Seventeen older adults were screened for eligibility, of whom 15 met the study criteria and were included in the intervention. Two individuals were not included: one had a history of heart disease and vertigo, which met the exclusion criteria, and one was unwilling to complete the entire study period. The sample of 15 participants therefore represented all eligible participants identified from the screened population rather than a sample determined through an a priori statistical power calculation. This approach should be considered a purposive, eligibility-based sampling strategy, and the resulting small sample size limits the precision and generalizability of the findings.

All participants received the same SSE program over four weeks, with three sessions conducted per week, resulting in a planned total of 12 sessions. The intervention was delivered and supervised directly by the researcher, who demonstrated each movement pattern before participants performed the exercise and monitored the sessions to maintain safety and reduce the risk of falls. The program was structured progressively according to the participant's ability. During week 1, participants performed basic level patterns consisting of forward and lateral stepping. During weeks 2 and 3, the program progressed to intermediate patterns involving forward, backward, and lateral stepping, while week 4 used advanced multidirectional and diagonal patterns. Each stepping pattern was performed for approximately 4 to 10 repetitions, with the core exercise lasting approximately 15 to 20 minutes per session, preceded by 5 to 10 minutes of warm up and followed by 5 to 10 minutes of cool down.

Progression was determined according to the participant's ability to perform the prescribed pattern correctly. When a participant was unable to complete a pattern correctly, the level of difficulty was maintained until the movement could be performed appropriately before further progression. No specific additional treatment or protocol modification outside this progression principle was recorded. All 15 participants completed the planned 12 SSE sessions, corresponding to 100% attendance according to the available attendance information. No adverse event resulting in termination of exercise was reported during the intervention period. However, activities performed outside the SSE sessions were not systematically recorded or monitored, and no quantitative measure of intervention fidelity beyond the documented delivery of the planned program was available. These factors were therefore considered potential sources of uncontrolled variation in the observed outcome.

Dynamic balance and functional mobility were assessed using the Timed Up and Go Test (TUGT). The TUGT was performed at both pretest and posttest using the same procedure and measurement conditions. Participants began seated on a standard chair with their back supported and both feet in contact with the floor. On the verbal command to start, the participant stood up, walked 3 m toward a cone, turned around, walked back to the chair, and sat down until the buttocks contacted the seat. Participants did not use a walking aid during the test. Completion time was measured with a stopwatch, beginning when the participant initiated standing and ending when the participant had returned to the chair and was seated stably. Each participant performed two trials at each assessment point. The measurement, recording, and data collection were performed directly by the researcher, who used the same procedure for both pretest and posttest assessments. The operational procedure was standardized across assessment occasions to minimize variation attributable to testing conditions. Evidence supporting the validity and reliability of the specific TUGT administration used in this study should be supported by an appropriate measurement property reference, preferably one addressing clinician administered TUGT in community dwelling older adults rather than self-administered TUGT.¹²

Before the intervention, baseline TUGT performance was recorded as the pretest measure. The same participants were reassessed after completion of the four-week SSE program to obtain the posttest measure. No participants were lost to follow up between the pretest and posttest assessments, and no TUGT outcome was reported as missing. Because the study did not include a comparison group, the pretest posttest comparison was interpreted as a within participant change and not as a direct estimate of the causal effect of SSE. Potential confounding factors, including usual physical activity outside the intervention, were not systematically monitored. The absence of such monitoring was considered during interpretation of the findings.

For statistical analysis, continuous TUGT data were summarized using the mean and standard deviation (SD). The primary change score was defined as pretest TUGT time minus posttest TUGT time, such that positive values represented a reduction in completion time after the intervention. The distribution of the within participant difference scores was assessed using the Shapiro Wilk test, because the normality assumption relevant to a paired comparison concerns the difference scores rather than the pretest and posttest distributions considered separately. Potential outliers in the difference scores were additionally examined using a boxplot.¹³ The choice of inferential test was based on the distributional characteristics of the difference scores. The statistical significance threshold was set at $\alpha = 0.05$, and two-sided testing was used. Mean difference and its 95% confidence interval were calculated to quantify the magnitude and precision of the observed change. An appropriate paired sample effect size was calculated from the individual change scores and reported together with its confidence interval.¹⁴ The statistical analysis was conducted using the original pretest and posttest observations without excluding participants solely on the basis of statistical outlier status.

Ethical approval was obtained from the Health Research Ethics Committee of Universitas Binawan under approval number 140/KEPK-UBN/V/2026. The study did not have a publicly registered protocol or trial registration. The research was independently funded by the authors and did not receive a specific grant from any public, commercial, or nonprofit funding agency. The authors declared no conflict of interest. These statements are included to provide transparency regarding ethical oversight, funding, conflicts of interest, and study registration.

