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Effectiveness of a Motor Rehabilitation Program on Proprioception and Visuospatial Processing in Children with Intellectual Developmental Disabilities

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A B S T R A C T

Objective: This study aimed to determine the effectiveness of a motor rehabilitation program on proprioception and visuospatial processing in children with intellectual developmental disabilities.

Methods and Materials: The research method was quasi-experimental, using a pretest-posttest design with a control group and a two-month follow-up. From the population of trainable children with intellectual developmental disabilities aged 7 to 12 years from exceptional elementary schools in Tehran during the 2023-2024 academic year, a sample of 30 children with an intelligence quotient range of 50 to 75 was selected using a convenience sampling method. They were randomly assigned to two groups of 15 participants (experimental and control groups). Data were analyzed using repeated measures analysis of variance.

Findings: The results indicated that the posttest and follow-up test scores of proprioception and visuospatial processing in children with intellectual developmental disabilities in the experimental group increased compared to the pretest. The results of the repeated measures analysis of variance also showed a significant difference between the experimental and control groups in terms of proprioception and visuospatial processing, and this difference persisted over time ($p < 0.0001$).

Conclusion: Based on the findings, it is recommended to use the motor rehabilitation program in this study to improve the cognitive status of children with intellectual developmental disabilities.

Keywords: *Visuospatial Processing, Motor Rehabilitation, Proprioception, Children with Intellectual Developmental Disabilities*

1. Introduction

Intellectual developmental disability is a significant limitation in intellectual functioning, markedly below average, that manifests simultaneously with deficits in adaptive behavior and becomes evident before the age of 18 (Suchyadi et al., 2018). Children with this disorder pose various challenges and difficulties for family, school, and society, making them vulnerable to psychosocial disturbances during adolescence and adulthood (Galmarini-Kabala, 2019). The definition of the American Association on Intellectual and Developmental Disabilities is based on three core concepts: intellectual functioning, adaptive behavior, and developmental period (Endriyani & Yunike, 2017). According to the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders, the severity of intellectual developmental disability (mild, moderate, severe, or profound) is determined by the individual's ability to meet developmental and sociocultural standards for independence and social responsibility, rather than by the intelligence quotient score (Pascual-Morena et al., 2023).

Some children with intellectual developmental disabilities exhibit behavioral problems, while others struggle academically, ultimately leading to difficulties in daily activities (Ortega et al., 2023). One of the issues faced by these children involves proprioception (Riquelme et al., 2024). Proprioception refers to the sense of the relative position and movement of body parts. Mechanoreceptors embedded in joint muscles, tendons, and skin provide proprioceptive information (Ager et al., 2020). Proprioception, defined as the composite input from joint capsules, ligaments, muscles, tendons, and skin, is a multisystem mechanism that influences behavior regulation and motor control (Blanche et al., 2012). Proprioception is essential for effective muscle control and voluntary movement. Children with conditions such as autism, Down syndrome, and developmental disorders like intellectual developmental disabilities consistently exhibit proprioceptive deficiencies, affecting motor control (Holst-Wolf et al., 2016). Children with intellectual developmental disabilities often struggle with processing proprioceptive information. Furthermore, since proprioception affects movement speed and timing, muscle force regulation, and muscle tension control, it impacts these children's motor planning ability (Blanche et al., 2012). Overall, proprioception is crucial for motor learning, particularly in refining skills, given its critical role in ascending feedback mechanisms (Li et al., 2021).

Another fundamental neuropsychological skill in which children with intellectual developmental disabilities are deficient is visuospatial processing. Visuospatial memory, as one of the central nervous system's complex abilities, gives meaning to visual observations and influences students' learning (Moshirian Farahi et al., 2016). Visuospatial processing involves distinguishing visual features (e.g., color, shape, texture) from spatial features (e.g., relative or absolute distance, positions, and metric relationships) in mental representations (Safari Vesal et al., 2022). Visuospatial ability is a critical dimension of cognitive ability and is referred to as the ability to express and transfer symbolic or nonverbal information. Deficits in visuospatial processing lead to incorrect environmental information reception, which in turn affects cognitive processes and learning (Morey, 2019).

