ORIGINAL ARTICLE

Effects of combined square stepping and BOSU training on balance, postural control, and vertical jump in badminton players: Protocol for a randomized controlled trial

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ABSTRACT

Square stepping exercise (SE) and BOSU ball exercise (BE) have independently shown beneficial effects on balance, strength, and coordination; however, their combined effects in badminton players remain unclear. This study aims to present the protocol of a randomized controlled trial designed to investigate the effectiveness of combined SE and BE on postural sway, dynamic balance, and vertical jump performance. Fifty-one badminton players will be randomly allocated into three groups: combined SE and BOSU group (SBG, n = 17), BOSU group (BG, n = 17), and control group (CG, n = 17). The intervention will last 8 weeks. The SBG will perform SE (three sessions per week) and BE (two sessions per week), the BG will receive BE with conventional training, and the CG will follow conventional training only. Outcomes will be assessed at baseline, week 4, and week 8, and post-intervention using the Y-Balance Test for dynamic balance, Wii Balance Board measures for postural sway, and the Sargent jump test for vertical jump performance. Data will be analysed using repeated-measures analysis of variance to determine within- and between-group differences over time. The findings of this study are expected to provide evidence on the effectiveness of combined neuromuscular and balance training strategies for improving lower limb performance and postural control in badminton players and reduce health risks in these athletes.
Keywords: Performance analysis, Dynamic balance, Postural stability, Vertical jump, Square stepping exercise, BOSU training, Health risks, Human well-being.

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INTRODUCTION

Badminton is a common sport that calls for rapid powerful shots and quick footwork. One of the world's fastest racquet sports (Malwanage et al., 2022a). In addition, badminton players must conduct extremely quick and asymmetrical movements of their upper limbs while keeping their centre of gravity within the base of support (Teu et al., 2005). Therefore, improved body balance is essential for developing badminton skills, improving sports performance, and preventing injuries(Refahi et al., 2022). Competent badminton players must maintain exceptional postural control, dynamic balance, accuracy in their shots, and strength in their lower extremities to perform at their best. Balance is the ability to support the body while standing or moving with little to no movement (static balance), whereas dynamic balance involves some level of anticipated movement around the centre of gravity projection (Rizzato et al., 2023). Postural sway, dynamic balance, and lower limb strength are vital components of athletic performance, influencing the execution of fundamental movements such as lunging, pivoting, and sudden shifts in weight distribution (KAVIYARASAN et al., 2025). To achieve optimal performance and prevent injuries during rapid movements in the court, the players need a high level of dynamic balance (Han et al., 2022; Hassan, 2017). Multiple evidence suggested a correlation between dynamic balance and the incidence of lower extremity injuries in different populations (Farhadi, 2013; Kurihara et al., 2024; Sarto et al., 2019). Furthermore, rapid nature of the sport demands elements like maximum strength, rapid strength, explosive power, agility, and balance when performing dynamic movement patterns such as change of direction and jumping actions(Manjrekar et al., 2023). In badminton, lower body strength is crucial because it promotes quicker and more accurate footwork. The powerful lower body enhances speed when moving around the badminton court by enabling quick stops and direction changes. Additionally, by transmitting energy from the legs to the upper body, stronger lower limb muscles enable the production of stronger smashes (Hassan, 2017). Therefore, Vertical jump performance was used as paradigm for explosive strength and lower limb abilities (Nishiumi et al., 2023; Praveenkumar et al., 2025).

BOSU ball is a tool specifically designed for balance training in athletes. It has a flat, stable surface that produces an unstable surface on a flat, stable surface. Additionally, it is employed to enhance stability in both upright and horizontal position (Yaggie & Campbell, 2006). The BOSU ball can be used as an additional tool for balance training since it improves static and dynamic balance, agility and functional performance (Cigrovski et al., 2017; Loh & Chong, 2018). In this context, BOSU ball training significantly improved single-leg hop and jump height in football athletes.