Results

A total of 17 older adults were assessed for eligibility at Posyandu RW 27 Cipariuk, Bandung Regency, during the recruitment period in May 2026. Fifteen participants met the eligibility criteria and were included in the study, while two were excluded. One individual was excluded because of a history of heart disease and vertigo, which met the exclusion criteria, and one individual declined to participate in the complete study protocol. All 15 included participants completed both the pretest and posttest assessments and were retained in the final analysis. According to the confirmed attendance record, all 15 participants completed the planned 12 SSE sessions, corresponding to 100% attendance. No participants were lost to follow up, and no TUGT outcome data were missing. The participant flow and status at each stage are presented in Figure 1.

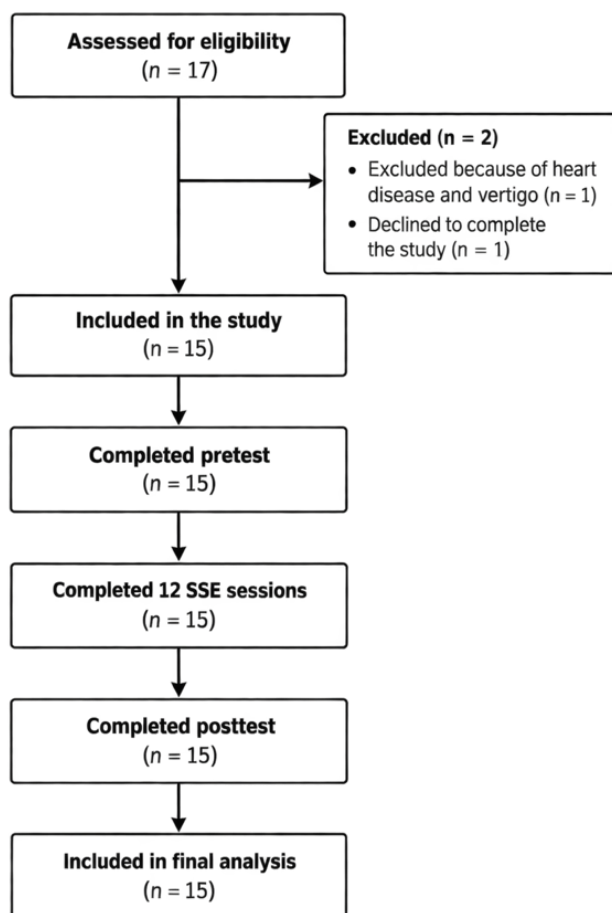


Figure 1. Participant flow

The characteristics of the 15 participants are summarized in Table 1. The mean age was 67.00 ± 3.87 years, with an observed range of 62 to 74 years. The largest age group was 66 to 70 years, comprising 7 participants (46.7%), followed by participants aged 60 to 65 years (40.0%). Women represented the majority of the sample, with 12 participants (80.0%), whereas three participants (20.0%) were men. Thus, the study population consisted predominantly of older women, an important characteristic when considering the external generalizability of the findings.

Table 1. Participant characteristics

Characteristic	Participants, n = 15
Age, years, mean $\pm$ SD	67.00 $\pm$ 3.87
Age group, n (%)	
60 to 65 years	6 (40.0)
66 to 70 years	7 (46.7)
71 to 75 years	2 (13.3)
Sex, n (%)	
Male	3 (20.0)
Female	12 (80.0)

SD, standard deviation.

Changes in TUGT performance are presented in Table 2. Mean TUGT completion time decreased from 14.60 $\pm$ 2.23 seconds at pretest to 11.60 $\pm$ 2.72 seconds at posttest. The mean within participant reduction, calculated as pretest minus posttest time, was 3.00 $\pm$ 0.85 seconds, indicating shorter completion times after the intervention period. The observed values ranged from 12 to 20 seconds at pretest and from 8 to 18 seconds at posttest. The descriptive findings therefore showed a lower average TUGT completion time following the four-week SSE program.

Table 2. TUGT performance before and after the intervention

Outcome	Pretest, mean $\pm$ SD	Posttest, mean $\pm$ SD	Mean difference, mean $\pm$ SD
TUGT, seconds	14.60 $\pm$ 2.23	11.60 $\pm$ 2.72	3.00 $\pm$ 0.85

TUGT, Timed Up and Go Test; SD, standard deviation. Mean difference = pretest minus posttest.

The distribution of the pretest and posttest TUGT scores was initially assessed using the Shapiro Wilk test. As shown in Table 3, the pretest scores did not significantly depart from normality ($W = 0.900$, $p = 0.097$), and the posttest scores likewise did not significantly depart from normality ($W = 0.917$, $p = 0.173$). However, these tests assess the distributions at each measurement point separately and do not establish the normality of the within participant difference scores, which is the relevant assumption for a paired sample t test. An exploratory boxplot assessment of the difference scores identified two outliers, corresponding to cases 9 and 10 with a 4 second reduction, and one extreme outlier, corresponding to case 2 with a 5 second reduction.¹³ The available statistical documentation does not contain a separate Shapiro Wilk output for the difference scores; therefore, normality of the paired differences cannot be stated as formally confirmed from the available output.