Children and adolescents with intellectual developmental disabilities are characterized by deficits in fundamental motor skills (Moyano et al., 2023) because intellectual developmental disability is associated with impaired brain functioning, affecting both cognition and motor skills (Top, 2023). Motor skill development includes gross motor skills, fine motor skills, and bilateral coordination skills. The two main types of motor skills are fine motor skills and gross motor skills. Fine motor skills involve manipulating objects with the fingers, whereas gross motor skills require less precise control of hand and finger movements (Gonzales et al., 2023).

It has been shown that children with intellectual developmental disabilities are less physically active than typically developing children, and this reduced physical activity can impact their proprioception and visuospatial processing. Improving these skills in children may be crucial for increasing participation in physical activities or sports. Numerous studies using either a single physical activity session or a prolonged motor intervention have reported acute (after one session) and chronic (after several sessions) positive effects on aerobic capacity, gross motor skills, and psychosocial and cognitive functioning in individuals with intellectual developmental disabilities (Cerrillo-Urbina et al., 2015).

Among various motor exercises and rehabilitation programs, isotonic and isometric resistance training can be effective strategies for improving balance in children with intellectual disabilities. Incorporating these exercises into regular motor rehabilitation programs may enhance motor skills and balance in children with intellectual developmental disabilities. The role of isotonic and

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isometric exercises as components for addressing sensory integration disorders has been established (Yan et al., 2022). Isotonic exercise involves the concentric shortening of the agonist muscle while the antagonist muscle lengthens eccentrically (or vice versa), utilizing the stretch-shortening cycle to increase muscle length immediately following muscle shortening (Davies et al., 2015). Isotonic exercises improve muscle size and strength, cardiovascular fitness, bone density, and injury risk reduction. In contrast, isometric exercise is a static activity where the muscle length remains constant despite force application. Isometric muscle function can involve holding a position to resist impact forces or pushing against stable resistance (Schaefer & Bittmann, 2017). Isometric training enhances joint flexibility, reduces blood pressure, and can be used in rehabilitation. Additionally, incorporating isotonic and isometric resistance exercises into regular training programs may increase muscle strength and range of motion and improve overall health and quality of life (Laskowski, 2015).

Participation in resistance training is associated with reduced central obesity and unhealthy fat accumulation and can promote weight loss (Kuznetsova et al., 2020). A meta-analysis involving children with intellectual developmental disabilities showed that acute and chronic physical activity or motor interventions improved physical health (e.g., cardiovascular fitness, motor skills, muscle strength), psychological well-being (e.g., self-esteem, well-being, socio-emotional skills), and cognitive functioning (Azeem & Zemková, 2022). Individuals with intellectual developmental disabilities often experience functional and cognitive decline, reduced physical performance, lower social engagement, and a sedentary lifestyle. Therefore, aerobic exercise interventions designed to enhance motor skills and physical fitness and adaptive functioning in children with intellectual developmental disabilities are essential for optimal health outcomes. Evidence supports the beneficial impact of exercise interventions on motor proficiency in young people with intellectual developmental disabilities (Hsu & Tseng, 2024).

However, the current understanding of the effects of isotonic and isometric interventions on motor skills and range of motion in children with intellectual developmental disabilities is limited. Hsu et al. (2024) examined the effects of a 12-week floor hockey training program on motor skills, physical fitness, and adaptive development in youth with mild intellectual disabilities. The results demonstrated significant improvements in motor skill scores, physical fitness, and adaptive development indicators following the 12-week program (Hsu & Tseng, 2024).

Overall, the research literature indicates a research gap regarding the effectiveness of isotonic and isometric exercises on the variables examined in this study. Given the potential impact of isotonic and isometric training on proprioception and visuospatial processing in children with intellectual disabilities, the present study aimed to investigate the effects of isotonic and isometric training on proprioception and visuospatial processing in children with intellectual developmental disabilities.

2. Methods and Materials

2.1. Study Design and Participants

A quasi-experimental method was employed in this study, utilizing a pretest-posttest design with an unmatched control group and a follow-up assessment period. The study population consisted of trainable children with intellectual developmental disabilities aged 7 to 12 years, enrolled in exceptional elementary schools in Tehran during the 2023-2024 academic year. Using a convenience sampling method, two schools in District 5 of the Education Department were selected. Thirty male students (15 from each school), with intelligence quotient scores ranging from 50 to 75 as indicated in their academic records, were chosen and assigned to two groups. The random assignment was conducted through a lottery, with one group designated as the experimental group and receiving the intervention, while the control group received no intervention.

