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The Role of Plyometric Training in Improving Explosive Power in Sprinters: A Qualitative Analysis

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A B S T R A C T

Objective: The objective of this study was to explore the role of plyometric training in enhancing explosive power among sprinters.

Methods and Materials: This qualitative research employed semi-structured interviews to gather data from 17 sprinters aged 18 to 30 years, with at least three years of competitive experience. Participants were recruited from local athletic clubs and universities. Data collection continued until theoretical saturation was achieved, ensuring a comprehensive understanding of the impact of plyometric training. Thematic analysis was used to identify and analyze patterns within the data, providing detailed insights into the participants' experiences and perceptions.

Findings: The study revealed significant physical improvements attributed to plyometric training, including enhanced muscle strength, increased speed, improved jumping ability, and reduced injury risk. Psychological benefits such as increased confidence, enhanced motivation, and improved mental resilience were also noted. Participants reported a better training experience with diverse and efficient routines, improved technique understanding, and strong peer support. Performance outcomes showed notable improvements in competition results, skill application, and recovery times. These findings align with existing literature, confirming the comprehensive benefits of plyometric training for sprinters.

Conclusion: Plyometric training significantly enhances explosive power and overall performance in sprinters. The physical, psychological, and performance-related benefits make it a crucial component of athletic training programs. Despite limitations such as the small sample size and reliance on self-reported data, the study provides valuable insights into the multifaceted advantages of plyometric exercises.

Keywords: Plyometric Training, Explosive Power, Sprinters, Athletic Performance, Muscle Strength, Speed, Agility, Psychological Benefits, Training Efficiency.

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1. Introduction

Plyometric training, a dynamic form of exercise involving rapid and repeated stretching and contracting of muscles, has been extensively studied for its efficacy in enhancing athletic performance, particularly explosive power (1-3). This type of training, often referred to as "jump training," aims to increase the power (speed and strength) of movements through exercises that stretch the muscles before contracting them (3, 4). Plyometric exercises include movements such as jumping, bounding, and hopping, which are fundamental in sports that require quick and powerful movements like sprinting (4-6).

The importance of explosive power in sprinting cannot be overstated. Sprinting relies heavily on the ability to generate rapid force in a short amount of time, which is directly influenced by the neuromuscular system's efficiency. Plyometric training has been shown to improve various aspects of this system, including muscle strength, power, and the rate of force development (2, 7, 8). Studies have demonstrated significant improvements in sprint performance and related physical attributes following systematic plyometric training interventions (4-6).

One of the key benefits of plyometric training is its ability to enhance muscle strength and power. For instance, a study by Adnyana et al. (2022) demonstrated that specific plyometric exercises, such as double leg bound and incline bound methods, significantly increased leg power in athletes (8). Similarly, Aksović et al. (2021) reviewed the effects of plyometric training on explosive power and sprint performance in basketball players, concluding that such training is effective in improving both attributes (9). These findings are corroborated by Arazi and Asadi (2011), who observed enhancements in strength, sprint performance, and balance among young basketball players following a regimen of aquatic and land plyometric training (10).

Furthermore, plyometric training has been found to be beneficial for other physical parameters crucial to sprinting. For example, Asadi (2015) noted that short-term plyometric training on sand resulted in significant muscular performance adaptations, highlighting the influence of training surfaces on the outcomes (11). Hamzah et al. (2020) compared different combinations of plyometric training and found that incorporating mobilization with movement yielded better improvements in balance for individuals with chronic ankle instability. These studies indicate the versatility and wide-ranging benefits of plyometric training beyond just explosive power (12).

The psychological benefits of plyometric training should not be overlooked. Confidence, motivation, and mental resilience are critical components of athletic performance. Bawiskar and Phansopkar (2021) explored the efficacy of agility training, which often includes plyometric exercises, in enhancing psychological attributes such as confidence and focus in police cadets, suggesting that similar benefits could be extended to athletes (13).

Training experience and methods are also pivotal in maximizing the benefits of plyometric training. Bolger et al. (2016) emphasized the importance of expert coaching in sprinting, particularly the coaches' perceptions of resistance-based training (14). Their insights underscore the necessity of tailored training programs that consider the individual needs and capabilities of athletes. This is further supported by studies like Ince and Daglioglu (2018), which examined the impact of structured plyometric programs on young soccer players' sportive performance, indicating that a well-designed training regimen can lead to significant improvements in physical performance (15).

