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Original research

Normative values of the motor competence assessment (MCA) from 3 to 23 years of age

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ABSTRACT

Objectives: Growing evidence of the importance of motor competence for developing a healthy lifestyle has been established in the last decade. Nonetheless, no single instrument or observation tool have been able to fully measure this construct, particularly because most were built for the diagnosis of children in risk for motor impairment; are limited to a few years of the developmental span; lack objectivity in the assessment protocols; or do not include the locomotor, stability, and manipulative components. This led to the difficulty of comparing researches, and longitudinally follow children into adulthood. Recently, a novel proposal to assess motor competence was presented - the Motor Competence Assessment (MCA) - and this study aims to present the MCA normative data from 3-to-23 years.
Design and methods: Two thousand and eighty-seven participants (1102 boys) between 3 and 23 years of age were evaluated in the MCA (standing long jump, 10 m shuttle run, throwing velocity, kicking velocity, lateral jumps, shifting platforms). Results for each test were introduced in the LMS Chartmaker 2.3. The best model for test and sex was used, resulting in normative curves and percentile values.
Results: Final norms showed a good fit to the instrument developmental expectations, allowing to differentiate and classify performances along the age interval.
Conclusions: The MCA age- and sex- normative values allow to assess motor competence from childhood to early adulthood. Future directions will include obtaining a total MCA score and the normative scores for the MCA components (stability, locomotion, object control), and to expand the norms to adulthood and old age.

Practical implications

- The MCA is the first assessment tool designed to be used to evaluate motor competence that uses all the three components (locomotor, stability, and manipulative) and the same tests, along the life span.
- The MCA normative values presented in this study allow to assess motor competence from childhood to early adulthood, according to sex and age.
- The use of the MCA normative values will also allow to follow individual changes on motor competence occurring from the age of 3 to 23 years of age.
- General population (families, parents, educators) can easily use the MCA charts and tables to assess young children, adolescents, and young adults.

1. Introduction

In the last decade, there has been growing evidence of the importance of motor competence (MC) for developing a healthy life style.[1–3]

Motor competence relates to the development and performance of human movement and it is been defined in the literature as a person's ability to be proficient in a broad range of locomotor, stability

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and manipulative gross motor skills.[4] Furthermore, it is expected to facilitate the learning of new skills, and the motor proficiency on novel motor tasks throughout the lifespan. Motor competence has shown to have a negative effect in fat mass development in children and adolescents[5,6]; to be associated with higher physical activity status and future health outcomes[7]; to have an high impact in physical fitness[8–10]; and to be associated with cognitive performance.[11,12]

Even so, the published research on the topic has used several different instruments and observation tools (e.g. TGMD, M-ABC, KTK, etc.) in order to measure this construct of motor competence.[13] The limitations of these instruments have been well characterized in the literature: some were built mostly for the diagnosis of children in risk for motor impairment; others are limited to a few years of the developmental span; some others lack objectivity or fidelity in the assessment protocols; and most do not include the three fundamental domains (stability, locomotor, and manipulative) of motor skill competence.[13,14] This reality leads to the difficulty of comparing results over different studies, and to longitudinally follow children into adulthood, since the instruments keep changing according to the age stage. Very recently, a novel proposal to assess motor competence has been made, trying to answer these problems: the MCA – Motor Competence Assessment.[15] In the original publication, authors were able to establish the construct validity of the MCA, subdivided into three components of MC: Locomotor, Stability, and Manipulative (or Object Control), each of them assessed by two different objectively measured tests. Other specifications of the MCA are that all motor tests are quantitative (product-oriented), without a marked developmental (age) ceiling effect, and of feasible execution in order to diminish observation errors.

In this study we intend to present the Portuguese age-related normative values for the six tests of the MCA, extending its use as a valid instrument for the assessment and classification of motor competence from childhood to early adulthood (3 to 23 years of age).