The square-stepping exercise (SE) was developed by Shigematsu and Okura to augment the lower limb functional fitness in elderly population and to reduce their fall risk. The SE pattern consists in stepping on the floor alternately forward, backward, to the side and diagonal. The task is performed on a thin mat (250 cm x 100 cm) with the surface divided into 40 equated squares. SE is a form of motor task that challenges motor and cognitive capabilities (Shigematsu & Okura, 2006). The precise footwork and spatial orientation utilized in the SE pattern may facilitate enhanced movement patterns and body control in older adults(Y.-H. Wang et al., 2021). Evidence suggested that SE may accelerate the executive function in individuals with Parkinson (Liu et al., 2022) and enhances balance in individuals with stroke(Yumlembam et al., 2025). However, there is no evidence that SE can effectively help badminton players. In addition, Bosu ball exercises performed on a semi-stable surface challenge proprioception, muscle activation and balance control and could conceivably improve an individual’s capacity to negotiate different terrains and court conditions. Whereas the effectiveness of individual exercises—square stepping exercises and Bosu ball exercise has been investigated, there is paucity of literature whether combining them will have effect on postural sway and balance in badminton players well-being. Therefore, the objective of this study is to investigate the synergistic effect of square stepping and Bosu ball exercises on enhancing postural sway, dynamic balance and jump height in badminton players. First phase of the study will be running a randomized pilot study to determine the effect of SE on balance and agility in badminton players. Second phase of the study will be implementing the combination of both SE and BE to examine its synergistic effect on balance and jump height in badminton athletes. The proposed hypothesis for this study is that there will be a significant improvement in postural stability, balance and jump height following 8 weeks of structured intervention.

MATERIAL AND METHODS

Study design and participants

The study employed a assessor-blinded randomized controlled trial that adhered to the CONSORT guidelines for randomized trials. A priori sample size calculation was conducted using G*Power version 3.1.9.4. Given an effect size of 0.23 obtained from dynamic balance ability from a previous study (Z. Lu et al., 2022) with an alpha level of .05 and a desired statistical power of 80%. The estimated sample size was 42. Considering a 20% attrition rate, the final sample size was computed as 51 participants. After screening, the eligible participants will be allocated to SBG (n = 17), BG (n = 17) and CG (n = 17) based on the generated random number at the time of group allocation as shown in Figure 1. Participants' inclusion criteria were: Both genders, aged between 18 and 30, having a minimum of 1 year of experience in badminton, and having competed in a minimum of 2 club-level badminton tournaments in the past 6 months. The exclusion criteria were any lower limb surgery, ACL injury, or any other injury in the lower extremity in the past 1 year, involved any other form of physical training other than badminton-specific training, or neurological disorders that may affect the balance and proprioception. Participants will be recruited from a private indoor badminton club located in Nilai, Malaysia. The study centre will be selected based on the available eligible participants and the investigator's convenience of access. To eliminate the potential bias, the participants were randomly assigned to three groups using computer-generated randomization. Subjects will be unaware of their designated group following randomization. Additionally, assessors will be qualified sports physiotherapist with over 7 years of experience, and they will also be blinded to the grouping. The principal investigator who delivered the exercise will not be involved in data collection to avoid his influence on outcome measurements.

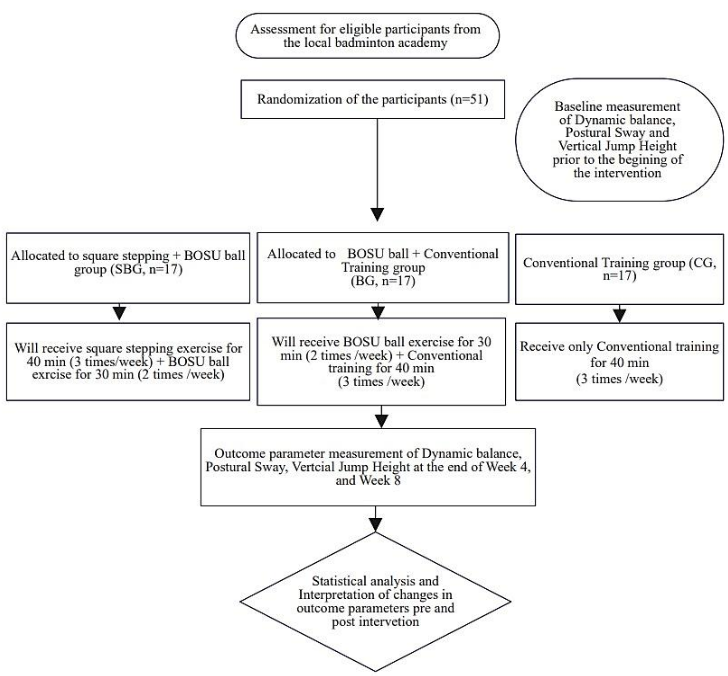


Figure 1. Randomization and intervention allocation chart.

