



Original Research

Maximum-Speed Warm-Up Without External Load Improves the Chest Pass Distance in Female Basketball Players

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Abstract

International Journal of Exercise Science 19(6): 1-11, 2026. <https://doi.org/10.70252/IJES2026602>

Chest pass distance, which reflects upper-limb power, is a practical indicator of performance level in basketball. This study investigated whether a non-weight-bearing warm-up performed at maximum speed could improve chest pass distance in young female basketball players. Forty-five players performed three warm-up conditions in a randomized order using a crossover design: maximum-speed, slow-speed, and control (sitting). The warm-up protocol comprised eight sets of six dynamic upper-limb exercises performed without external load. Chest pass distance was measured before and after each condition. The results indicated that the maximum-speed warm-up significantly increased chest pass distance ($p < 0.01$) by an average of 0.50 m (6.0%) in 93% of the participants, while no significant changes were observed in the other conditions (slow-speed: $p = 0.11$, control: $p = 0.36$). The improvement may be due to enhanced muscle power resulting from activation of the stretch-shortening cycle, increased muscle temperature, optimized motor unit recruitment, and improved intermuscular coordination. Additionally, the maximum-speed warm-up has three practical advantages over traditional high-load warm-ups: it does not require specialized equipment or training experience, induces less fatigue, and is highly accessible in typical basketball environments. These findings support the application of non-weight-bearing, velocity-focused warm-up strategies as an effective and practical method for enhancing chest pass performance in basketball players. This warm-up may be beneficial when performed before match play or during periods of inactivity, such as while seated on the bench, to help improve chest pass distance and potentially enhance offensive performance.

Keywords: High-velocity movement, explosive passing, ball passing, dynamic movement

Introduction

Basketball is a globally popular sport, and its reach has continued to expand in recent years. According to the International Basketball Federation (FIBA), more than 450 million people played basketball worldwide in 2007,¹ and by 2023, the number of participants had exceeded 610 million.² Basketball requires fundamental skills such as dribbling, passing, and shooting. Among these, the two-handed chest pass is one of the most frequently used passing techniques, accounting for about 40% of all passes.³ A greater number of successful passes is associated with winning; for example, winners recorded 27.9 ± 7.7 assists per 100 possessions, compared with 21.4 ± 6.1 for losing teams in Spain's ACB League.⁴ Additionally, in elite women's play (WNBA), assist rate helps discriminate starters from non-starters (0.08 vs 0.06 assists min^{-1}),

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underscoring the tactical importance of effective passing.⁵ The ability to execute successful chest passes over greater distances is an essential skill in basketball. It enables players to move the ball quickly and efficiently across the court, facilitates fast breaks with fewer passes, and enhances versatility in playmaking by stretching defensive formations and creating opportunities for high-percentage shots.^{3,6} Given its tactical significance, evaluating chest pass performance in a meaningful and sport-relevant manner is crucial. Such assessments can provide valuable insights into player ability and help guide effective training interventions.³

Cronin and Owen⁷ developed a method to assess upper-body strength and power based on the distance of a netball chest pass; the study was conducted with competitive female netball players. They reported significant correlations between chest pass distance and upper-body power derived from a bench press assessment, indicating that upper-body power is a key determinant of chest pass performance. Given that the chest pass is a common passing technique in netball and basketball, the protocol developed by Cronin and Owen⁷ would be highly relevant for basketball players. However, to our knowledge, no study has directly examined chest pass distance as an assessment of upper-limb power in basketball, highlighting a gap that our study aimed to address.

Muscle power is calculated as the product of force and velocity,⁸ and therefore, targeted warm-up strategies that improve these factors may enhance chest pass performance. Warm-up protocols aimed at enhancing force alone typically involve high-load, low-velocity exercises that activate the neuromuscular system, increasing muscle recruitment and force production,⁹ often referred to as post-activation potentiation enhancement.¹⁰ For instance, performing heavy resistance exercises before a performance task can temporarily enhance muscle force output.¹¹ Similarly, warm-up strategies targeting both force and velocity often involve high-load and high-velocity conditions. Complex training alternates heavy resistance movements with explosive plyometric exercises to boost overall muscular power.¹² This approach leverages both the increased force from heavy loads and the enhanced speed from rapid movements to improve performance.¹³ However, it should be noted that potentiation effects elicited by such high-load conditioning activities do not persist indefinitely. Performance is often reduced immediately after a heavy conditioning activity due to fatigue, with improvements typically emerging after several minutes, peaking around 7-10 minutes, and dissipating within ~10 minutes.^{14,15} Thus, a single warm-up before a game may not be sufficient to maintain performance benefits throughout play. Furthermore, heavy conditioning activities typically require large equipment, which is cumbersome and impractical prior to basketball games. Re-warm-up exercises could be a more practical alternative activity strategy to acutely enhance sport-specific upper limb performance.