The students were chosen within the 7-12 age range because it is a highly sensitive developmental period where many foundational educational interventions take place. To avoid dissemination of the intervention program and due to the limited number of students enrolled in these educational centers, two schools from the same educational district were selected, and each was randomly assigned as either the experimental or control group. The participants in both groups were matched based on variables such as age, intelligence quotient, severity of intellectual disability, and socioeconomic status, forming two parallel groups. Inclusion criteria included being 7-12 years old, having an intellectual disability, an intelligence quotient of 50-75, enrollment in schools for children with intellectual disabilities, and willingness to participate in the study.

Exclusion criteria involved students who used stimulant medication or had disorders such as autism, attention-deficit/hyperactivity disorder, hearing impairment, visual

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impairment, or motor problems, and those who participated in similar therapy sessions were excluded from the study. Ultimately, the participants were divided into two groups: 1) the experimental group (motor rehabilitation program including a combination of isometric and isotonic exercises, 15 participants), and 2) the control group (15 participants), with the experimental group undergoing intervention sessions led by a therapist while the control group received no intervention. Confidentiality of participant information was emphasized, and collected data were used exclusively for research purposes, maintaining participant privacy throughout the study. The research methodology was in accordance with social, cultural, and religious values. Data were analyzed using repeated measures analysis of variance.

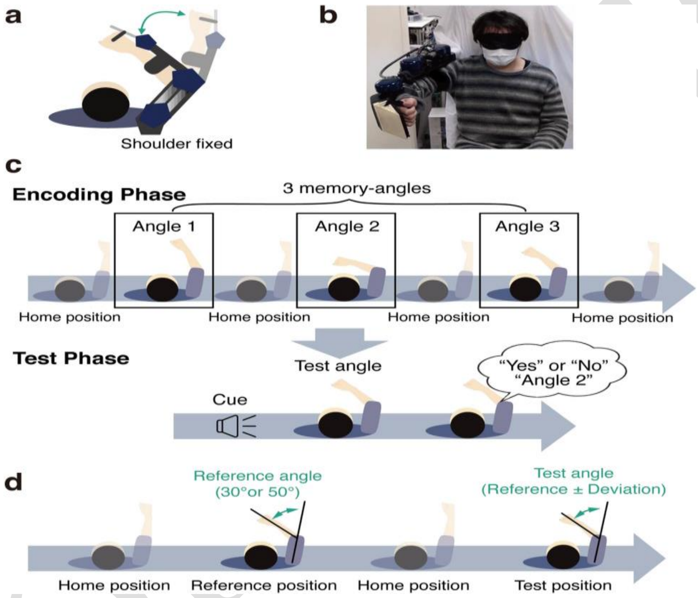
2.2. *Measures*

2.2.1. *Proprioception*

To measure joint position sense, an Autocad-based imaging technique was used.

Figure 1

Proprioceptive Functioning (Chiyohara, Furukawa, Neda, Morimoto, & Yamamizu, 2023)



a. Setup and experimental tasks for measuring proprioceptive function of participants

b. An exoskeleton robot guiding the participant's elbow joint in flexion and extension within a horizontal plane. Images of the exoskeleton robot from the front view

