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Open Journal of Pediatrics and Child Health

ISSN: 2640-7612 DOI: https://dx.doi.org/10.17352/ojpch

Prospective Study

Preliminary Validation and Standardization of a New Test Battery for the Assessment of Motor Intelligence in Childhood

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Received: 20 November, 2025
Accepted: 04 December, 2025
Published: 05 December, 2025

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Keywords: Motor intelligence; Motor development; Locomotion; Object-control; Functional assessment; Childhood

Abstract

Background: Motor intelligence encompasses locomotor abilities, object-control skills, visuomotor coordination, and executive components of movement planning. Although several international instruments exist, such as the TGMD, BOT-2, and MABC-2, no standardized, simple, and culturally adapted tool is currently available for the Italian context. In this preliminary study, 480 children aged 3 to 10 years, recruited from six sport disciplines, were evaluated using a newly developed motor intelligence battery. Raw scores were converted into age-specific Standard Points (SP) and subsequently transformed into normative percentiles using a proportional scaling formula. Preliminary normative tables for locomotion, object-control, and global motor intelligence were generated, showing patterns consistent with known developmental trajectories. The proposed battery represents a promising instrument for assessing motor intelligence in Italian children. Future studies will expand the sample and examine reliability and validity metrics more extensively.

Methods: A total of 480 children aged 3–10 years were assessed across six sport disciplines (soccer, karate, swimming, gymnastics, basketball, athletics). Raw scores obtained in the tests were converted into Standard Points (SP) using age-specific tables and subsequently transformed into normative percentiles.

Results: Preliminary raw-to-SP and SP-to-percentile tables were constructed. Score distributions were coherent with known patterns of motor development.

Conclusion: The proposed battery represents a new tool for assessing motor intelligence in the Italian pediatric population. Future studies will expand the sample and further examine statistical reliability.

Introduction

Motor intelligence is increasingly recognized as a multidimensional construct reflecting the child's capacity to coordinate, adapt, and execute movement patterns efficiently across a wide variety of contexts. It includes locomotor abilities, object-control proficiency, visuomotor coordination, executive functioning related to action planning, decision-making speed, and the overall fluidity and coherence of fundamental motor patterns. Research has consistently shown that higher levels of motor competence are associated with improved executive functions, better academic performance, enhanced self-efficacy, more stable postural control, and increased participation in sports during adolescence.

Despite the availability of robust international instruments such as the Test of Gross Motor Development (TGMD), the Bruininks–Oseretsky Test of Motor Proficiency (BOT-2), and the Movement Assessment Battery for Children (MABC-2), several limitations remain with respect to their applicability in the Italian educational and sport context. These tests often require extensive scoring time, complex administration, or culturally adapted norms that are not yet available.

To address these gaps, a new Italian battery was developed to provide a practical, rapid, and scientifically structured method for assessing locomotion, object-control skills, and global motor intelligence in children aged 3 to 10 years. The aim of this study is to present the structure of the battery, describe the development of age-specific Standard Points (SP),

Citation: Zisi M. Preliminary Validation and Standardization of a New Test Battery for the Assessment of Motor Intelligence in Childhood. Open J Pediatr Child Health. 2025;10(1):007-010. Available from: https://dx.doi.org/10.17352/ojpch.000060

introduce the preliminary percentile norms derived from raw-to-SP conversion, and report the initial results obtained from a wide and ecologically valid sample of 480 children practicing six different sport disciplines.

Methods

Participants

A total of 480 children between 3 and 10 years of age participated in the study. All children were regularly engaged in structured sport programs and represented six distinct athletic disciplines, including soccer, karate, swimming, gymnastics, basketball, and athletics. Each participant completed the full battery of tests under standardized conditions and under the supervision of trained evaluators who followed a uniform administration protocol. This sample size allowed for an initial examination of raw score distributions, developmental progression across age groups, and the construction of age-specific Standard Points (SP) and preliminary percentile norms.

Demographic characteristics were recorded to better describe the sample. The 480 children included 241 girls (50.2%) and 239 boys (49.8%). All participants resided in the same regional area of Northern Italy (Emilia-Romagna), representing a homogeneous geographical context. Socioeconomic status was typical of the general population in this region and did not include extreme deprivation or elite athletic backgrounds. Although participants were recruited from organized sport programs, none were engaged in competitive or high-performance pathways. No non-sport children were included, and this is acknowledged as a limitation of the preliminary normative phase. Future studies will incorporate both sport and non-sport populations to broaden representativeness.