Although heavy-loaded conditioning activities effectively prime the neuromuscular system, they require a certain level of training experience and baseline strength to perform safely and effectively.¹⁶ Individuals with less training experience or lower baseline strength—such as untrained adults, women, and children—may find it challenging to execute these exercises, potentially increasing the risk of injury or excessive fatigue.¹⁷ Additionally, priming exercises involving external resistance require the relocation of heavy equipment to a basketball court, which is cumbersome for practitioners priming athletes for games.¹⁸ Therefore, applying these warm-up methods with heavy equipment, or to populations with limited strength or experience, is often impractical.

In contrast to strategies that enhance strength or combined strength and velocity, a third approach focuses specifically on improving velocity through maximum-speed movements without

external load. While no research has examined non-weight-bearing movements solely focused on maximizing velocity in athletes as priming protocols, some studies have been conducted in rehabilitation and geriatrics, particularly among older adults and postoperative patients. For example, the maximum velocity of the trunk and lower limbs without an external load has been found to be a more important determinant of gait function than strength.^{19,20,21,22} Intervention studies have demonstrated that maximum velocity training without an external load improves gait function. For instance, Sano et al.²³ demonstrated that a 3-week training program involving seated high-velocity lateral trunk movements, referred to as Seated Side Tapping (SST), significantly improved gait speed in patients following total knee arthroplasty. Similarly, Honma et al.²⁴ reported immediate improvements in gait speed following a single session of SST in patients after total hip arthroplasty. Although these findings come from clinical settings, studies in athletes also suggest the relevance of movement velocity. Fletcher,²⁵ for example, showed that faster dynamic stretches enhanced subsequent jump performance compared with slower movements, and suggested that this effect was likely due to priming of the stretch-shortening cycle (SSC). Taken together, these findings from both clinical and athletic settings suggest that non-weight-bearing warm-up protocols performed explosively can enhance motor performance and may also be applied to warm-up strategies in sports.

Therefore, the purpose of this study was to examine whether a non-weight-bearing warm-up for the upper limbs performed at maximum speed could increase chest pass distance in basketball players. To our knowledge, no previous study has examined such a protocol in athletes, and we hypothesized that a maximum-speed warm-up without external load would significantly improve chest pass distance.

Methods

Participants

Forty-five female basketball players who participated in Japan's national high school or college championships volunteered to participate in this study. Their characteristics are as follows: age, 18.2 ± 2.1 years; height, 164.9 ± 7.6 cm; body mass, 60.1 ± 7.5 kg; and body mass index (BMI), 22.1 ± 1.7 kg/m². Before participation, all athletes received an explanation of the study, including its risks and benefits, and completed and signed an informed consent form. This study was approved by the Research Ethics Committee of XX (approval number: XX) and adhered to the ethics code of the Declaration of Helsinki. Furthermore, this research was carried out fully in accordance with the ethical standards of the *International Journal of Exercise Science*.²⁶

The inclusion criteria were: (1) female basketball players belonging to a high school or college team who had competed in a national-level championship in Japan, and (2) no current musculoskeletal injuries affecting the upper limbs; players with a history of upper limb injuries were eligible if they had fully recovered and were able to perform chest passes and warm-up exercises without pain or restriction.

An a priori power analysis was conducted using G*Power (version 3.1.9.7),²⁷ assuming a medium effect size ($f = 0.25$) based on Cohen's guidelines,²⁸ with $\alpha = 0.05$ and power = 0.80. As no prior studies have examined this specific warm-up protocol, a medium effect size was conservatively selected. The required sample size was calculated as 36. To account for potential dropouts, we recruited 45 participants.