Data collection and ethical approval

Baseline data on dynamic balance, postural sway, and vertical jump height will be collected a week before the commencement of the intervention. Subsequent outcome measurements will be conducted during the 6th and 8th weeks of the intervention. Collected data will be anonymized by the research helper who was not involved in delivering interventions. The main study was registered with ClinicalTrials.gov with identification number NCT07353866. The study was approved by the institutional ethics panel with reference number INTI-IU/FHLS-RC/BPHTI/1NY12024/018 and was in line with the ethical guidelines of the Declaration of Helsinki. All participants will be given a clear explanation of the study procedure and potential risks, and consent will be obtained before the commencement of the study.

Intervention procedure

Control Group (CG)

The CG underwent 40 minutes of traditional shadow training over 3 days per week for 8 weeks, which included 5 minutes of warm-up exercises such as arm swings, lunges, torso twists, and leg swings for 3 minutes, followed by 2 minutes of jogging around the court. Subsequently, the first phase consists of 10 minutes of basic 6-corner footwork (front, side, and rear court, both right and left sides), 4 sets x 45 seconds, 60 seconds rest, followed by Forward and backward recovery, four sets x 30 seconds. Next, the second phase comprises 20 minutes of quickness training, including right front net lunge and left rear scissor jump. Switch between right mid-court drive and left mid-court drive, followed by a 3-point sequence from the centre of the court (net shot, backcourt clear, back to centre 4 sets x 45 sec, 30 sec rest between the sets. Finally, the end phase will be 5 minutes of cool-down activities, such as gentle arm swings and static stretches for the quadriceps, glutes, triceps, and pectoralis major.

BG (BOSU ball group)

All participants in BG will undergo BOSU ball training for a period of 2 days per week for 8 weeks, and each session lasts for 30 minutes along with traditional shadow training. The following exercise will be performed. The exercise protocol was listed in Table 1.

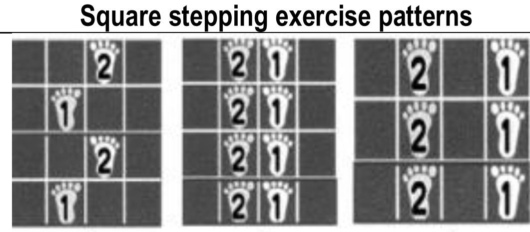
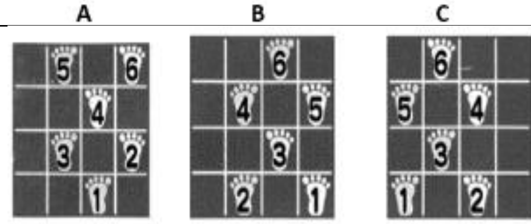
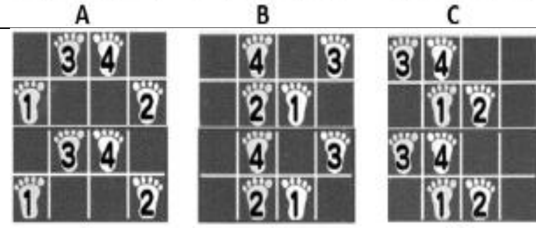
Table 1. BOSU ball intervention protocol.

Phase 1 (Week 1-3)	Phase 2 (Week 4-6)	Phase 3 (Week 7-8)	Rest interval
Bipedal static stance on centre of the dome 3 Sets, 30 sec/set	Jump squats on BOSU flat side 3 sets ,8 reps / set	BOSU burpee with vertical jump 3 sets ,10 reps / set	A constant 60 seconds of rest period between each set was maintained throughout the protocol in each phase
Single leg stance 3 sets, 15 sec/set /leg	Lateral BOSU hop 3 sets, 8 hops/set	Single-leg balance + shuttle reach 3 sets ,10 reps / set	
Mini Squat with hands on hip 10 reps x 3 sets	Push-up with hands on BOSU 3 sets ,8 reps / set	Single- leg balance with flat side up 3 sets ,10 reps / set	
Alternate step up 3 sets ,10 reps/ set/leg	BOSU Mountain climbers 3 sets ,8 reps / set	Bosu Reverse lunge with knee drive 3 sets ,10 reps / set	

SBG (Square stepping + BOSU ball exercise group)

