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Fundamental Motor Skills Assessments Predicting Academic Performance: A Systematic Review

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Abstract

Background: Motor skills are crucial predictors of academic achievement in preschool children; effective motor skill interventions require assessment tools to evaluate motor performance and intervention efficacy. This study aimed to evaluate motor skill assessment tools in terms of their domains and psychometric properties to determine and understand the effect of motor ability on academic performance.

Methods: A comprehensive electronic search was performed in PubMed, Scopus, ProQuest databases, and Google Scholar motor engine between January 2013 and May 2025 for all accessible articles involving the application of standardized, psychometrically sound motor proficiency skill tools.

Results: A total of eight motor proficiency assessment tools were identified. The MABC-2 and BOT-2 were the most commonly used for predicting academic performance. The psychometric properties and applications of all tools were appraised and compared.

Conclusion: Applying these standardized and psychometrically sound tools provides crucial insights into the link between motor competence and students' academic achievement, which has important implications for early identification, intervention, and educational practices.

Keywords: Academic performance, Motor skills, Perceptual motor performance, Preschool children, Review

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Introduction

During the last decade, the link between academic performance and motor skills has been at the center of much attention (2-4). Therefore, it has been established that academic performance is influenced by several motor factors, such as balance, visual-motor integration (5), dexterity and locomotor skills (6), and bilateral motor coordination (7), as per research findings.

Katagiri et al. suggested that motor skills are an important factor in predicting later academic performance among preschoolers (8).

Macdonald et al.(2018) (2) conducted a systematic review summarizing research on the association between motor proficiency and academic outcomes in math and reading among typically developing school-aged children and adolescents. On the other hand, numerous studies (9-11) have established the efficacy of motor skills interventions in improving academic performance.

All types of motor skill interventions require motor skills assessment tools, which can appraise motor skills, monitor children's motor performance, evaluate intervention programs (12), and prepare normative references for comparison to peers (13).To date, several studies have

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↑What is "already known" in this topic:
Children's academic achievement is positively linked to their fine and gross motor skills. This relationship is supported by evidence linking motor development to cognitive processes such as attention, memory, and executive function.

→What this article adds:
This study examines widely used tools for evaluating motor skills used to explore links between motor skills and academic performance, focusing on their domains and psychometric qualities. It identifies the most widely used and practical tools to guide researchers and practitioners in selecting suitable instruments.

provided guidance on the most effective approaches to using motor assessment tools. For example, a review published in 2009 by Cools et al. (14) summarized seven of the most applicable Tools for assessing movement skills in typically developing preschoolers. These tools were the Motoriktest für Vier- bis Sechjärige Kinder (MOT4-6), the Movement Assessment Battery for Children (Movement-ABC), the Peabody Development Scales (PDMS), the Körperkoordinationtest für Kinder (KTK), the Test of Gross Motor Development (TGMD), the Maastrichtse Motoriek Test (MMT), and the Bruininks-Oseretsky test of Motor Proficiency (BOTMP). A notable gap between this article and similar research (15-18) was that the findings from these studies emphasized the detection of the most appropriate tools for assessing motor proficiency in children without considering the relationship between motor assessment skills and academic performance. However, there is a lack of research examining the relationship between motor assessment tools and academic performance.

Regarding the importance of motor skills in predicting the academic performance of school-aged children, this study aimed to investigate motor skill tools used to appraise the impact of motor proficiency on academic performance in terms of their domains and psychometric properties. Furthermore, the highly used motor assessment tools were determined, and the most applicable tools in this field were identified.

Methods

Search Strategy

We conducted a systematic evidence-based review following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework for systematic reviews and meta-analyses (15). To gather data, two researchers, both occupational therapists with expertise in motor skills development in children, performed an exhaustive literature search in the PubMed, Scopus, ProQuest databases, and Google Scholar motor engine using relevant keywords between January 2013 and May 2025.

Search Terms

The keywords, whether applied individually or combined using Boolean operators like AND, OR (based on MeSH terms), were as follows: motor skill, motor performance, motor coordination, fine motor, tools, assessment, evaluation, academic performance, academic achievement, children, and preschool children. The details of the search strategy are presented in Table 1.