Protocol

The outcome measure was chest pass distance, which was assessed before (pre-test) and after (post-test) each warm-up condition using the same chest pass protocol described below. A randomized crossover design was employed to compare the acute effects of three warm-up types on the chest pass distance in elite female basketball players. Each participant visited the gymnasium four times, with each visit at least 24 hours apart. The first session included familiarization with warm-up exercises and chest pass throwing, during which height and body mass were also measured. During the three subsequent visits, the participants performed one of the three warm-up types in random order.

Each of the three experimental sessions comprised four stages: (1) pre-warm-up, (2) pre-test, (3) warm-up, and (4) post-test (Figure 1). The elapsed time between phases was minimized and standardized for all participants. The pre-test was performed immediately after the pre-warm-up, the warm-up began immediately after the pre-test, and the post-test was conducted immediately after the warm-up. The starting times were slightly staggered to ensure that participants did not wait between phases. During the pre-warm-up stage, participants cycled on an ergometer for 5 minutes at a speed of 60 rpm and a power output of 50 W to standardize their physiological condition before each intervention, in accordance with previous studies that employed a short, low-intensity cycling warm-up.^{29,30} After the pre-test, the participants performed one of three warm-up types: maximum-speed warm-up, slow-speed warm-up, or sitting-only control.

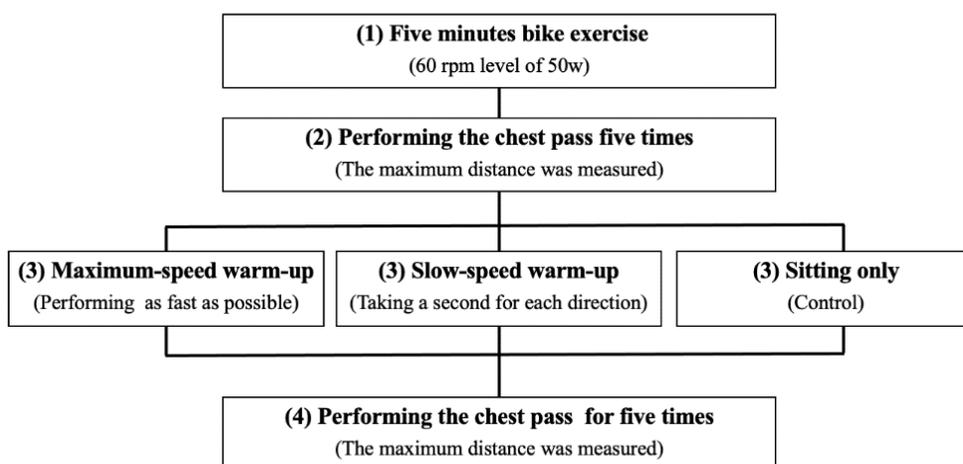


Figure 1. Procedure of the experimental sessions. (1) Pre-warm-up: Participants performed 5 minutes of cycling on an ergometer. (2) Pre-test: Participants performed the chest pass with maximum effort five times. (3) Warm-up: Participants performed one of the three warm-up types, randomly assigned for each day. (4) Post-test: Immediately following the warm-up, participants performed the chest pass with maximum effort five times.

The maximum- and slow-speed warm-ups comprised six dynamic upper extremity exercises per set (Figure 2). Participants performed each exercise in a standing position without external load, following the order listed, for 10 seconds each: (a) wrist flexion and extension, (b) radial deviation and ulnar deviation, (c) elbow flexion and extension, (d) scapular elevation and depression, (e) scapular adduction and abduction, and (f) scapular upward and downward rotation. The selection of these six movements was supported by previous kinematic evidence from basketball passing studies³¹ and biomechanical analyses describing the essential role of scapular upward rotation in maintaining optimal shoulder function.³² During the maximum-speed warm-up, participants

were instructed to perform movements within the full range of motion as rapidly as possible. For the slow-speed warm-up, participants were advised to take 1 second for each direction of movement (e.g., flexion and extension). One set (six exercises \times 10 seconds) was completed in 1 minute and repeated for eight consecutive sets without rest. The total warm-up duration was standardized at 8 minutes for both the maximum- and slow-speed conditions, and timing was controlled with a stopwatch to ensure consistency across participants. The control condition involved sitting on a bench for 8 minutes.