2. Methods

Two thousand and eighty-seven participants (1102 boys) between 3 and 22 years of age were evaluated in the six tests of the Motor Competence Assessment (standing long jump, 10 m shuttle run, throwing ball velocity, kicking ball velocity, lateral jumps, and shifting platforms). Sample size by age was of 50 or more participants, accordingly to the statistical considerations for building normative growth values.[16]

The cross-sectional data used in this study belongs to a larger ongoing project that aims to collect data on motor competence, physical activity, physical fitness, somatic fitness, cognitive performance, and academic achievement in Portugal, Europe. This sample data was collected in three different Portuguese locations: Viana do Castelo, Lisboa, and Melgaço. Participants were students of all education levels, from Preschool to University, with no motor or cognitive impairment.

The study was approved by the Scientific Council of the Polytechnic Institute of Viana do Castelo. School directors approved the study, adult participants and parents or tutors of underage children gave their informed consent, and children gave verbal accent prior to data collection. Ethical approval: All procedures were in accordance with the 1964 Helsinki declaration and its later amendments.

Researchers were trained in the specifications of the assessment's protocols and, at least one of the three first authors of this study, supervised personally every data collection. Evaluations were done in the in the school gymnasium of the three different locations.

The Motor Competence Assessment is composed of two tests for each MC component (stability, locomotor, and manipulative). All tests are quantitative (product-oriented) motor tests without a marked developmental (age) ceiling effect, and of feasible execution.[15]

Testing conditions were arranged prior to beginning. Children performed all the tests in small groups (usually about 5 children for each task). All participants completed a 10 min general and standardized warm-up before the beginning of the tests. Examiners were previously trained in administering all tests and the following requirements were used as standard: (a) a proficient demonstration of each test technique was provided along with a verbal explanation; (b) every participant experimented each task before the actual test administration; (c) the instructions emphasized that children should try to perform the task at their maximum potential (e.g., “as fast as possible” for the stability tests and 4 × 10 shuttle run; “as far as possible” for the standing long jump; and “as hard as possible” for the manipulative tests); (d) motivational feedback was given, however no verbal feedback on skill performance was provided.

Shifting platforms (SP) – the test starts with the participant standing with both feet on one of the two wooden platforms (25 cm × 25 cm × 2 cm with four 3,7 cm feet at the corners) and having the second wooden platform at his side in the floor (right or left as convenient). At the starting voice (Ready and Go) the participant reaches for the platform in the ground next to him, moves it to the opposite side and steps into it as quick as possible. This process is repeated for 20 s and each successful transfer from one platform to the other is scored with two points (one point for moving the platform from side; one point for moving the body for the platform). Participants have two trials with a 2 min interval between trials. Only the best score is considered. - *Jumping Sideways* (JS) – standing on one side of a rectangular surface (100 cm length × 60 cm width) divided by a small wooden beam (60 cm length × 4 cm high × 2 cm width) in the middle, the participant jumps sideways with two feet together (simultaneously) as fast as possible for 15 s. The test starts at the voices Ready and Go, and each correct jump (two feet together, without touching outside the rectangle, and without stepping in the wooden beam) scores 1 point. The best result over two trials is considered. Both of these two tests are originally from the KTK.[15,17] Their reliability has been described as good to excellent in the literature[18] and in this sample, the Intraclass Correlation Coefficient's (ICC) values of 0.950 and 0.987 were found respectively for SP and JS.

Shuttle Run (SHR) – from the start line (100 cm × 5 cm), and at the voice of Ready and Go, the participant runs at maximal speed to a second line (100 cm × 5 cm) placed 10 m apart where two rounded blocks (10 cm high, 5 cm in diameter) are placed immediately after the line and 25 cm apart from each other. The participant picks up one of the blocks, runs back to the starting line and places it in the ground after the line (no matter what position), and runs back to retrieve the second block. The test finishes when the participant passes through the start/finish line carrying the second block. Two trials are allowed with a 2 min interval between them. The final score is the best time of the two trials. *Standing Long Jump* (SLJ) – placed below a starting line, the participant must jump as far as possible, using both feet simultaneously on the take-off and landing. The jump is made over a surface with marked measuring lines, or with a measuring tape placed on one side of the free jumping space, perpendicular to the starting line. The distance (in cm) is measured between the starting line and the place where lands the back of the heel closest to the starting line. The final score is the best of 3 correct trials. These tests are derived from the AAHPER Youth Fitness Test.[19] Their reliability has been described in the literature as ranging from good to excellent.[20,21] In our sample we found ICC values of 0.968 and 0.987 respectively for SHR and SLJ.