c. Short-term memory task for proprioception

d. Proprioceptive judgment task

2.2.2. *Visuospatial Processing*

Stanford-Binet Visuospatial Processing: The fifth edition of the Stanford-Binet Intelligence Scale, developed by Roid in 2003 and standardized in 2006 by Afroz and Kamkari, was used. The scoring for the visuospatial processing scale includes both verbal and nonverbal components. The verbal component comprises 44 questions, and nonverbal fluid reasoning includes 36 questions. Based on student performance and scores obtained, nonverbal performance was assessed using Question Booklet 2. The verbal component includes 44 questions that the student answers using Question Booklet 3. Raw scores obtained from both fluid reasoning (nonverbal) and knowledge (verbal) were standardized and converted to visuospatial intelligence quotient scores. Roid and Gall (2003) used the split-half method to calculate the reliability coefficient for scores of ten subtests, four IQ areas, and five factor indices, which were corrected using the Spearman-Brown formula. All reliability coefficients demonstrated internal consistency of the scale. In a study by Mahdavi Najmabadi, Kadover, Arjmandnia, and Pooshneh (2021), significant correlations were found between the total scale scores and nonverbal (0.48) and verbal (0.41) domains, with a correlation of 0.97 between verbal and nonverbal scores. The reliability of the visuospatial processing IQ scale was reported as 0.98 using

Cronbach's alpha (Moshirian Farahi et al., 2016; Safari Vesal et al., 2022).

2.3. Intervention

2.3.1. Motor Rehabilitation Program

The rehabilitation program in this study consisted of a combination of selected isometric and isotonic exercises. The program was implemented over 11 weeks, with three 45-minute sessions per week. The exercises engaged most of the head, neck, trunk, upper and lower limbs, progressing from single-joint movements (to strengthen neural connections to specific muscle groups) to compound exercises (to enhance neuromuscular cooperation). Most exercises involved active participation from the individual, with gradual resistance. In some cases, the trainer provided active assistance, which transitioned into active and eventually resisted movements.

For isometric exercises, no fixed duration for holding a position was set, as it depended on the individual's endurance, with time gradually increased. Due to the variety of exercises, the program was distributed across weeks based on motor developmental stages. Weeks 1 to 3 included a combination of isometric and isotonic exercises in positions like "prone," "supine," and "side-lying." Weeks 4 to 6 incorporated exercises in positions like "quadruped," "sitting with legs extended," "kneeling, squatting, and kneeling on one knee," and "sitting on a chair." Weeks 7 to 9 focused on "standing" exercises. Although "hands" were emphasized throughout, the exercises in weeks 10 and 11 were dedicated specifically to "hand" exercises.

Before practical exercises were carried out, instructions were verbally provided, and if necessary, demonstrated. During the study, participants warmed up for 5 minutes, followed by a combination of isometric and isotonic exercises, and concluded with a 10-minute cool-down session.

2.4. Data analysis

Data were analyzed using repeated measures analysis of variance through SPSS-26.

3. Findings and Results

In this study, 30 children with intellectual developmental disabilities participated, with a mean age of 9.43 years (SD = 3.13). The mothers of these children also participated, with a mean age of 37.12 years (SD = 5.32).

The study sample included 215 working adolescents (69 females and 146 males) with a mean age of 14.87 years and a standard deviation of 1.31 years. Table 1 presents the means, standard deviations, and correlation coefficients among mental health, stressful life events, emotional intelligence components, moral intelligence, and addiction proneness

Table 1

Descriptive Data for Proprioception and Visuospatial Processing Variables Across Pretest, Posttest, and Follow-Up Stages

Variable	Group	Test Stage	N	Mean	Standard Deviation
Proprioception	Intervention	Pretest	15	58.20	8.43
		Posttest	15	78.33	8.54
		Follow-Up	15	79.20	9.89
	Control	Pretest	15	59.00	6.98
		Posttest	15	58.26	7.89
		Follow-Up	15	58.33	7.43
Visuospatial Processing	Intervention	Pretest	15	6.33	1.78
		Posttest	15	9.66	2.24
		Follow-Up	15	9.86	2.53
	Control	Pretest	15	6.46	1.78
		Posttest	15	6.26	1.52
		Follow-Up	15	6.06	1.76

As shown in Table 1, descriptive statistics for proprioception and visuospatial processing are provided for the pretest, posttest, and follow-up stages for both the intervention and control groups. The data comparison reveals that the mean scores for proprioception and visuospatial processing in the intervention group increased from the pretest to the posttest and follow-up, whereas the control group showed no noticeable changes.