Participants in the SBG will perform both SE and BOSU ball training. SE will be implemented on Monday, Wednesday and Friday for a period of 8 weeks, each session lasts for 40 minutes. Meanwhile, all participants in this group will undergo specified BOSU ball protocol mentioned in Table 1 on Tuesday and Thursday for the same duration of 8 weeks, 30 minutes each session. The SE training comprises of a series of forward, backward, lateral, and diagonal steps, with the complexity of pattern increasing from week 2 to week 8. Participants were directed to walk into the SE mat from one side of the mat to the opposite end of the mat as per the step sequence on the mat and walk on their toes with elevated heels and avoiding contact with square frame. The sequences of the protocol will be structured to include initial 2 step pattern for first 2 weeks, followed by a 3-step pattern from week 3-5, and progressed to 4-step pattern from 6-8 weeks as illustrated in Table 2. Each sub pattern (A, B, C) will be executed 2 sets (3 reps each set) with 1 minute rest periods between each set, for a total duration of 40 minutes. Prior to the commencement of the intervention, participants will receive a visual stepping pattern in the form of a poster to memorize the pattern and are instructed to reproduce it on the SE mat. Initially, participants will be given a trial session to implement the learned pattern on the mat. Participants would be encouraged to start slowly and increase their speed once they were comfortable with the pattern. Other than initial demonstration no other auditory or visual cues will be provided. The intervention sessions will be standardized in terms of the number of repetitions and rest time. All repetitions were executed at the pace as directed by the principal investigator to maintain consistency across participants. A fixed 1-minute interval was retained between the set. However, participants were instructed to perform at a comfortable, sustainable pace under supervision to minimize variability. A licensed physiotherapist with over 10 years of experience in sports rehabilitation, who received training about the SSE protocol, will deliver the exercise protocol. Fidelity checks will be conducted by an independent research assistant who will attend one randomly selected session each week, using a standardized checklist to ensure that the exercises will be delivered correctly, their progression will be monitored, and participant adherence will be verified. All training sessions will be conducted in an indoor badminton hall made up of PVC flooring with a length and width of 13.4m x 6.1m.

Table 2. Patterns used in square stepping exercise.

	Square stepping exercise patterns	**Intensity and rest**
Week 1-2 (2 Step Pattern)	 A B C	
Week 3-5 (3 Step Pattern)	 A B C	2 sets (3 reps each set) with 1 minute rest periods between each set. Duration: 40min Each pattern (A,B,C) will be performed 2 sets
Week 6-8 (4 Step Pattern)	 A B C	

Note: Each pattern was performed at own pace. Rate of Perceived Exertion (RPE) was monitored using Borg scale (12–15 RPE).

Outcome measure

Dynamic balance

The Y-balance test constitutes a prominent tool in the research literature for assessing the dynamic balance of the lower extremities. It demonstrates a good inter-rater and intra-rater reliability when administered to healthy adults, as evidenced by an Intraclass Correlation Coefficient (ICC) ranging from 0.83 to 0.96 (Powden et al., 2019). A YBT Kit consists of three interconnected cylindrical tubular plastic rods, calibrated in half-centimetre increments. Each rod is equipped with a movable indicator plate, which the participant manoeuvres by applying force with their foot or toes while avoiding weight-bearing on the indicator itself. Before the test, participants engaged in a trial session. Subsequently, they were allowed to undertake six practice trials on each leg across the three designated reach directions before the formal testing phase commenced. The participant was instructed to assume a standing position on the leg under evaluation, centrally positioned on the platform, with the most distal aspect of the longest toe just posterior to the red line. While maintaining a single-leg stance, the participant was directed to extend the free limb anteriorly for three trials, followed by three trials in both the posteromedial and posterolateral directions. Participants were instructed to propel the distance indicator as far as feasible toward the designated direction under evaluation. The researcher monitored the participants during testing to ensure adherence to the protocols, prohibiting any movement of the indicator via kicking or acceleration at the conclusion of the push. The maximal reach distance was documented at the most distal point attained by the foot at the proximal edge of the indicator, measured to the nearest half centimetre. Trials were to be discarded and repeated if participants (1) lost their balance during execution, (2) lifted the heel of the foot remaining on the platform, (3) failed to maintain contact with the distance indicator while it was in motion (e.g., if the indicator was kicked), or (4) experienced a loss of balance during the return to the initial position after the distance had been recorded. The maximum reach distance from the three trials for each reach direction was utilized for analysis. Furthermore, the maximum reach distances in each direction were aggregated to obtain a composite reach distance, which was normalized by limb length for evaluating overall performance on the test.