Ball Throwing Velocity (BTV) – standing below a 1 m line marked in the floor that is at least 6 m apart from a wall (at least 5 m × 5 m), the participant, using an overarm action, throws a ball at a maximum speed against the wall. In the middle of the wall, 170 cm from the ground, a cross (40 cm × 40 cm) marks the intended target. The participant can choose to have a preparatory balance (one or two steps) before throwing the ball. All attempts made in the direction of the wall (the target is only for helping on the alignment of the action) with a correct movement are counted. For children between 3 and 10 years old a tennis ball is used (diameter: 6.5 cm; weight: 57 g). For 11-years-old and older a baseball ball is used (diameter: 7.3 cm; weight: 142 g). Ball peak velocity is measured in m/s with a velocity radar gun (e.g. Pro II Stalker radar gun) placed in the side of the participant dominant hand, close to the line in the floor, at about his/her shoulder level and facing the target wall (outbound). The final score is the best of 3 correct trials. *Ball Kicking Velocity* (BKV) – standing below a 1 m line that is at least 6 m apart from a wall (at least 5 m × 5 m) the participant kicks a soccer ball at a maximum speed against the wall. The participant can choose to have a preparatory balance (one or two steps) before kicking the ball. For children between 3 and 8 years old a soccer ball no. 3 is used (circumference: 62 cm, weight: 350 g). For children of 9 and 10 years of age a soccer ball no. 4 is used (circumference 64 cm, weight: 360 g). For participants older than 10 years of age a soccer ball no. 5 (circumference 68 cm, weight: 410 g) is used. Ball peak velocity is measured in m/s with a velocity radar gun (e.g. Pro II Stalker radar gun) placed in the side of the participant dominant foot, close to the line in the floor at 1 m from the ground and facing the target wall (outbound). Every subject performs three trials, with the final score being the best result. Intraclass correlation coefficients of 0.979 and 0.983 were found for BV and BKV in this study.

Results for each of the six tests of the MCA were inspected for the normality of distribution according to age (full year) and sex. Comparison between boys and girls was made using a t-test for age, and an ANCOVA test for each motor test (Age as covariant, and Sex as factor). Smoothed percentile curves were created by sex for each test, by using a Box–Cox transformation-based semiparametric method for normalizing the data with the Lambda-Mu-Sigma approach.[22] Individual data relative to decimal age was introduced into the LMS Chart Light Version 2.54 software.[23] The percentile curves resulted from smoothing three age-specific curves: L (lambda; skewness), M (Mu; median), and S (sigma; coefficient of variation). The best model for each test and sex was used according to the goodness of fit values produced, resulting in age related (six-month interval) normative curves and percentile values per sex and test.

3. Results

Analysis of the sample showed that boys and girls had similar age ($p > 0.05$), but as expected, boys showed better performances on all motor competence tests after controlling for decimal age (all p-values < 0.05). A significant effect of age was also found for all tests and independently of sex (all p-values < 0.05), corresponding to one of the major assumptions of the MCA construction: the ability to differentiate between age related motor competence performance.

The developmental normative graphs (p05, p15, p25, p50, p75, p85, and p95) for the three MCA components are represented in Figs. 1–3, respectively for the stability, locomotor, and manipulative components from 3 to 23 years of age. Percentile values (p05, p10, p20, p30, p40, p50, p60, p70, p80, p90, and p95) and LMS values relative to an age interval of 0.5 decimal years (every 6 months) can be found in Supplementary Tables 1 to 12.

The LMS parameters described in the tables are the median (M), the generalized coefficient of variation (S), and the power in the Box-Cox transformation (L). These LMS values can be used to generate exact z-scores (Z), and corresponding percentiles, and from any individual value (X) using the following equation: $Z = (((X/M)^L) - 1) / LS$.[22]