Test battery

The battery comprises two primary domains: locomotor abilities and object-control skills. Each test includes predefined observational criteria, and performance is quantified through raw scores based on accuracy, execution quality, and task-specific behavioral indicators. The operational definitions and scoring rubrics are documented in the accompanying test manual.

Raw Score to Standard Points (SP) conversion

Raw scores were converted into Standard Points (SP) using age-specific tables. Each age group was assigned a unique SP maximum (SPmax), with separate values for locomotion, object-control, and the overall Motor Intelligence Quotient (QIM). This structure ensures that children are compared only with peers of the same age, consistent with the normative processes used in established motor assessment tools.

Percentile computation

Percentiles were obtained using a proportional scaling formula in which the SP achieved by a child is divided by the SP maximum for that age and multiplied by 100. This method yields an interpretable percentile rank reflecting the child's standing within the normative distribution for their developmental stage. Percentile tables included in the supplementary materials reflect the preliminary norms derived from this dataset.

Normative framework

The normative process was modeled on established methodologies used during the development of the TGMD. Raw scores were collected from a heterogeneous and ecologically valid sample, and SP scoring ranges were derived empirically for each age group. Because motor development is nonlinear and performance ceilings differ substantially between ages, SPmax values were determined separately for each cohort based on observed distributions rather than theoretical expectations. This mirrors the methodological choices found in TGMD-2, TGMD-3, BOT-2, and MABC-2.

Statistical rationale

The statistical rationale was grounded in classical norm-referenced test development. In motor development research, the goal is not to model idealized population distributions but to produce accurate, age-specific normative references based on real-world performance. Motor scores are known to be non-Gaussian, exhibit biological ceilings related to maturation, and vary substantially across early developmental years. Therefore, non-parametric proportional scaling was used in place of z-scores or T-scores. This approach aligns with established motor assessment literature and supports the development of age-appropriate scoring systems that account for natural variability in children's growth and skill progression.

Motor development indeed shows relevant variability within the same chronological age. However, most standardized motor tests (TGMD, BOT-2, MABC-2) adopt "one-year" age bands during their first normative phase. This allows stable estimation of raw score distributions before introducing narrower subgroups. Because the present study is a preliminary investigation, we followed the same approach: each age is treated as a complete normative unit. Future validation phases will refine age bands into six-month ranges (e.g., 6.0–6.5; 7.0) once a larger multi-site dataset becomes available, improving accuracy and sensitivity.

Calculation of normative percentiles

This ensures that each child is compared only with peers of the same age, as required by normative standards.

Percentiles included in the supplementary materials represent preliminary norms derived from the real sample of 480 children.

Norming and standard point construction

The norming procedure followed the classical methodology used by Ulrich in the development of the TGMD. Raw scores were collected from a large and heterogeneous sample and subsequently transformed into age-specific SP.

Since motor development does not progress linearly across ages and maximum attainable performances naturally differ

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between groups, an age-specific SPmax was defined based on the actual distribution of scores, consistent with normative literature (TGMD-2, TGMD-3).

This allows comparisons strictly within age groups, in line with international motor assessment norms.

Statistical rationale

The statistical rationale for constructing SP and percentiles reflects classical motor norming principles, particularly those used in all three editions of the TGMD. In developmental motor tests, the goal is not inferential estimation but rather age-specific norms derived from real performance distributions.

Age-based norming rationale: Motor development is nonlinear: some skills mature early (e.g., basic locomotor patterns), others consolidate later (e.g., object-control, eye–hand coordination), some abilities increase in amplitude, others in precision.

Therefore, comparing children of different ages is methodologically inappropriate.

Like TGMD, BOT-2, and MABC-2, age-specific performance ceilings were constructed.

Definition of Standard Points (SP): SP are normalized scores:derived from raw scores in the real sample,separated by age, proportionate to what is realistically attainable at that age.

This approach reduces maturation bias,anchors performance to age expectations,unifies scaling across locomotion, object-control, and QIM.

Results

Analysis of the 480 collected datasets revealed developmental patterns consistent with existing literature on motor growth. Raw scores for both locomotion and object control increased progressively from ages 3 to 8, followed by a relative stabilization between ages 8 and 10. Variability was highest among younger children, especially in the 3–6-year range, reflecting the natural heterogeneity of early motor development.

The use of age-specific SP scales allowed for a uniform and fair representation of performance within each age group and minimized the influence of biological maturation on comparative evaluations. Percentile distributions, generated through proportional scaling, exhibited coherent internal consistency across domains and age brackets. Detailed normative tables for raw scores, SP scores, and percentile conversions are provided in the supplementary materials.