Table 3. Shapiro Wilk test of pretest and posttest TUGT scores

Variable	W	n	p value
Pretest TUGT	0.900	15	0.097
Posttest TUGT	0.917	15	0.173

TUGT, Timed Up and Go Test.

The within participant comparison showed a mean reduction of 3.00 seconds in TUGT completion time, with a 95% confidence interval (CI) of 2.53 to 3.47 seconds. The original paired sample t test produced $t = 13.748$ with 14 degrees of freedom and $p = 0.001$. The corresponding paired sample effect size, calculated as Cohen's d_z from the mean difference divided by the standard deviation of the within participant differences, was 3.55.¹⁵ This represents a large standardized within participant effect. The statistical results are summarized in Table 4, with the direction of the difference defined such that positive values indicate shorter TUGT completion times after the intervention.

Table 4. Within participant comparison of TUGT performance

Outcome	Mean difference, seconds	95% CI	t	df	p value	Cohen's d_z
TUGT	3.00	2.53 to 3.47	13.748	14	0.001	3.55

TUGT, Timed Up and Go Test; CI, confidence interval; df, degrees of freedom; Cohen's d_z , standardized within participant effect size. Mean difference = pretest minus posttest.

Overall, the results demonstrate a statistically significant reduction in TUGT completion time after the four-week SSE program. The magnitude of the observed change was 3.00 seconds, equivalent to a shorter average completion time after the intervention period. All 15 participants completed the planned intervention and both outcome assessments, providing a complete pretest and posttest dataset for the final analysis. Nevertheless, because the study used a one group pretest posttest design, the observed statistical difference represents a within participant change and does not by itself establish that SSE was the sole cause of the improvement. The identified difference score outliers and the absence of a formally reported normality test for the paired differences should also be considered when interpreting the inferential analysis.

Discussion

This study observed a statistically significant reduction in Timed Up and Go Test (TUGT) completion time following a four-week Square Stepping Exercise (SSE) program administered three times per week among older adults at Posyandu RW 27 Cipariuk, Bandung Regency. Mean TUGT completion time decreased from 14.60 $\pm$ 2.23 seconds at pretest to 11.60 $\pm$ 2.72 seconds at posttest, corresponding to a mean within participant reduction of 3.00 $\pm$ 0.85 seconds. The 95% confidence interval for the mean reduction was 2.53 to 3.47 seconds, and the paired sample analysis yielded $t = 13.748$, $df = 14$, $p = 0.001$. The standardized within participant effect size was large (Cohen's $d_z = 3.55$). These findings indicate a substantial improvement in TUGT performance over the study period. However, the magnitude of the statistical effect should not be interpreted as definitive evidence of an SSE specific treatment effect because the study did not include a comparison group.

The observed improvement is consistent with previous evidence regarding SSE among older adults.^{9,16} A systematic review and meta-analysis involving 10 studies and 920 participants reported favorable effects of SSE based interventions on dynamic balance, static balance, fall risk, and agility.¹⁶ Another systematic review involving 12 studies and 577 adults aged 60 years and older also reported improvements across several physical and cognitive domains, including balance, lower limb strength and power, gait speed, and flexibility.⁹ These findings provide a plausible context for the improvement observed in the present study. Nevertheless, previous studies have used heterogeneous intervention protocols, participant characteristics, intervention doses, and outcome measures, making direct comparison of effect magnitudes inappropriate.

The present findings are also broadly comparable with individual studies using SSE. Wijianto and Faliha reported reduced TUGT completion time after four weeks of SSE performed three times per week, while Segita et al. reported improved balance measured using the Berg Balance Scale after a comparable intervention period.^{10,11} The current study used a similar intervention frequency and duration, although differences in baseline mobility, participant characteristics, progression of exercise, intervention delivery, and measurement procedures may account for differences in observed outcomes. Therefore, the 3.00 second reduction observed in this study should be interpreted as evidence of change within this particular sample rather than as an expected response for older adults generally.

Several characteristics of SSE may plausibly explain the observed improvement in TUGT performance.^{8,9} SSE requires participants to perform multidirectional stepping while continuously adjusting the relationship between the center of mass and base of support.⁸ The activity also involves lower limb coordination, spatial orientation, attention, and recall of movement sequences.^{8,9} Repeated exposure to these tasks may provide task specific stimulation for postural control and functional mobility.¹⁷ In the present intervention, the exercise progressed from basic forward and lateral stepping during the first week to intermediate forward, backward, and lateral patterns during weeks two and three, followed by multidirectional and diagonal patterns during week four. Each pattern was performed for four to ten repetitions, with approximately 15 to 20 minutes of core exercise per session, in addition to warm up and cool down. This progressive structure may have provided repeated practice of increasingly complex movement demands.