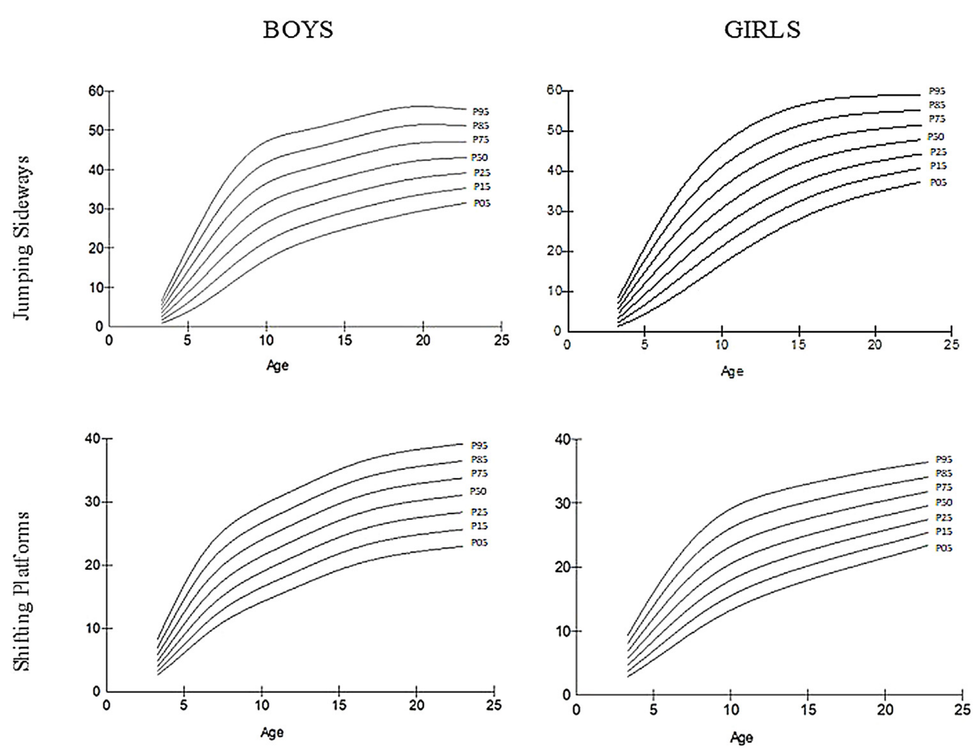

Fig. 1. Stability component. Percentile graph representing p05, p15, p25, p50, p75, p85, and p95, of Jumping Sideways, and Shifting Platforms, for boys and girls from 3 to 23 years of age.

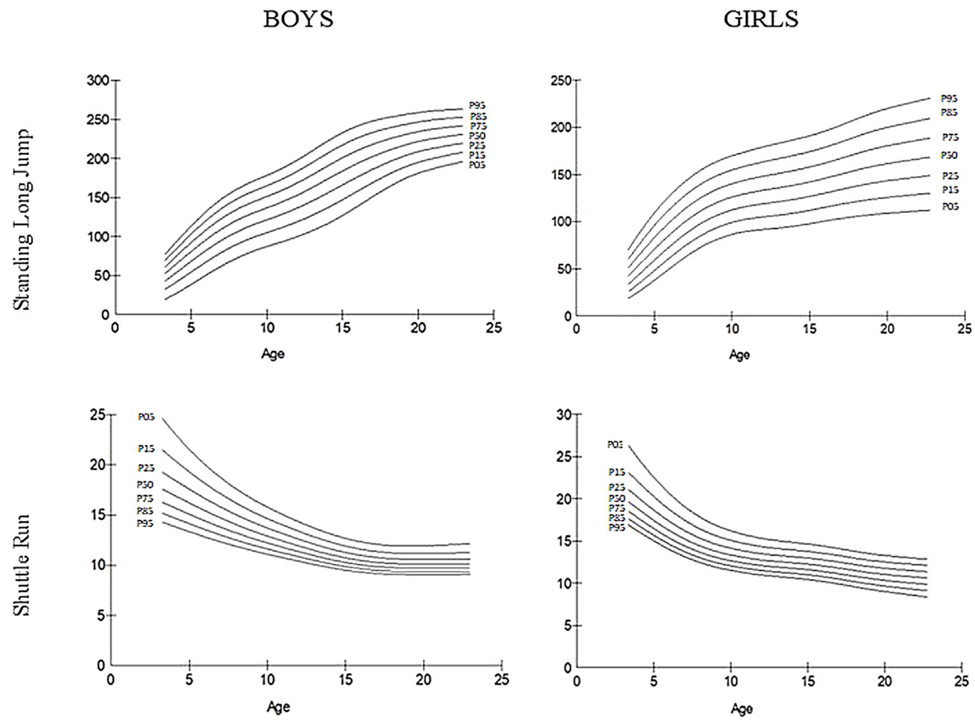

Fig. 2. Locomotor component. Percentile graph representing p05, p15, p25, p50, p75, p85, and p95, of Standing Long Jump, and Shuttle Run, for boys and girls from 3 to 23 years of age.