Table 2

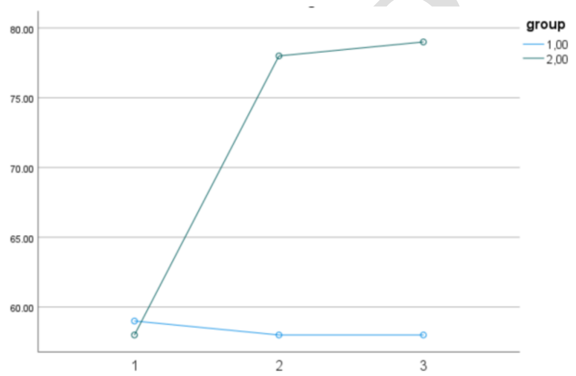
Repeated Measures Analysis of Variance Results for the Impact of Motor Rehabilitation on Proprioception and Visuospatial Processing

Variable	Effect	F Value	Hypothesis df	Error df	p-Value	Eta Squared	Statistical Power
Proprioception	Time	68.807	2	27	<.001	.836	.164
	Group × Time Interaction	77.380	2	27	<.001	.851	.149
Visuospatial Processing	Time	14.400	2	27	<.001	.516	.484
	Group × Time Interaction	24.927	2	27	<.001	.649	.351

As indicated in Table 2, the F-value for proprioception (F = 77.380) and for visuospatial processing (F = 24.927), associated with the interaction between time and group membership, demonstrates a significant difference between the intervention and control groups for both variables. To illustrate the results across the test stages (pretest, posttest, and follow-up), Figures below provide visual comparisons.

Figure 2

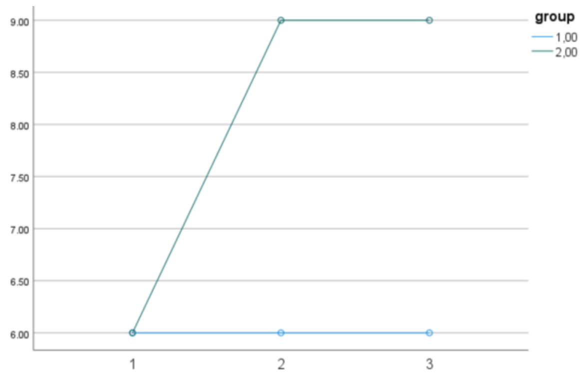
Comparison of Proprioception Means Between the Control and Motor Rehabilitation Intervention Groups at Pretest, Posttest, and Follow-Up Stages



As shown in Figure 2, the mean proprioception scores of the motor rehabilitation intervention group differ from those of the control group at the posttest and follow-up stages. This indicates that the motor rehabilitation program had a sustained impact on the motor skills of children with intellectual developmental disabilities.

Figure 3

Comparison of Visuospatial Processing Means Between the Control and Motor Rehabilitation Intervention Groups at Pretest, Posttest, and Follow-Up Stages



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As shown in Figure 3, the mean visuospatial processing scores of the motor rehabilitation intervention group differ from those of the control group at the posttest and follow-up stages. This suggests that the motor rehabilitation program had a lasting effect on the proprioceptive depth of children with intellectual developmental disabilities.

4. Discussion and Conclusion

This study aimed to determine the effectiveness of a motor rehabilitation program on proprioception and visuospatial processing in children with intellectual developmental disabilities. The first finding indicated that the motor rehabilitation program had a lasting positive effect on the proprioception of these children. This result aligns with the prior research (Babaei Mobarakeh et al., 2017; Dehghani Zadeh & Rahmati Arani, 2021). Proprioception is a crucial sense that enables individuals to be aware of their bodies and to recognize and control applied force and pressure. It plays a significant role in monitoring and controlling sensory processing. In other words, proprioceptive input data can help control responses to sensory stimuli (De Baets et al., 2023). Children with intellectual developmental disabilities who have poor proprioception often face motor skill challenges. Creative and effective activities can be used to enhance proprioception, allowing children to gain the vital skills necessary for performing daily activities with greater confidence. The motor rehabilitation sessions in this study focused on sensory-motor stimulation to help children better understand and control their movements. These methods aid in improving proprioception, essential for understanding body position in space (Lindsay et al., 2023). Motor rehabilitation can strengthen proprioception, thereby enhancing children's motor skills, which is well-documented in research and rehabilitation contexts (Gilmour & Lidstone, 2023; Stern et al., 2023).