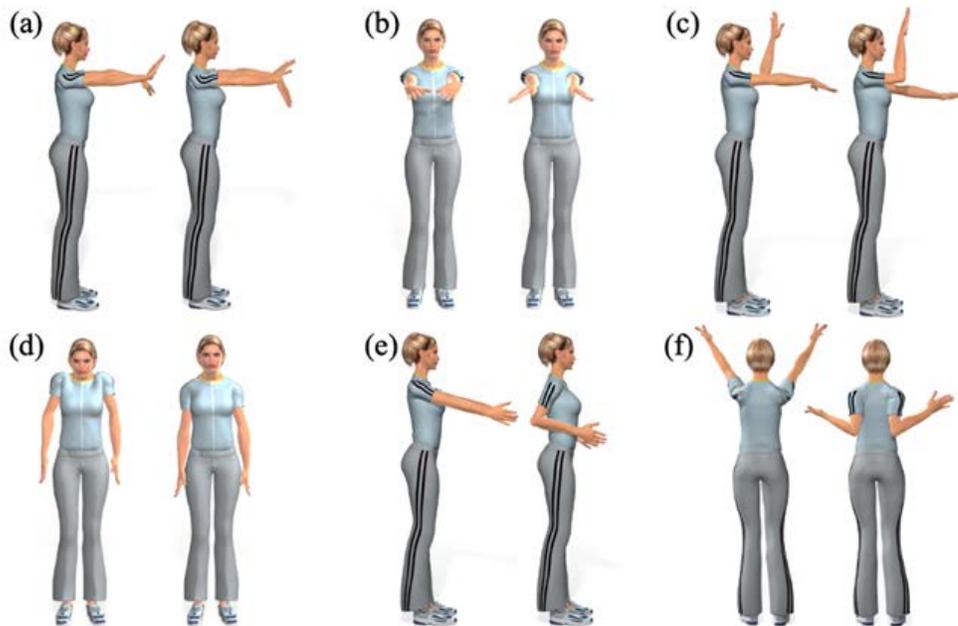


Figure 2. Warm-up exercises. (a) wrist flexion and extension; (b) radial and ulnar deviation; (c) elbow flexion and extension; (d) scapula elevation and depression; (e) scapula adduction and abduction; (f) scapula upward rotation and downward rotation.

A chest-pass test was conducted before and after the warm-up in all three experimental sessions. Figure 3 depicts the setup during the chest pass distance measurement. A volleyball referee stand, set up at the starting line, was used to standardize the measurement. Participants were secured to the stand with elastic strapping of the trunk and the ankles to minimize trunk and lower body movements while throwing. There was no footrest, and the participants' feet were not supported by any surface. This setup was a modified version of the seated chest pass test as described by Cronin and Owen,⁷ designed to enhance trunk stabilization and isolate upper-limb power. The seat height was adjusted to 1.8 m from the ground to the participant's acromion using seat pads (1, 5, and 10 cm). Participants were instructed to "Perform a chest pass as far as possible without using their trunk or legs." Chest pass distance was defined as the distance from the starting line to the point where the ball landed. Two research assistants visually identified the first contact point of the ball with the floor and measured the distance from the starting line using a tape measure, consistent with the field protocol used in seated medicine ball throw testing.³³ If excessive trunk or lower-limb movement was observed, the trial was deemed a failure. Participants were instructed to throw until five successful attempts were made. The maximum distance was used for subsequent analyses.

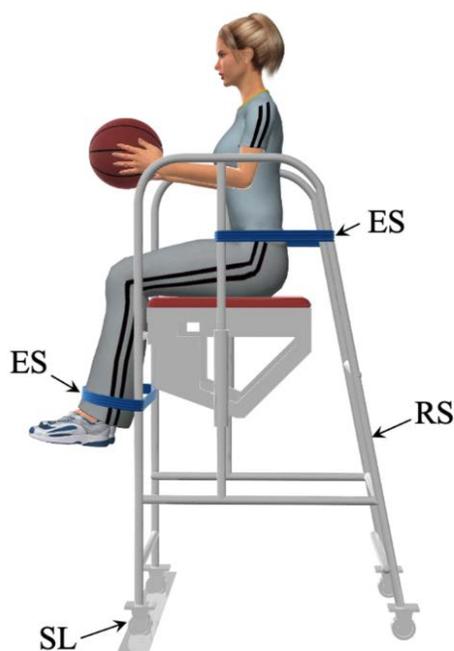


Figure 3. Setup for chest-pass distance measurement. Participants performed chest passes with maximum effort while seated on the referee stand. RS: Referee Stand; ES, Elastic Strapping; SL: Starting Line.