Study Selection and Data Extraction

Two researchers independently reviewed all selected articles in line with the inclusion and exclusion criteria. Any disagreements were settled through consensus, with a third researcher making the final decision if consensus could not be reached.

Inclusion and Exclusion Criteria

Articles that included five inclusion criteria—target population, study design, measurement tools, publication Date Range, and Language —were selected.

Target population. The target population for this study consisted of typically developing children in preschool and elementary school settings. Studies involving children with disabilities were excluded from the synthesis to ensure a focus on a typically developing population.

Study design. Only peer-reviewed studies were considered for inclusion. The study design included in this review comprised intervention, cross-sectional, longitudinal, and correlational studies, randomized and non-randomized controlled trials, and quasi-randomized studies. All studies were required to focus on preschool and elementary-aged typically developing children.

Table 1. Search strategy for different databases

Database	Search strategy
PubMed	(exp Motor skill) AND (exp Academic performance OR exp ASSESSMENT) (exp Motor skill) AND (exp Academic performance, OR ASSESSMENT)1 (exp Academic performance) AND (exp Motor skill) (1 AND 2) OR (1 AND 3) – limited to human, English, and studies published between January 2013 and March 2024. (inclusive)
ProQuest	(exp Motor skill) AND (exp Academic performance OR exp School OR exp Assessment OR exp tools OR Academic achievement OR exp Motor skill) (exp Academic performance OR exp Motor skill) AND (exp Academic performance OR exp Academic achievement) (exp Academic performance OR exp Academic achievement) AND (exp "Motor skill") (1 AND 2) OR (1 AND 3) – limited to human, English, and studies published between January 2013 and March 2024. (inclusive)
Scopus	(exp Academic performance) AND (exp Motor skill OR exp ASSESSMENT) (exp Motor skill) AND (exp ASSESSMENT, Motor skill OR exp ASSESSMENT TOOLS) (exp School) AND (exp Motor skill) (1 AND 2) OR (1 AND 3) – limited to research and studies published between January 2013 and March 2024 (inclusive)
Google Scholar	"Motor skill" AND ("Academic performance" OR "Children" OR "Preschool children") AND ("Assessment" or scale or evaluation) - limited to studies published between January 2013 and March 2024.

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Measurement tools. In evaluating the studies selected for inclusion in this review, a distinction was made between tools assessing motor skills and those measuring physical activity. Motor skill assessments are designed to evaluate participants' coordination, control, and developmental skill levels, emphasizing both fine and gross motor abilities (16). These assessments focus on the quality and precision of movement—how well specific actions are executed—requiring refined coordination and control. In contrast, Physical activity measurements assess an individual's overall movement patterns and energy expenditure (17, 18). They capture the quantity of movement by tracking parameters like frequency, intensity, duration, and type of physical activity (e.g., aerobic vs. anaerobic), often in the context of fitness or health monitoring.

While physical activity measurements focus on how much movement occurs, motor skills assessments prioritize the quality and skillfulness of that movement. For this review, only studies involving the application of standardized, psychometrically sound motor proficiency skill tools were also included. Furthermore, Tools such as accelerometers and pedometers, which exclusively measure kinematic aspects like acceleration and movement intensity (indicative of physical activity levels), were excluded. Additionally, Tools rarely used or not used in authoritative articles were omitted to ensure methodological rigor and relevance in assessing motor proficiency.

Publication Date Range. The articles included in this review were published between January 2013 and May 2025. This timeframe was selected to capture relevant studies within the last decade, ensuring the findings reflect current trends and advancements in this field.

Language. Only original, peer-reviewed studies published in the English language qualified for inclusion in this review.

The Measurement Properties

The Consensus-based Standards for the Selection of Health Measurement Instruments (COSMIN) checklist is a standardized tool used to evaluate the methodological quality of studies examining measurement properties (19). In this study, these properties are categorized into three main primary domains: reliability, validity, and Responsiveness. Following the psychometric criteria outlined by Terwee et.al. (20), each aspect was rated as Very good / Adequate / Doubtful / Inadequate. We evaluated motor assessment tools across all relevant psychometric characteristics, including various forms of validity and reliability, and responsiveness.