Moreover, given that fine motor skills and hand movements are crucial in the rehabilitation of children with intellectual developmental disabilities, the protocol used in this study appears to have significantly impacted the children's motor functions. Repeatedly implementing this rehabilitation program may facilitate sensory input from upper limb receptors, activating more neurons and thereby improving children's proprioception.

Isometric and isotonic exercises are also central to understanding this finding. Isometric exercises, which involve muscle contractions without movement, have been shown in studies on children with muscle disorders to improve motor function and proprioception (Pérez et al., 2023). Isotonic exercises involve muscle contractions that enhance muscle fiber strength and power, making them suitable for increasing muscular fitness in children. Isotonic exercises, whether weightless (home-based) or weighted (gym-based), can strengthen muscles (Rodrigues da Silva Barros et al., 2023). One possible mechanism for the observed proprioceptive improvement may be the activation of neural pathways, increased synapse formation, and sensory area expansion linked to neuroplasticity. These exercises may activate previously inactive muscles, enabling the central nervous system to receive more effective proprioceptive inputs from afferent nerves, thereby enhancing motor planning and execution (Shen et al., 2023).

Additionally, the motor rehabilitation program in this study emphasized structured developmental and functional stages for children with developmental or acquired impairments. The ultimate goal was to maximize children's developmental and functional potential, improving motor skills. Studies confirm that motor rehabilitation strengthens proprioception, helping children enhance their motor skills. Techniques used in this program, such as trunk extension and flexion, scapular retraction, and various lower and upper limb exercises, have shown to improve proprioception in children with intellectual developmental disabilities (Shahid et al., 2023).

Another finding was that the motor rehabilitation program had a sustained positive effect on visuospatial processing in children with intellectual developmental disabilities. This result is consistent with prior research (Dehghani Zadeh & Rahmati Arani, 2021). Motor activities play a fundamental role in cognitive functions. People appear to think through bodily movements, and motor experiences activate different brain areas, improving spatial recognition and performance (Zhao et al., 2024). Studies indicate that motor exercises and movement-based activities can enhance visuospatial performance across groups. Rhythmic motor exercises, in particular, are a simple and effective way to explore brain capabilities, improving attention, focus, and cognitive function in children (Ren et al., 2024).

The dynamic systems theory suggests that movement and motor disorders are not solely controlled by the central nervous system or cognitive processes. Instead, this theory views motor development as being influenced by the interaction of multiple systems, including organismic systems (e.g., strength, balance, and flexibility),

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environmental factors (e.g., surface stability, wind, temperature), and the nature of the task (e.g., hitting a moving ball vs. a stationary one). The central nervous system significantly impacts motor coordination, but other factors like muscle strength, balance, and flexibility also influence movement. For example, muscle weakness can hinder walking, and reduced balance and flexibility can lead to motor delays. The nature of the task also impacts motor difficulties. The treatment focus in the dynamic systems model is on identifying and overcoming organismic limitations while modifying environmental and task constraints to facilitate movement (Laskowski, 2015). Therapists design engaging programs using therapy balls, balance boards, and resistance bands to improve strength, balance, flexibility, and visuospatial processing.

Rhythmic motor exercises combined with structured routines were employed in this study's rehabilitation program. These exercises engage the limbic system and promote sensory-motor integration, enhancing cognitive skills like visuospatial processing through rhythm perception and faster auditory response. This type of motor rehabilitation stimulates excitatory or inhibitory neurotransmitters, improving visuospatial processing through interactions between the limbic system, sensory-motor integration, and cortical-frontal regions (Zeng et al., 2023). Rhythmic motor exercises also require children to follow predetermined patterns, and repeated practice helps improve visuospatial processing.

5. Limitations & Suggestions

The primary limitation of this study was the use of a non-random sampling method, and it only included male participants, limiting the generalizability of the findings to females. Parental education, immigrant status, and financial situation were not controlled, despite evidence that these factors influence children's and families' outcomes. Future research should use random sampling to improve generalizability and examine the influence of contextual variables such as parental education, immigrant status, and socioeconomic class on the effectiveness of motor rehabilitation for children with intellectual developmental disabilities.

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Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants. Each participant received an informed consent form to understand the study's objectives.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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Authors' Contributions

All authors equally contributed in this article.

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