Statistical analyses

Reliability was assessed based on the intraclass correlation coefficient (ICC). According to established guidelines³⁴, ICC values are interpreted as follows: < 0.50 indicates poor reliability, 0.50–0.75 indicates moderate reliability, 0.75–0.90 indicates good reliability, and > 0.90 indicates excellent reliability. These guidelines were applied to evaluate the consistency of the measurements. Continuous values are presented as means \pm standard deviation (SD). Two-way repeated-measures analysis of variance (ANOVA) (warm-up type \times time) was employed to compare chest-pass distance across the three warm-up types, with the alpha level set at $p < 0.05$ to indicate statistical significance. If a significant interaction was identified, we examined the simple main effect of time using pairwise comparisons, including t-tests with the Bonferroni correction ($p < 0.05/3 = 0.017$). The magnitude of the change after each warm-up mode was expressed using Cohen's effect size (d), with thresholds of <0.20 (trivial), 0.20–0.49 (small), 0.50–0.79 (moderate), and ≥ 0.80 (large). All data were entered into Microsoft Excel and imported into IBM SPSS Statistics version 29 (IBM Corp., Armonk, NY, USA) for statistical analysis. \square

Results

Two participants were excluded because of elbow or shoulder injuries unrelated to the study. The ICC for the chest pass distance was 0.897 (95% CI, 0.838–0.939), indicating good test-retest reliability. Table 1 presents the main findings. A significant two-way interaction (warm-up type \times time, $p = 0.001$) was observed for the chest pass distance. A significant simple main effect of time was noted for the maximum-speed warm-up. The average increase in the chest pass distance after the maximum-speed warm-up was 0.49 ± 0.30 m (6.0% improvement) compared to the pre-test measurement. However, no significant changes were observed in the slow-speed warm-up or control conditions.

Table 1. The results of two-way analysis of variance.

Warm-up type	Chest-pass distance (m)				Interaction (type×time) p-value	Simple main effect (time) p-value	Effect size	
	Pre-test		Post-test				d	Interpretation
	Mean	SD	Mean	SD				
Maximum-speed warm-up	8.21	0.90	8.70	0.98		0.001**	0.50	moderate
Slow-speed warm-up	8.39	1.07	8.47	1.10	0.001*	0.110		
Control	8.28	0.99	8.32	1.01		0.356		

SD: standard deviation; *: Significant interaction ($p < 0.05$); **: Significant simple main effects ($p < 0.05/3 = 0.017$)

Discussion

This study aimed to investigate whether a non-weight-bearing warm-up at maximum speed could improve the chest pass distance—a crucial index for measuring upper limb power. The results indicated a significant increase of approximately 0.50 m (+6.0%) in the chest pass distance following the maximum-speed warm-up, while no improvement was observed in the slow-speed warm-up or control conditions. Notably, 93% (40/43) of the participants demonstrated an improvement in chest pass distance after the maximum-speed warm-up. These findings not only align with the stated hypothesis but also highlight the potential impact of non-weight-bearing, velocity-focused warm-up strategies. This suggests that targeting velocity can effectively improve chest pass distance. It is plausible that these trends were reflective of enhanced upper limb power, similar to force-focused approaches using external loads reported in previous studies^{9,15}

Two key factors might explain the observed improvement in the chest pass distance. First, the maximum-speed warm-up strategy incorporates a stretch-shortening cycle (SSC) during dynamic upper limb movements. The SSC—a natural muscle action—combines eccentric and concentric muscle contractions, wherein stored energy from the eccentric phase enhances the subsequent concentric phase.⁸ Faster eccentric contractions facilitate greater accumulation of elastic energy within the musculotendinous complex, which is converted into more potent concentric actions.³⁵ In this study, the participants performed non-weight-bearing upper-limb movements at maximum speed, effectively engaging the SSC. This SSC engagement likely increased the power during the concentric phase of the chest pass, thereby promoting longer pass distances.