Results

The flow diagram of the search process and results, based on the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (15) is presented in Figure 1. In total, 287 studies were identified through searches in electronic databases and Google

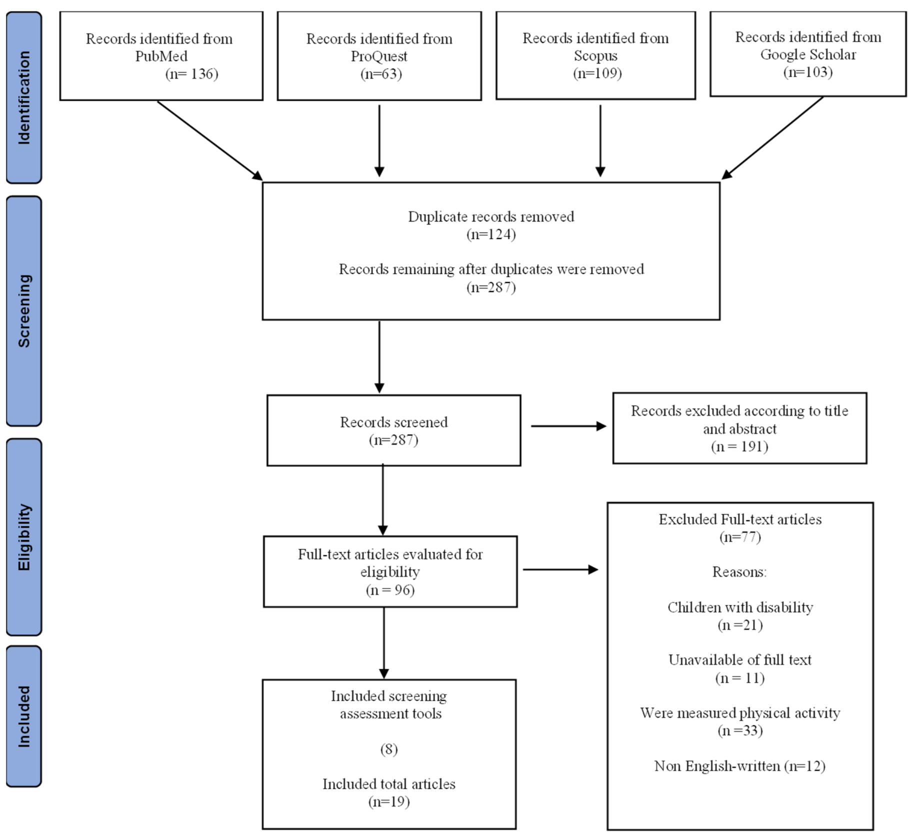

Figure 1. Study selection flowchart (PRISMA)

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Scholar search engines by the first author and a second independent researcher. After screening the articles and removing duplicates, 96 articles remained. These remaining articles were then re-evaluated based on the eligibility criteria. Articles were excluded if the children had disabilities or primary diseases (n = 21), they were unable to source full text (n = 11), they measured physical activity instead of motor skills (n = 33), or they were non-English-written (n =12).

Finally, 19 articles remained, which were reviewed by both authors, leading to the identification of 8 motor proficiency assessment tools, which include: The Bruininks-Oseretsky Test of Motor-Proficiency II (BOT-2), Movement Assessment Battery for Children II (MABC-2), Learning Accomplishment Profile Diagnostic (LAP-D), The Beery-Buktenica Developmental Test of Visual-Motor Integration IV (Beery VMI-4), Test of Gross Motor Development (TGMD), Körperkoordination Test für Kinder (KTK), European physical fitness test battery (EUROFIT) and Functional Dexterity Test (Table 2).

An analysis of the reviewed studies indicated that various assessment tools have been utilized to measure different domains of academic performance, as presented in Table 3.

The assessment tools identified in the findings can be classified into two main categories: perceptual-motor tools, which assess the integration of sensory/ cognitive processing and motor functions, and motor tools, which primarily evaluate motor skill and physical performance. Table 4 provides an overview of these classifications.