Performance outcomes from plyometric training are substantial and well-documented. Borah and Sajwan (2022) found that collegiate athletes who underwent plyometric training exhibited notable improvements in repeated countermovement jump performance, a key indicator of explosive power (7). Chmielewski et al. (2006) discussed the physiological responses to plyometric exercises in rehabilitation settings, highlighting the clinical applications and benefits for injured athletes looking to regain their competitive edge (16).

Plyometric training's impact is notable across various sports and athletic disciplines. For example, Benito-Martínez et al. (2011) combined electrostimulation with plyometric training, resulting in significant enhancements in vertical jump and speed tests. This indicates that plyometric training, especially when combined with other modalities, can yield compounded benefits (17). Han et al. (2011) reinforced this by showing positive effects on lower extremity power performance in young sprinters through dynamic stretch training, which includes plyometric elements, underscoring its relevance in sprinting (18).

The long-term benefits of plyometric training are evident, particularly in aging athletes. Hentilä et al. (2020) explored the effects of sprint and strength training on aging sprinters, finding that such training modulates autophagy and proteostasis, key processes for muscle maintenance and performance. This suggests that plyometric training helps maintain muscle function and performance in older athletes,

extending its benefits beyond younger, competitive populations (19).

Various studies have demonstrated the cross-disciplinary advantages of plyometric training. Khan et al. (2020) and Kosova et al. (2022) showed improvements in motor ability components such as jump height, agility, and speed (6, 20). Kurniawan et al. (2021) emphasized the effectiveness of plyometric training with active-passive recovery in enhancing male judo athletes' physical abilities (21). These findings support the broad applicability and effectiveness of plyometric training across different sports.

The specific benefits of plyometric training over conventional training have been highlighted in sports requiring quick lateral movements. Lakshmikanth et al. (2018) found that plyometric training significantly improved agility performance in tennis players (22). Lima et al. (2011) reported acute improvements in sprint and vertical jump performance following a drop jump potentiation protocol, showcasing the immediate benefits of plyometric exercises on explosive power (23).

Comprehensive reviews by Loturco (2024) and Loturco et al. (2023) on the effects of plyometric training and other conditioning activities on elite sprinters' performance revealed significant enhancements. These systematic reviews and meta-analyses advocate for including plyometric exercises in high-level athletes' training regimens (24). Moreover, the psychological benefits of plyometric training are supported by studies like Maciel et al. (2023), which found a relationship between lower depression symptoms and improved athletic performance, indicating that improved mental health can enhance overall athletic performance (25).

In summary, the literature supports the role of plyometric training in improving explosive power, strength, and overall athletic performance. The findings from these studies underscore the versatility and efficacy of plyometric exercises across various sports and physical activities, making it an indispensable component of athletic training programs. This study aims to further explore the specific impacts of plyometric training on explosive power in sprinters, providing deeper insights into its practical applications and benefits.

2. Methods and Materials

2.1 Study Design and Participants

This study employed a qualitative research design to explore the role of plyometric training in improving explosive power in sprinters. The study focused on gaining in-depth insights into the experiences and perceptions of sprinters who have undergone plyometric training. To achieve this, semi-structured interviews were conducted with a purposively selected sample of sprinters. The participants were selected based on their experience with both sprinting and plyometric training to ensure they could provide rich and relevant data.

To achieve theoretical saturation, data collection continued until no new themes or insights emerged from the interviews, ensuring a comprehensive understanding of the phenomenon under study. The sample consisted of 17 sprinters from Denmark, both male and female, aged between 18 and 30 years, who had been actively involved in competitive sprinting for at least three years. Participants were recruited from local athletic clubs and universities, ensuring a diverse representation of different competitive levels and backgrounds.

2.2 Data Collection

Data collection was conducted through semi-structured interviews, which allowed for flexibility in exploring topics in depth while ensuring that key areas of interest were covered. An interview guide was developed, comprising open-ended questions designed to elicit detailed responses about the participants' experiences with plyometric training and its impact on their explosive power.