The length of the subjects' limbs was measured before the test. They were positioned supine on a table, with their hips and knees flexed. Subsequently, the subjects elevated their pelvis and passively returned it to the table. The examiner then performed passive stretching of the lower limbs into an extended position to achieve pelvic equilibrium. The right leg of each subject was measured in centimetres utilizing a tape measure, extending from the bottom edge of the anterior superior iliac spine to the distal margin of the medial malleolus.

The composite score will be calculated using the following formula:

$$\text{Composite score} = (\text{Anterior} + \text{posteromedial} + \text{posterolateral}) / (3 \times \text{limb length}) \times 100$$

Vertical Jump Performance (VJH)

The Sargent Jump Test is a test to measure lower body power (Markovic et al., 2004). To measure the standing reach height the participant will be asked to stand along wall side and instructed to reach as high as possible and mark the point on the wall using some chalk. Subsequently, ask the participants to stand away from the wall at a distance of 10 cm for free arm swinging, the fingers are chalked, and the subjects will be instructed to perform countermovement by bending their knees and swinging the arms back to reach as high as possible and mark on the wall with chalked finger. The highest point marked on the wall is calculated as jump height. The difference between the jump height and the standing reach height will be computed as VJH. Three trials are performed with 30 seconds rest between each trial and average of the three trials will be used for analysis.

Postural Sway (PS)

PS will be assessed using the Wii board incorporated with Physiosensing Balance Software® v.21.5.0.0 (Sensing Future, Coimbra, Portugal). The Wii board has excellent inter- and intra-rater reliability in assessing the centre of pressure (COP) path length and velocity (ICC: 0.89-0.79) (Clark et al., 2018; Park & Lee, 2014). The Wii Balance Board (WBB) quantified the overall centre of pressure (COP) sway length, representing the sum of postural sway in both the anteroposterior and mediolateral directions. The WBB will be interfaced with a laptop running Microsoft Windows 11 to facilitate a Bluetooth connection to the WBB. The force platform data were recorded at 100 Hz. It is equipped with two dual-channel analogue-to-digital converters (ADCs) to sample the four load cells at each platform corner. The participants will be instructed to position themselves on the WBB (Sensing Future Technology, Portugal). The assessment of postural stability comprises two distinct conditions: one with the eyes open and the other with the eyes closed, performed on a stable surface with the feet positioned on either side of the WBB's centreline. Participants' arms are held in an extended position, and they look at a focused point placed on the wall. The entire procedure was repeated for 30 seconds with eyes open and eyes closed. Participants will be allowed to take one trial to familiarize themselves with the assessment. The Physio-Sensing Balance software was used to analyse the ellipse area (mm^2), the displacement of the COP in the anteroposterior (AP) and mediolateral (ML) directions, and the mean velocity (mm/s).

Statistical analysis

Data analysis will be employed using SPSS for Windows Inc. version 22. Chicago, Illinois, and the continuous data will be represented in mean and standard deviation. A two-way repeated-measures ANOVA will be used to determine the mean difference between groups at three time points (baseline, 6th week, and 8th week) during the intervention period. A significance level of $p < .05$ was set to determine statistical significance.

EXPECTED OUTCOMES

The most critical predictors of badminton performance and injury prevention are lower limb strength and balance. The rapid changes of direction, lunges, jumps, and rebounds are identical features of badminton that strongly rely on strong lower-extremity function. Balance and neuromuscular control deficiencies are directly associated with an increased risk of typical badminton injuries, specifically knee and ankle joint injuries. Therefore, it is essential to investigate specific interventions that may help to improve such attributes (Hiruntrakul et al., 2025; T. Wang et al., 2025). This randomized controlled trial protocol aims to clarify the synergistic effects of square-stepping exercise and BOSU ball training on lower-extremity balance and strength among badminton players, a group prone to ankle and knee injuries due to the sport's dynamic movements and rapid directional changes (Nugraha et al., 2022). This study will examine the impact of various training modalities on essential performance metrics —agility, power, and proprioception, which is vital for injury prevention and improved athletic performance in badminton (Zhao et al., 2021).