Table 5 presents the characteristics of the eight assessment tools documented in the included studies and manuals. Two of these tools are specifically designed for children, including the LAP-D and the TGMD. Additionally, six tools— the MABC-2, BOT-2, Beery VMI-4, KTK, EUROFIT, and FDT—are suitable for assessing both children and adolescents.

All assessment tools reviewed have been used in developed countries, except for the FDT, due to limited available data. This supports the reliability and standard application of these tools in high-resource settings.

The psychometric properties of the assessment tools based on the COSMIN checklist are presented in Table 6. These results provide insights into each tool's reliability, validity, and responsiveness in assessing motor competence.

Discussion

The purpose of this comprehensive systematic review was to identify, compare, summarize, and critically appraise the existing standardized, psychometrically sound motor skill assessment tools that can predict academic

Table 2. An overview of the 8 tools to predict academic performance in typically developing children

Assessments*	Author (year)	Study design	Participants' age (M± SD)
LAP-D	Dinehart and Manfra (2013)- Ricciardi et al. (2021)	Longitudinal longitudinal cohort	5.2 years± 3.6 (Month) 4 to 11y
Beery VMI-4	Pienaar et al. (2013)-Hwang et al. (2024)	Crosssectional Longitudinal	(6.78 ± 0.49)- (5 to 6 y)
BOT-2	Pienaar et al. (2013)- Cadoret et al. (2017)- da Silva Pacheco et al. (2016)- Hwang et al. (2024)	crosssectional longitudinal crosssectional Longitudinal	(6.78 ± 0.49)- (4, 5, 7y)- (10.5(range, 8.5–11.11 y))- (5 to 6 y)
TGMD TGMD-2 TGMD-3	Cinar et al. (2023)- Cook et al. (2019)- D'Anna (2025)	Cross-sectional cross-sectional cross-sectional	(7.08 ± 0.25)- (4.23 ± 8.28)- (6-10 y)
MABC-2	Resaland et al. (2015)- Houwen et al. (2018)-Roebers et al. (2013)- Oberer et al. (2018)- López-de-la-Fuente et al. (2024)- Dinehart and Manfra (2013)	Cluster randomized controlled trial- cross-sectional-longitudinal-cohort-longitudinal-cross-sectional	(10 y)- (3;0 to 5;11y)- (5.78 ± 4.28)- (6.42 ± 3.84)- (7.5 ± 4.2)- (10 y)
KTK	Lopes et al. (2012)- Oberer et al. (2018)- Vanhala et al. (2024)	Crosssectionl-longitudinal-longitudinal	(9 to 12 y)- (6.42 ± 3.84)-(4.5 ± 7.2)
EUROFIT	van der Niet et al. (2014)- Dinehart and Manfra (2013)	Crosssectionl-crosssectional	(9.5 ± 1.2)- (10 y)
FDT	Khoury-Metanis and Khateb (2024)	Longitudinal	(6.25 ± 3.41)

*Note: [LAP-D = Learning Accomplishment Profile Diagnostic; Beery VMI-4 = The Beery-Buktenica Developmental Test of Visual-Motor Integration IV; BOT-2 = The Bruininks-Oseretsky Test of Motor-Proficiency II; TGMD = Test of Gross Motor Development;
MABC-2 = Movement Assessment Battery for Children II; KTK = Körperkoordination Test für Kinder; EUROFIT = European Physical Fitness Test Battery; FDT = Functional Dexterity Test]

Table 3. Academic skills are measured by each tool

Tool	Academic domain
MABC-2	Academic performance- mathematics- phonological processing- Inhibition- cognitive flexibility- working memory- Recall word- executive function
BOT-2	Academic performance- mathematics- phonological processing-Handwriting legibility
LAP-D	Academic Achievement- school readiness
TGMD	Academic performance- receptive vocabulary- Numeracy- attention- executive function- working memory- Inhibition- Shifting
Beery VMI-4	Academic performance- Handwriting legibility
EUROFIT	Executive function- Problem-solving- cognitive flexibility- Inhibition-working memory- Academic performance
KTK	Executive function- academic performance
FDT	Executive function- Literacy achievement tasks

Table 4. Classification of assessment tools

Motor assessment tools	Perceptual-motor assessment tools
TGMD-EUROFIT-KTK-FDT	BOT -2-MABC-2- LAP-D- Beery VMI-4

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Table 5. An integrative review of motor assessments.