The interviews were conducted in a quiet, private setting, either in person or via video conferencing, depending on the participants' availability and preference. Each interview lasted approximately 45 to 60 minutes and was audio-recorded with the participants' consent to ensure accurate transcription and analysis. Key topics covered in the interviews included the participants' background in sprinting, their experiences with plyometric exercises, perceived benefits and challenges, and specific instances where they noticed improvements in their explosive power.

2.3 Data Analysis

Data analysis was conducted using thematic analysis, a method suitable for identifying, analyzing, and reporting patterns within qualitative data. The process involved several steps:

Familiarization with Data: Transcripts of the interviews were read and re-read to become deeply familiar with the content. Initial impressions and potential themes were noted.

Generating Initial Codes: The data were systematically coded using an open coding approach, where segments of the text were labeled with descriptive codes. This step helped in organizing the data into meaningful groups.

Searching for Themes: Codes were examined for patterns and grouped into broader themes that captured significant aspects of the data related to the research question.

Reviewing Themes: The identified themes were reviewed and refined to ensure they accurately reflected the data. This involved checking if the themes worked in relation to the coded extracts and the entire data set.

Defining and Naming Themes: Each theme was clearly defined and named to capture the essence of the data it represented. Detailed descriptions were developed for each theme, supported by illustrative quotes from the interviews.

Writing the Report: The final step involved integrating the themes and accompanying quotes into a coherent narrative that addressed the research question and highlighted the role of plyometric training in improving explosive power in sprinters.

3. Findings and Results

The study included 17 participants, comprising 10 males and 7 females, aged between 18 and 30 years. The average age of the participants was 24 years, with a standard deviation of 3.2 years. All participants had been actively involved in competitive sprinting for at least three years, with the average duration of their sprinting careers being 5.8 years. The participants were recruited from various local athletic clubs and universities, ensuring a diverse representation of different competitive levels and backgrounds. In terms of competitive experience, 5 participants had competed at national levels, 8 at regional levels, and 4 at international levels.

Table 1. The Results of Thematic Analysis

Main Themes	Subthemes	Concepts
Physical Improvements	Enhanced Muscle Strength	Increased leg strength, Improved core stability, Greater muscle endurance
	Increased Speed	Faster sprint times, Better acceleration, Improved reaction time
	Improved Jumping Ability	Higher vertical jump, Longer horizontal jump, Better landing techniques
	Reduced Injury Risk	Stronger tendons and ligaments, Better joint stability, Enhanced flexibility
	Enhanced Agility	Quicker direction changes, Improved coordination, Enhanced balance
	Better Overall Fitness	Increased stamina, Improved cardiovascular health, Better body composition
	Enhanced Explosive Power	Improved burst power, Stronger initial push-off, Enhanced muscle contraction speed
Psychological Benefits	Increased Confidence	Greater self-assurance, Positive self-image, Improved mental toughness
	Enhanced Motivation	Higher training engagement, Better focus on goals, Increased desire to compete
	Reduced Anxiety	Lower pre-race nervousness, Improved stress management, Greater relaxation during training
	Improved Mental Resilience	Better coping with setbacks, Enhanced perseverance, Greater ability to overcome challenges
	Positive Attitude Towards Training	More enjoyment in training, Better attitude towards workouts, Greater willingness to try new exercises
	Enhanced Focus and Concentration	Better attention during drills, Improved task execution, Greater ability to stay in the moment
Training Experience	Variety in Training Routine	Diverse exercises, Reduced boredom, Increased engagement
	Better Understanding of Techniques	Improved exercise execution, Greater awareness of body mechanics, Better comprehension of training goals
	Increased Training Efficiency	More effective workouts, Time-efficient routines, Reduced unnecessary exercises
	Enhanced Coaching Feedback	More personalized advice, Better coach-athlete communication, Improved feedback implementation
	Improved Peer Support	Greater camaraderie, More encouragement from teammates, Better shared experiences
	Better Adaptation to Workouts	Faster recovery times, Increased workout intensity tolerance, Greater ease in learning new exercises
Performance Outcomes	Improved Competition Results	Higher race placements, More personal bests, Greater success in competitions
	Enhanced Skill Application	Better transfer of training to races, Improved technique under pressure, Greater consistency in performance
	Increased Medal Count	More podium finishes, Greater recognition, Enhanced reputation
	Greater National/International Success	Higher rankings, Better performance in international meets, Greater representation in national teams
	Improved Recovery Times	Faster recuperation post-race, Reduced muscle soreness, Enhanced recovery protocols

Enhanced Tactical Awareness	Better race strategies, Improved opponent analysis, Greater adaptability during races
Increased Sponsorship Opportunities	More sponsorship deals, Greater brand interest, Enhanced financial support

3.1 Physical Improvements

Participants highlighted several physical improvements attributed to plyometric training.