The interpretation of clinical relevance also requires caution.¹⁸ Statistical significance does not necessarily indicate that the magnitude of change is clinically meaningful.¹⁸ The observed 3.00 second reduction is considerably larger than the approximately 0.41 second minimal clinically important difference reported in a systematic review of community based exercise interventions among prefrail older adults.¹⁸ However, thresholds for clinically meaningful TUGT change may vary according to population and functional status, and therefore the 0.41 second estimate should not be treated as a universal threshold for the present sample.¹⁸ The finding is consequently better interpreted as potentially meaningful improvement in functional mobility rather than definitive evidence of a clinically important reduction in fall risk.^{18,19}

The completeness of intervention participation strengthens the description of the observed within participant change. All 15 participants completed the planned 12 SSE sessions, corresponding to 100% attendance, and all participants completed both outcome assessments. No event resulted in discontinuation of exercise. Nevertheless, attendance alone does not establish intervention fidelity or dose response. Activities performed outside the SSE sessions were not systematically monitored, and the study did not collect information that would allow the influence of usual physical activity to be quantified.

An important statistical consideration concerns the paired analysis. The available Shapiro Wilk results showed no statistically significant departure from normality for either the pretest or posttest TUGT scores. However, the relevant assumption for a paired sample t test concerns the distribution of the within participant difference scores rather than the two measurement distributions separately.²⁰ Exploratory boxplot assessment identified two outliers with a 4 second reduction and one extreme outlier with a 5 second reduction. Because a separate normality test for the difference scores was not available, the assumptions of the paired analysis cannot be regarded as fully documented. This limitation should be acknowledged when interpreting the reported effect size and significance.

The study design represents the principal limitation when interpreting these findings. Without a control or comparison group, improvements may reflect the intervention, repeated exposure to the TUGT, temporal changes, usual physical activity, learning effects, or other factors that were not measured. The small sample of 15 participants also limits statistical precision and generalizability, particularly because 80% of participants were women. In addition, no follow up assessment was conducted, so the persistence of the observed improvement remains unknown.

Overall, the findings provide preliminary, context specific evidence that a structured four-week SSE program was associated with improved TUGT performance among older adults participating in a community based Posyandu program. The large within participant effect and complete attendance support further investigation, but they should not be interpreted as proof of causal effectiveness. Future studies should use controlled designs with larger and more diverse samples, prospectively document adherence and intervention fidelity, monitor physical activity outside the intervention, assess potential confounders, and include follow up measurements to determine whether improvements in functional mobility are sustained.

Conclusion

This study found that a four-week Square Stepping Exercise (SSE) program, performed three times per week, was followed by an improvement in dynamic functional mobility among older adults at Posyandu RW 27 Cipariuk, Bandung Regency. Mean Timed Up and Go Test (TUGT) completion time decreased from 14.60 ± 2.23 seconds before the intervention to 11.60 ± 2.72 seconds after the intervention, with a mean within participant reduction of 3.00 ± 0.85 seconds (95% CI 2.53 to 3.47; $p = 0.001$). The observed change was accompanied by a large standardized within participant effect size (Cohen's $d_z = 3.55$).

These findings indicate that participants demonstrated better TUGT performance following completion of the SSE program. However, because this study used a one group pretest and posttest design without a comparison group, the observed improvement cannot be attributed exclusively to SSE. Factors such as repeated testing, natural changes over time, usual physical activity, or other unmeasured influences may also have contributed to the change.

Therefore, SSE may be considered a promising exercise approach for improving functional mobility in older adults, but the present findings should be interpreted as preliminary evidence of an observed within participant improvement rather than definitive evidence of causal effectiveness. Further controlled studies with larger samples, documented intervention fidelity, monitoring of activities outside the intervention, and longer follow up are needed to determine the effectiveness and sustainability of SSE for functional mobility and balance among older adults.

Author Contribution

Nurul Desriani: Conceptualization, Methodology, Formal Analysis, Investigation, Writing Original Draft.
 Touris Aan Suhadaq: Conceptualization, Methodology, Writing Review and Editing, Supervision.
 Feny Oktaviyani: Conceptualization, Methodology, Writing Review and Editing, Supervision.

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Conflict of Interest Statement

The authors declare no conflict of interest.

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Ethics Statement

This study received ethical approval from the Health Research Ethics Committee of Universitas Binawan, Indonesia, under approval number 140/KEPK UBN/V/2026. All participants received an explanation of the study objectives, procedures, benefits, and potential risks and provided informed consent before participation.

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