Assessment	Application frequency	Purpose	Subtests	Age range	Time for administration	Considerable features
MABC-2	6	Identifying and characterizing motor performance deficits in children	Manual Dexterity, Aiming and Catching, and Balance.	3-17 years.	20-40 minutes.	Diagnosis of Developmental Coordination Disorder (DCD).
BOT-2	4	Diagnosing motor impairment, screening.	Fine motor precision, fine motor integration, manual dexterity, bilateral coordination, balance, running speed and agility, upper limb coordination and strength.	4-21 years.	40-60 minutes.	
LAP-D	2	Assess development.	Fine motor (writing and manipulation), cognitive (matching and counting), and language (comprehension and naming).	30-72 months.	45-60 minutes.	Assess school readiness.
Beery VMI-4	2	The screening of difficulties with respect to the integration of visual and motor ability in children and adults.	Visual perception, motor coordination (especially hand control).	3-18 years.	10–15 minutes.	
KTK	3	Detection of children with mild to severe motor difficulties, measuring gross motor Coordination.	Balance, Rhythm, Strength, Laterality, and Agility.	4–15 years.	20 minutes.	Relevant for multiple fields such as physical education, sports, health promotion, and talent identification
TGMD	3	Assess individual progress in gross motor skill development.	Locomotor and object control.	3-10 years.	20–30 minutes.	
EUROFIT	2	Determine physical fitness.	Flexibility, speed, agility, endurance, and Strength.	Primarily 6-18 years old, but it can be successfully applied in older age groups.	35-40 minutes.	
FDT	1	clinical evaluation of the patient's ability to perform functional daily tasks requiring a three-jaw chuck grasp between the fingers and thumb.	Manipulation, speed, 3-jaw chuck prehension pattern (also referred to as palmar pinch, pencil pinch, or tripod grip).	Not mentioned	15 seconds to 2 minutes.	

Table 6. Methodology quality of each tool based on the COSMIN checklist. (Psychometric properties)

Assessment Tools	Internal consistency	Reliability	Measurement error	Content validity	Structural validity	Hypothesis testing	Cross-cultural validity	Criterion validity	responsiveness
MABC-2 (21)	****	***	NR	****	****	NR	*	****	***
BOT-2 (22)	***	**	***	****	***	NR	***	***	****
TGMD (23, 24)	**	****	**	**	***	**	NR	NR	NR
LAP-D (25)	****	***	**	NR	***	NR	NR	**	NR
Beery VMI (26, 27)	****	***	NR	**	NR	NR	?	**	NR
FDT (28, 29)	****	***	NR	NR	**	NR	NR	NR	NR
KTK (14, 30)	****	****	NR	NR	**	NR	NR	NR	NR
EUROFIT (31, 32)	***	****	NR	NR	NR	NR	NR	***	NR

*Note: [****Very Good, ***Adequate, **Doubtful, *Inadequate. NR, Not Reported. ? = Lack of consensus among studies.]

performance in primary school children.

This review adds new insights to the literature by incorporating updated knowledge on the psychometric properties of the assessment tools, thus enabling researchers to interpret the results with greater confidence (Table 6).

This review includes studies published within the last ten years up to May 2025, focusing on typically developing children in the preschool and elementary school age range. Studies involving children with disabilities or participants outside this age range were excluded.

The review identified eight such tools (Table 2), which were classified into two main categories - perceptual mo-

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tor assessment tools and motor assessment tools (Table 4).

The term "motor assessment tools" refers to fundamental motor skills tools (FMS) (e.g., fine motor, gross motor, sensorimotor, neuromotor) (33). According to Logan (2017) (34), fundamental motor skills can be defined as :

‘ The foundational components necessary for engaging in advanced, complex movements in sports, games, or other specific physical activities encompass object control/manipulative skills, locomotor skills, and balance/stability skills’ .

These tools predominantly focus on assessing gross motor skills, physical fitness, physical activities, endurance, strength, and overall motor competence. And appraise the kinematic characteristics of movement as well.