Enhanced Muscle Strength was frequently mentioned, with sprinters reporting increased leg strength, improved core stability, and greater muscle endurance. One participant noted, "I felt my legs getting stronger and more stable, which really helped with my sprinting technique."

Increased Speed emerged as a significant benefit, with faster sprint times, better acceleration, and improved reaction time being common themes. "My start times have improved drastically since incorporating plyometrics into my routine," shared another sprinter.

Improved Jumping Ability was another advantage, with participants describing higher vertical jumps, longer horizontal jumps, and better landing techniques. A sprinter remarked, "My vertical jump increased, and I can definitely see the difference in my performance on the track."

Reduced Injury Risk was also highlighted, with stronger tendons and ligaments, better joint stability, and enhanced flexibility contributing to fewer injuries. "Since starting plyometric training, I've noticed I don't get injured as often," said one athlete.

Enhanced Agility was reported, with quicker direction changes, improved coordination, and enhanced balance being key outcomes. "I'm able to change direction much faster, which is crucial during races," noted a sprinter.

Better Overall Fitness included increased stamina, improved cardiovascular health, and better body composition. "I feel fitter and can sustain my performance for longer periods," a participant mentioned.

Enhanced Explosive Power was commonly cited, with sprinters noting improved burst power, stronger initial push-off, and enhanced muscle contraction speed. "The explosive power in my starts has significantly improved," said one sprinter.

3.2 Psychological Benefits

The psychological benefits of plyometric training were equally noteworthy.

Increased Confidence was a recurrent theme, with sprinters reporting greater self-assurance, a positive self-image, and improved mental toughness. "I feel more confident in my abilities on and off the track," shared a participant.

Enhanced Motivation was frequently mentioned, with higher training engagement, better focus on goals, and an increased desire to compete. "Plyometric training has really boosted my motivation to train harder," said one sprinter.

Reduced Anxiety was another benefit, with lower pre-race nervousness, improved stress management, and greater relaxation during training being noted. "I don't get as anxious before races anymore," commented an athlete.

Improved Mental Resilience was highlighted, with better coping with setbacks, enhanced perseverance, and a greater ability to overcome challenges being significant outcomes. "I feel more resilient and able to handle setbacks," noted a sprinter.

Positive Attitude Towards Training emerged as a theme, with more enjoyment in training, a better attitude towards workouts, and a greater willingness to try new exercises being reported. "Training has become more enjoyable, and I look forward to it," shared a participant.

Enhanced Focus and Concentration was frequently mentioned, with better attention during drills, improved task execution, and a greater ability to stay in the moment. "My focus during training has improved significantly," noted a sprinter.

3.3 Training Experience

Participants also reported improvements in their overall training experience.

Variety in Training Routine was a notable theme, with sprinters appreciating diverse exercises, reduced boredom, and increased engagement. "The variety in plyometric exercises keeps training interesting," said one participant.

Better Understanding of Techniques was highlighted, with improved exercise execution, greater awareness of body mechanics, and better comprehension of training goals being noted. "I have a much better understanding of the techniques involved," shared a sprinter.

Increased Training Efficiency emerged as a theme, with more effective workouts, time-efficient routines, and reduced unnecessary exercises being reported. "My workouts are more efficient now, and I get more done in less time," commented an athlete.

Enhanced Coaching Feedback was frequently mentioned, with more personalized advice, better coach-athlete communication, and improved feedback implementation being noted. "The feedback from my coach has been invaluable," said a sprinter.

Improved Peer Support was another benefit, with greater camaraderie, more encouragement from teammates, and better shared experiences being highlighted. "The support from my teammates has been amazing," shared a participant.

Better Adaptation to Workouts was reported, with faster recovery times, increased workout intensity tolerance, and greater ease in learning new exercises being noted. "I adapt to new workouts much quicker now," said a sprinter.