Second, maximum-speed warm-up inherently incorporates the benefits of dynamic stretching. Dynamic stretching elevates muscle temperature,³⁶ thereby potentially enhancing muscle performance by increasing neuromuscular excitability and optimizing motor unit recruitment.³⁷ Additionally, velocity-focused warm-up activities optimize the recruitment of motor units, including fast-twitch fibers that are essential for explosive action.³⁸ Improved intermuscular coordination among the muscles involved in the chest pass, such as the wrist flexors or extensors, elbow flexors or extensors, and scapular rotators,³⁹ may further enhance force transmission and increase pass distance. The combined mechanisms of elevated muscle temperature, optimized motor unit recruitment, and improved intermuscular coordination likely contributed to the significant increase in chest pass distance observed following the maximum-speed warm-up.

Maximum-speed warm-ups without external loading offer three distinct advantages over alternative warm-up methods. First, they do not require specialized experience or highly developed muscular strength. Wilson et al.¹⁵ suggested that heavy-loaded warm-ups typically require at least 1 year of training experience. Additionally, Wade et al.⁴⁰ reported that adolescent

athletes require sufficient upper-body strength to safely perform high-intensity warm-up activities with moderate external loads, such as bench presses with weights equivalent to their body mass. Conversely, the participants in this study – young female basketball players with an average one-repetition maximum bench press of 44.5 ± 9.0 kg and a body weight ratio of 0.7 – did not meet the strength criteria required for safely performing such loaded warm-ups. Nevertheless, all participants successfully completed the maximum-speed warm-up, indicating that this warm-up method can be effectively performed by most athletes.

Second, this warm-up may cause less fatigue than conventional warm-up activities involving external loads. Previous reviews suggest that heavily loaded warm-up activities typically require a rest period of 3–10 minutes to allow recovery and prime the neuromuscular system.¹⁵ Galazoulas et al.⁴¹ observed a relatively rapid decline in jumping and running performance after a warm-up, following a period of inactivity among basketball players. Given that frequent player substitutions occur in basketball games⁴², warm-up protocols that minimize fatigue, yield immediate effects, and can be performed regularly should be implemented, as traditional warm-up protocols requiring longer rest periods may not be suitable for this context. Considering these findings, warm-up protocols before and during a basketball game should ideally involve minimal rest periods post-exercise. Therefore, a maximum-speed warm-up may serve as a practical preparation method for basketball training or games, although its application during games may be limited because the protocol requires approximately 8 minutes to complete.

The third advantage was accessibility. Unlike heavy-load warm-ups, the maximum-speed warm-up does not require any special equipment, such as a bench press or chest press machines. As most gymnasiums where basketball matches occur do not have such equipment, it is difficult to implement traditional high-load warm-up protocols. Conversely, maximum-speed warm-up is highly accessible and easy to incorporate into regular training sessions and pre-game routines.

Although this study provides valuable insight, it has two limitations. First, as we intended to clarify the effects of the speed component during warm-up, the effectiveness of a high-intensity warm-up in improving the chest pass distance was not assessed. Consequently, the most effective approach remains vague. Nonetheless, it can be stated with confidence that the non-weight-bearing maximal velocity warm-up proposed in this study is evidently more versatile than warm-up activities involving external loads. Second, the optimal parameters for a maximum-speed warm-up, such as the speed of movement and number of sets and repetitions, remain ambiguous. Additionally, although upper limb power was an essential determinant of increased chest pass distance, it was not directly measured. Further research is required to explore these limitations and refine the warm-up protocols.

In conclusion, this study aimed to determine whether a non-weight-bearing maximum-speed warm-up could enhance the chest pass distance among young female basketball players. The results showed that maximum-speed warm-up significantly increased chest pass distance by approximately 0.50 m (+6.0%) among 93% of the participants, while no significant changes were observed in the slow-speed warm-up and control conditions. These findings demonstrate the effectiveness of velocity-focused warm-up strategies in improving the chest pass distance, possibly because of enhanced upper limb muscle power. Thus, this approach may provide a practical and efficient method for improving chest pass distance in basketball, which is related to upper-limb power.

Acknowledgements

The authors would like to thank all participants and research staff involved in this study for their valuable contributions. The authors declare that no funding, grants, or other support were received for the preparation of this study. They also have no relevant financial or non-financial conflicts of interest to disclose.

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