In contrast, the term ‘perceptual-motor assessment tools’ refers to those assessments that evaluate not only fundamental motor skills but also motor skills that have a cognitive basis (35) (e.g., spatial awareness, body awareness, temporal awareness, Visual-motor integration, and language domain (36)). These tools emphasize assessing perceptual-motor abilities, fine motor skills, and complex, integrated motor abilities, such as writing tasks (copying, drawing lines/shapes/words...), motor praxis, and sophisticated body/interlimb coordination.

The results demonstrate that perceptual-motor assessment tools, such as the Movement Assessment Battery for Children-2 (MABC-2) and the Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2), respectively, are more frequently used by researchers for predicting academic performance compared to pure motor assessment tools. This suggests that measures of perceptual-motor integration, which encompass the interaction between motor skills and cognitive/perceptual processes, may have a stronger association with academic achievement than isolated motor skills.

A key finding is that the MABC-2 and BOT-2 are the two most commonly used tools for this purpose. Both assessments are norm-referenced, standardized, reliable, and valid measures of motor proficiency that can identify developmental motor delays; furthermore, both are frequently used in research and in clinical practice. In accordance with the present results, previous studies (37) have demonstrated that the researchers' desire to apply MABC-2 for screening was greater than BOT-2. However, there are some notable differences between the two tools that may contribute to their differential usage.

The MABC-2 is less time-consuming to administer (20-40 minutes) compared to BOT-2 (40-60 minutes), and it has fewer subtests. This may make the MABC-2 more practical and feasible for use in research and clinical settings, especially when assessing larger samples of young children. Additionally, the MABC-2 appears more commonly used for preschool-aged children, whereas the BOT-2 has not been employed in studies on children under 5 years old.

On the other hand, the BOT-2 provides gender-specific norms and a more comprehensive assessment of various motor domains than MABC-2. This broader coverage may make the BOT-2 more suitable for evaluating the relationship between motor skills and specific academic abilities, such as mathematics and reading, as observed in some reviewed studies (35, 38).

An interesting finding is that the MABC-2 is more commonly used to assess the relationship between motor skills, executive functions, and working memory, while the BOT-2 is more frequently used to examine the link between motor skills and academic performance directly. This suggests that the different motor assessment tools may capture distinct aspects of the complex relationship between motor development and cognitive/academic outcomes.

MABC-2 and BOT-2, despite their strengths, have weaknesses that should be considered. The lengthy administration time may limit their feasibility and practicality, especially when assessing larger samples or in time-constrained educational settings. Furthermore, the complexity of administering and scoring these comprehensive motor assessments may pose challenges for some practitioners and researchers.

To address these limitations, future research should focus on developing and evaluating more time-efficient and user-friendly motor assessment tools that maintain robust psychometric properties and predictive validity for academic performance.

After a thorough review of the articles, it was found that there was a lack of research investigating the accuracy and precision of these predictive tools. While the reviewed assessments, such as the MABC-2 and BOT-2, have demonstrated strong psychometric properties and the ability to predict academic performance, no studies have directly examined the measurement and reliability of these predictive capabilities. Assessing the concurrent and predictive validity of these motor assessments of academic outcomes is crucial for future studies.

Conclusion

In conclusion, both the MABC-2 and BOT-2 are valid and reliable tools that can play a significant role in predicting academic performance in primary school children. The choice between these two assessments may depend on the specific research or clinical goals, the age range of the target population, and the desired level of detail in the motor skills assessment. Results provide guidance on their potential applications in research and practice.

Currently, there is no universally recognized gold standard for assessing motor competence in relation to academic performance. Each tool offers unique strengths, and their selection should be aligned with the context and objectives of the evaluation. Ultimately, using these standardized, psychometrically sound tools can provide valuable insights into the important link between motor competence and academic achievement, which has important implications for early identification, intervention, and educational practices.

Authors’ Contributions

R.A.K: supervision and data curation. S.F: supervision, formal analysis, and methodology. E.B: resources, data gathering, and writing. M.N.A: original draft investigation.

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Ethical Considerations

Not applicable.

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Conflict of Interests

The authors declare that they have no competing interests.

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