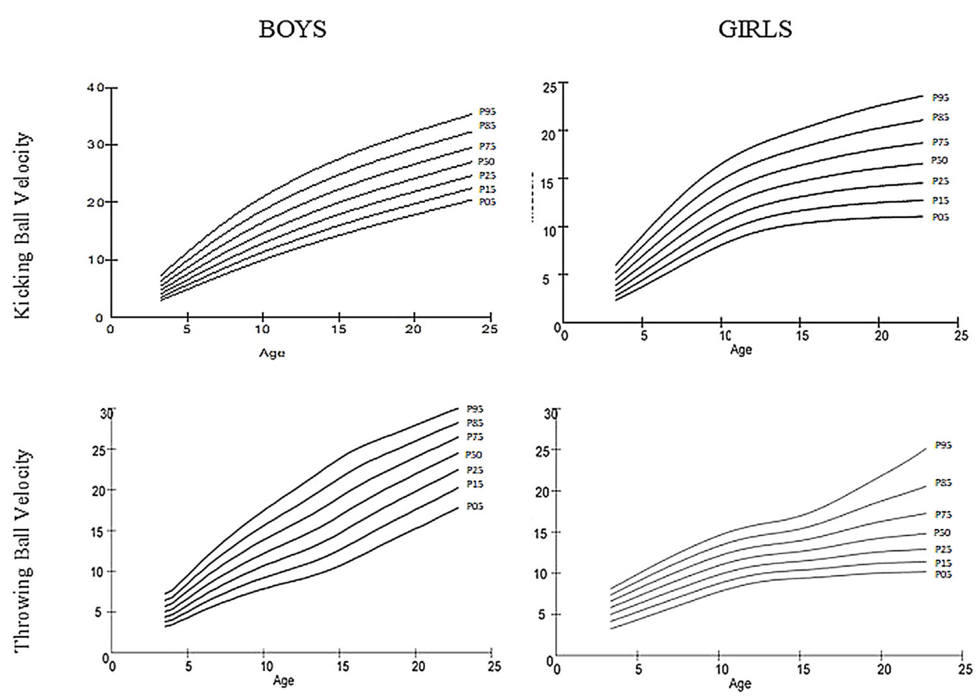

Fig. 3. Manipulative component. Percentile graph representing p05, p15, p25, p50, p75, p85, and p95, of Kicking Ball Velocity, and Throwing Ball Velocity, for boys and girls from 3 to 23 years of age.

4. Discussion

This study presents age- and sex-specific motor competence reference data for Portuguese children, adolescents and adults aged 3–23 years. To the best of our knowledge it is the first time that such a wide age range is studied regarding motor competence values on all the three components (locomotor, stability, and manipulative). The literature has established a developmental relationship between motor competence and physical activity that is expected to promote either positive or negative trajectories of physical activity,[1,3] along life. This highlights the need for having motor competence reference values starting at an early age, allowing to identify young children at risk of engaging in negative spirals of development. A few studies have established reference percentile values for primary school children in some motor competence tasks, starting from 6 years of age,[24–26] or 9 years of age,[28–30] but we could not find any reference values for motor competence of preschool children, besides the ones presented in this article. On the other hand, the motor competence of young adults is also mostly unknown. No studies were found with percentile age-referenced values for any of the motor competence tasks of the MCA over the age of 18. Probably, this lack of information is related to the characteristics of instruments to assess motor competence, since the most widely used instruments were built to assess only during childhood and tend to show a ceiling effect after late childhood or adolescence (e.g., TGMD is used until 11 years, and KTK until 14 years). However, as our results indicate (see Tables 1 to 12 in Supplementary materials), motor competence continues to change after adolescence and the MCA seems to be a valid instrument to measure it throughout different stages of the lifespan.