Qualitative observations indicated noticeable improvements in movement precision and execution stability beginning around age 6. Children engaged in sport-specific training displayed more refined object-control abilities, while locomotor abilities remained more homogeneous across disciplines.

Qualitative observations

Direct observation revealed significant improvements in movement precision after age 6, greater differentiation of technical abilities among sport-specific groups, more homogeneous locomotor abilities compared to object-control.

Explanation of missing cells in the standard-point conversion tables

Some cells in the raw score → Standard Points (SP) conversion tables are intentionally left blank. This is not an error but reflects a fundamental principle of age-specific motor development. The same raw score does not represent the same level of difficulty at different ages.

For example:

- A raw score of 35 at age 3 represents an *exceptional* performance relative to developmental expectations and therefore corresponds to the *maximum SP value*.
- The same raw score of 35 at age 10 represents an *age-appropriate* performance and corresponds to a *lower SP value*, because older children are expected to perform more complex, coordinated and efficient movements.

Because each age group has its own developmental ceiling, not all raw score ranges are meaningful or achievable at every age. For this reason, some cells naturally remain empty. This structure is fully consistent with international normative motor tests such as TGMD-2/3, BOT-2, and MABC-2, in which age-specific ceilings produce incomplete conversion matrices.

Thus, the presence of blank cells reflects correct developmental scaling and ensures that each age is evaluated according to its own normative expectations.

Discussion

This study presents a newly developed Italian battery for the assessment of motor intelligence in children aged 3 to 10 years. The preliminary norms derived from a large and diverse sample provide an initial framework for interpreting performance in locomotion, object-control skills, and global motor intelligence. By adopting a normative strategy similar to that used for the TGMD, the test ensures that performance comparisons remain age-appropriate and developmentally meaningful.

The battery demonstrates several key strengths. Its simplicity facilitates administration by educators, coaches, and clinicians, and the standardized SP and percentile conversion system offers immediate interpretability. The large and diverse sample enhances ecological validity and reduces potential bias related to specific sport backgrounds.

The results have significant practical implications. The battery may serve as a screening tool in schools, a baseline assessment in sport centers, a clinical indicator for developmental monitoring, or a resource for identifying children who may benefit from targeted motor development programs.

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Developmental interpretation of age-related differences

Performance differences across ages aligned closely with known motor developmental trajectories. Early childhood (3–4 years) is characterized by rapid emergence of fundamental motor patterns, followed by a consolidation phase around ages 5–6 where control, timing, and postural stability improve markedly. A major developmental transition occurs between 6 and 7 years, during which children demonstrate more advanced visuomotor integration, reduced decision latency, and enhanced executive contributions to movement planning. These cognitive–motor integrations explain why some children who appear skillful may still score lower in age-based percentiles; their peers experience simultaneous developmental gains that raise the expected performance level for the age group.

Between ages 8 and 9, the most pronounced gains occur in object-control skills, reflecting age-related increases in precision, anticipatory control, and perceptual–motor coordination. These findings reinforce the necessity of age-specific SPmax values and confirm that the normative approach adopted in this study accurately captures the natural progression of motor intelligence.

Developmental interpretation of age-related performance differences

Age-related differences in SP and percentiles align with developmental literature. Motor skills from ages 3 to 10 progress through non-linear developmental phases with distinct maturational "jumps."

Between 3 and 4 years, the first major developmental leap occurs.

Between 5 and 6 years, improvements in control, stability, timing, and proprioceptive sensitivity reduce intra-group variability.

Between 6 and 7 years, integration of motor and executive functions (anticipation, reduced decision latency, advanced visuomotor coordination) drives one of the largest transitions. Children who appear "skilled" may still fall into lower percentiles because cohort demands rise sharply.

Between 8 and 9 years, object-control ability improves significantly due to enhanced visuomotor precision and anticipatory capabilities.

These dynamics justify the use of age-specific SP and percentiles. Differences in SPmax and percentile distributions reflect natural developmental trajectories, consistent with TGMD, BOT-2, and MABC-2 frameworks [1-20].

Conclusion

The proposed battery represents an innovative and scientifically grounded tool for assessing motor intelligence in Italian children. The conversion system from raw scores to Standard Points and percentiles provides a clear and interpretable framework for evaluating motor competence. The preliminary norms derived from 480 children across six sport disciplines establish a robust foundation for future validation studies. This instrument has the potential to support educational, sport, and clinical assessment practices and to facilitate early identification of developmental challenges.

(Supplementary Files)

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