The outcome of this study is anticipated to yield evidence-based guidelines for the integration of specific balance and strength training into current conditioning protocols for badminton athletes, thereby enhancing their physical preparedness and minimizing injury risks during competitive games (Z. Guo et al., 2021). This research protocol outlines a stringent methodology for comparing these interventions, emphasizing objective metrics of physical attributes like dynamic balance and explosive strength of the lower extremity during sport-specific movements (Franco-García et al., 2022). The study aims to evaluate the influence of these exercises on cognitive functions pertinent to athletic performance, including reaction time and decision-making, while recognizing the complex interaction between physical and cognitive factors in elite sports (Franco-García et al., 2022).

SE is a complex, multidirectional pattern of stepping exercise designed to evaluate balance, coordination, and responsiveness through structured footwork exercises. It was originally intended to be used with the elderly population to reduce the fall risk. Nevertheless, its application has expanded to sports participants, which also emphasizes proprioceptive information, lower limb control, and neuromuscular training. Recent evidence indicated that step-based aerobic interventions have positive effects on postural control and dynamic balance among badminton players which are indicators that SE is relevant and effective in this situation. The implementation of such sport-agnostic versatile stepping protocol could have a holistic effect by addressing the deficiencies in multi-planar dynamic stability, which is a key component in competitive badminton (Hiruntrakul et al., 2025).

BOSU ball is an unstable surface that challenges neuromuscular and proprioceptive systems in athletes. Activities such as squats, lunges, or single-leg tasks on an unstable surface may additionally enhance the muscle activation and complexity of sensorimotor control and stimulate dynamic balance adaptation compared to stable surfaces (Pohl et al., 2020). Past studies have discovered that integrating BOSU ball exercises with other training regimens significantly improves postural stability, agility, and neuromuscular coordination, which are thought to be key factors in landing mechanics (Gidu et al., 2022; M. Lu et al., 2025; Shultz et al., 2013) This indicates that such effects may be applicable in the context of badminton, where rapid turns and explosive power generation are required in order to enhance performance on the court.

Balance training on an unstable surface stimulates the postural control and proprioceptive feedback, whereas tailored stepping exercise patterns induce a multidirectional complex movement pattern, which in turn induces the stability of the posture (Kathiresan & Mohanan, 2025). We further hypothesize that synergetic action between these two protocols may fortify both dynamic and static components of balance, escalate the lower extremity explosive power, and potentially lead to injury prevention outcomes.

The mechanism underlying our hypothesis is that both exercises target the sensorimotor system in two ways, neuromuscular synergy and proprioceptive integration along with strength training. In the context of SE, the patterns are multidirectional and require participants to memorize and execute the task, which challenges movement planning and inter-limb coordination (Siqueira et al., 2024). While exercise on BOSU ball compels the hip, knee and ankle muscles to continuously trigger the reflex mechanism to maintain postural control. This notion was supported by previous electromyographic study evidence identified that exercise with BOSU can elicit greater co-contraction of ankle muscle to provide joint stability (Lizardo et al., 2017; Teu et al., 2005). Recent studies related to athletic population have emphasized that multi-modal training showed better functional outcomes and mitigating the risk of injury (C. Guo & Xu, 2025; Hiruntrakul et al., 2025; M. Lu et al., 2025).

IMPLICATIONS OF THE PROTOCOL

In conclusion, the significance of combining SE and BOSU ball training intervention lies in its potential to address the critical gap in badminton-specific training. Even though numerous studies have highlighted the effects of plyometric and balance training protocols in isolation, there is a paucity of research on the synergistic effects of cognitive and dynamic footwork training and unstable-surface training. Hence, we firmly believe that this randomized trial will provide empirical evidence for an advanced integrated training protocol that not only enhances performance and health but also reduces the likelihood of injury among badminton athletes.

AUTHOR CONTRIBUTIONS

All authors meet the criteria for authorship in accordance with established ethical guidelines. Vinosh Kumar. P: Conceptualization, methodology, data collection, writing- original draft preparation. Vinodhkumar. R: Writing - reviewing and editing, data analysis. W. H. Chang: Review of literature, data collection plan, resources. Arun Vijay Subbarayalu: Review and editing of manuscript, revised the study protocol background. All authors have critically reviewed and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript.

AI USE DISCLOSURE

In accordance with current publishing ethics and transparency recommendations, artificial intelligence (AI) tools were used solely to assist with translation and language editing, with the aim of improving clarity and readability. No AI tools were used in the generation of scientific content, including the study design, data collection, analysis, interpretation of results, or the formulation of conclusions. The authors retain full responsibility for the content of the manuscript and confirm its originality, integrity, and accuracy.

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