3.4 Performance Outcomes

The impact of plyometric training on performance outcomes was significant.

Improved Competition Results was a major theme, with higher race placements, more personal bests, and greater success in competitions being reported. "I've achieved more personal bests since starting plyometric training," noted a sprinter.

Enhanced Skill Application was frequently mentioned, with better transfer of training to races, improved technique under pressure, and greater consistency in performance being highlighted. "My skills have definitely improved in competitive settings," shared an athlete.

Increased Medal Count was another benefit, with more podium finishes, greater recognition, and an enhanced reputation being noted. "I've won more medals since incorporating plyometrics into my training," said a participant.

Greater National/International Success emerged as a theme, with higher rankings, better performance in international meets, and greater representation in national teams being reported. "My performance in international competitions has improved," noted a sprinter.

Improved Recovery Times was highlighted, with faster recuperation post-race, reduced muscle soreness, and enhanced recovery protocols being significant outcomes. "My recovery times have improved significantly," shared an athlete.

Enhanced Tactical Awareness was another benefit, with better race strategies, improved opponent analysis, and greater adaptability during races being noted. "I've become more tactically aware during races," said a sprinter.

Increased Sponsorship Opportunities was frequently mentioned, with more sponsorship deals, greater brand interest, and enhanced financial support being reported. "I've gained more sponsorship opportunities since my performance improved," shared a participant.

4. Discussion and Conclusion

The findings of this study demonstrate that plyometric training significantly enhances explosive power in sprinters. Participants reported notable improvements in muscle strength, speed, jumping ability, and overall agility. These physical improvements align with the psychological benefits observed, such as increased confidence, motivation, and mental resilience. Furthermore, the enhanced training experience and performance outcomes underscore the comprehensive benefits of incorporating plyometric exercises into sprint training regimens.

Enhanced Muscle Strength was a key outcome, with participants noting increased leg strength, improved core stability, and greater muscle endurance. This is consistent with findings by Adnyana et al. (2022), who observed significant increases in leg power following plyometric training (8). Similarly, Arazi and Asadi (2011) reported improvements in strength among young basketball players, underscoring the effectiveness of plyometric exercises in developing muscle strength across different sports (10).

Increased Speed was another critical improvement, with participants experiencing faster sprint times, better acceleration, and improved reaction time. These findings are supported by Rimmer and Sleivert (2000), who documented enhanced sprint performance following a plyometric intervention program (26). Furthermore, Aksović et al. (2021) highlighted the positive effects of plyometric training on sprint and direction change speed in basketball players, which can be extrapolated to sprinting (9).

Improved Jumping Ability emerged as a significant benefit, with participants noting higher vertical jumps and longer horizontal jumps. This is corroborated by Benito-Martínez et al. (2011), who found that combined electrostimulation and plyometric training significantly improved vertical jump performance (17). The work of Singh and Singh (2018) also supports these findings, demonstrating that both vertical and horizontal plyometric exercises enhance running speed and jumping ability (27).

Reduced Injury Risk was another reported advantage, attributed to stronger tendons and ligaments, better joint stability, and enhanced flexibility. This aligns with the

findings of Hamzah et al. (2020), who reported that plyometric training combinations improved balance and reduced injury risk in individuals with chronic ankle instability (12). Additionally, Sugisaki and Kurokawa (2014) emphasized that lower-body plyometric training positively affects muscle-tendon properties, thereby enhancing joint stability and reducing injury susceptibility (28).

Enhanced Agility was highlighted, with participants noting quicker direction changes, improved coordination, and enhanced balance. These findings are supported by Lakshmikanth et al. (2018), who found that plyometric training improved agility performance in tennis players (22). Similarly, Romadhoni and Irianto (2018) observed that plyometric and strength training enhanced agility and power skills in volleyball players, further validating the versatility of plyometric exercises in improving agility across sports (29).

Better Overall Fitness and Enhanced Explosive Power were consistently reported, with participants noting increased stamina, improved cardiovascular health, and enhanced burst power. These outcomes are supported by studies like that of Kosova et al. (2022), who demonstrated significant improvements in jump height, agility, speed, and asymmetry following an eight-week plyometric training program (6). Pereira et al. (2022) also noted that post-activation performance enhancement varies with training surfaces, with plyometric training on both hard and sand surfaces yielding beneficial effects on explosive power (30).