Of all the tasks that compose the MCA, the standing long jump has been the most widely studied and age-referenced values for children and adolescents have been presented by different authors.[25,26,29] In general, and with some variations according to gender or age group, the 50th percentile found in our study is close to the 50th percentile found in Macedonian children,[25] and in the IDEFICS study[26]; a little lower, especially for girls, than the values found on Australian children[29] or the Eurofit values.[2] Since the MCA stability tasks (shifting platforms and jumping sideways) are derived from the KTK,[17] we were also able to compare our values with the normative ones found for Portuguese children from Madeira,[24] and Azores.[27] In general, our median values were slightly better than the 50th percentiles found in the Portuguese islands, but almost identical to the values (averaged from the two trials reported) found in a sample of 2470 Flemish children, aged 6–12-year-old.[31] We could not find normative values to compare regarding the shuttle run or the manipulative tasks.

The results show that boys outperformed girls in every motor competence test (all $p < .05$), but the differences were smaller in the stability component. These results are partially in line with previous reviews from Barnett et al.[32] and Iivonen and Sääkslahti,[33] which indicated that boys consistently outperform girls in the manipulative component, independent of age. However, the sex differences for the stability and locomotor components are not so consistent in the literature, maybe due to the nature of the instruments used to evaluate these tasks (i.e. quantitative vs qualitative). Although not consensual in the literature,[32–34] our stability and locomotor results (i.e. boys generally outperforming girls with a few exceptions for some age groups in the stability component) are in line with previous studies that used similar approaches.[9,35] Because boys usually spend more time in moderate and vigorous physical activity, are more encouraged to participate in sports activities, and typically have more movement opportunities in their daily life than girls, we believe our results are in line with the cultural and biological reality.

The results showed an increase in MC with age, corresponding to one of the major assumptions of the MCA construction, the ability to differentiate between age related motor competence without a clear celling effect. As mentioned before, to our knowledge this is the first study that addresses motor competence from early childhood to young adult's age, and the results show an increase in MC performance with age, although less pronounced after puberty years. Furthermore, most of the tests results displayed a higher rate of growth between the ages 3 to 10, aligned with the theoretical rational of the fundamental motor skills developmental phase,[36] and highlighting the importance of developing motor competence since younger ages to pursue healthy lifestyles. Interestingly, the manipulative component and the standing long jump task in boys did not show this pattern, displaying a more linear growth with age. These results can probably be explained due to the nature of the tasks, and its relationship with the acceleration in strength development and growth in height associated with puberty.

5. Conclusions

Looking to the percentile smoothed curves one can clearly note an increasing performance associated with age, a higher acceleration in performance during childhood years (up to about 9–11 years of age) resulting on a curvilinear pattern, and a growing variability across the developmental years (except for the shuttle run). These three characteristics are comparable to the expected developmental trajectories described on motor behavior,[2,25] and somatic characteristics.[37]

In addition to the described percentile values, the LMS parameters for each age can be used to generate age-related z-scores (Z), and corresponding percentiles for any individual value, helping to describe e compare different studies' results.

The final norms resulting from this sample showed a good fit to the developmental expectations of the instrument, allowing to differentiate and to classify performances along all the age span studied, 3–23 years of age. Future directions will include obtaining a full classification of the normative scores of the MCA components (stability, locomotion, and manipulative/object control), and of the total MCA score. We also pretend to extend the age range to adulthood and older ages.

The present study has both limitations and strengths. With time, adding more data to the longitudinal pool will allow to enhance details on developmental values for every test. This sample was taken from different regions of Portugal, and so the results must be confirmed and extended by adding cross-cultural data from other countries. Only participants with no motor or mental restrictions or impairments were assessed, and no maturational characteristics were evaluated. Data was cross sectional, so no true longitudinal inference can be taken from it. On the other end, this is the first time that motor competence performance was screened over such a long developmental time, and the results showed that MCA tests were capable of discriminating age and sex related changes without an obvious ceiling effect. This latter characteristic allows to be optimistic on the possibility of extending the MCA age range to older age groups.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.jsams.2019.05.009.

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