Psychological benefits were equally pronounced. Increased Confidence, Enhanced Motivation, and Improved Mental Resilience were frequently mentioned by participants. These findings resonate with the study by Bawiskar and Phansopkar (2021), who reported that agility training, inclusive of plyometric exercises, improved psychological attributes such as confidence and focus in police cadets. This psychological enhancement can lead to better training adherence and performance outcomes (13).

The overall training experience was significantly enhanced by plyometric training. Participants appreciated the Variety in Training Routine, Better Understanding of Techniques, and Increased Training Efficiency. These aspects are crucial for maintaining athlete engagement and ensuring effective training. Bolger et al. (2016) emphasized the importance of expert coaching in sprinting, noting that tailored training programs incorporating resistance-based and plyometric exercises lead to better performance outcomes (14). This study's findings support the need for diverse and well-structured training regimens.

Performance outcomes, such as Improved Competition Results, Enhanced Skill Application, and Increased Medal Count, were notably better in participants following plyometric training. These findings align with those of Borah and Sajwan (2022), who observed significant improvements in collegiate athletes' countermovement jump performance, indicative of enhanced explosive power (7). Villarreal et al. (2012) also confirmed through a meta-analysis that plyometric training effectively improves sprint performance, further validating the results of this study (31).

Despite the promising findings, this study has several limitations. Firstly, the sample size of 17 participants, though adequate for qualitative research, may limit the generalizability of the results. Future studies could benefit from larger and more diverse sample sizes to validate these findings across different populations and sports disciplines. Secondly, the study relied solely on self-reported data from semi-structured interviews, which may be subject to biases such as social desirability and recall bias. Objective measures of physical improvements, such as pre- and post-training performance tests, could provide more robust evidence of the benefits of plyometric training. Additionally, the study focused on sprinters; thus, the findings may not be directly applicable to athletes from other sports with different physical and physiological demands.

Future research should aim to address these limitations by incorporating larger sample sizes and including athletes from various sports disciplines to enhance the generalizability of the findings. Longitudinal studies that track athletes over extended periods could provide valuable insights into the long-term benefits and sustainability of plyometric training. Furthermore, combining qualitative and quantitative methods could offer a more comprehensive understanding of the effects of plyometric training. For instance, integrating physiological measurements (e.g., muscle hypertrophy, tendon stiffness) and performance metrics (e.g., sprint times, jump heights) with qualitative data would provide a holistic view of the training's impact. Research could also explore the optimal frequency, duration, and intensity of plyometric training for different athletic populations to develop evidence-based guidelines for practitioners.

Based on the findings of this study, several practical recommendations can be made for coaches and athletes. Firstly, incorporating plyometric training into regular training routines can significantly enhance explosive power,

strength, speed, and agility, which are critical for sprinting performance. Coaches should consider designing diverse and well-structured plyometric training programs tailored to the individual needs and capabilities of athletes. Ensuring proper technique and progression in plyometric exercises is essential to maximize benefits and minimize injury risk. Additionally, the psychological benefits of plyometric training, such as increased confidence and motivation, should be leveraged to enhance overall athlete well-being and performance. Regular monitoring and personalized feedback from coaches can further enhance the effectiveness of plyometric training, helping athletes to achieve their full potential. Finally, integrating plyometric training with other conditioning activities, such as resistance training and dynamic stretching, can provide a comprehensive approach to athletic development, as supported by the literature.

In conclusion, plyometric training is a valuable tool for improving explosive power and overall performance in sprinters. The findings of this study, supported by extensive literature, underscore the multifaceted benefits of plyometric exercises, highlighting their importance in athletic training programs. By addressing the limitations and building on the insights from this study, future research can further elucidate the optimal applications of plyometric training, contributing to the advancement of sports science and athlete performance.

Authors' Contributions

M.B. was responsible for conceptualizing the study, designing the research methodology, and conducting the majority of the interviews. G.O. facilitated participant recruitment, ensured the ethical standards of the research were maintained, and contributed significantly to data transcription and initial coding. Both authors collaboratively performed the thematic analysis, interpreted the data, and discussed the findings. They jointly prepared and critically revised the manuscript, and both approved the final version for publication.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethics Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

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