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Movement Assessment Battery for Children-2: validity, reliability and motor performance of age band 3 for Portuguese children

Supervisior: Maria Olga Fernandes Vasconcelos, PhD
Co-supervisior: Paula Cristina dos Santos Rodrigues, PhD

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Bárbara Fontes Costa de Freitas Vasconcelos

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Dedicatória

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Resumo

O *Movement Assessment Battery for Children* – 2ªed é das ferramentas mais utilizadas em investigação clínica no domínio das capacidades motoras das crianças, para identificar perturbações do desenvolvimento da coordenação. O teste divide-se em bandas de idade (BI1 – 3 a 6 anos; BI2 – 7 a 10 anos; BI3 – 11 a 16 anos) e utiliza 8 testes para avaliar 3 componentes: Destreza Manual, Atirar e Agarrar e Equilíbrio. Para ser aplicado em crianças portuguesas, as suas propriedades psicométricas têm que ser analisadas previamente. A BI1 encontra-se em validação e a BI2 já está validada, faltando a BI3. Os objetivos deste estudo foram (1) investigar a consistência interna e a fiabilidade teste-reteste da BI3; (2) avaliar a validade fatorial da BI3 através de uma análise fatorial confirmatória (modelo trifatorial) e (3) analisar os efeitos do sexo e da idade no desempenho motor das crianças avaliadas. Crianças portuguesas (n=231) entre os 11 e os 16 anos (117 rapazes e 114 raparigas) foram testadas com a BI3 em todos os estudos. No primeiro, a consistência interna foi avaliada através do α de Cronbach: Destreza Manual (DM) = 0.598; Atirar e Agarrar (A&A) = 0.725 e Equilíbrio (E) = 0.314) e da Correlação de Pearson: DM = 0.745; A&A = 0.614 e E = 0.489. A fiabilidade do teste-reteste foi significativa, ICC = 0.689. A consistência interna apresentou um α de Cronbach's baixo no E, mas os outros resultados variaram entre correlação significativa e elevada, indicando ser a BI3 um teste fiável. No segundo estudo, os valores da análise fatorial confirmatória indicam boa qualidade de ajustamento ao modelo (χ^2/df =1.813; CFI = .865; GFI = .954; RMSEA = .059, TLI = .811). Assim, ambos os estudos mostram que a BI3 é uma ferramenta válida para examinar as possíveis dificuldades motoras de crianças portuguesas (11 a 16 anos). Estudou-se ainda o efeito do sexo e da idade na performance motora. Os rapazes apresentaram valores significativamente superiores na DM e no A&A. Na idade, o desempenho foi inferior nos 11 e nos 16 anos no A&A e no E.

Palavras-chave: MABC-2; CONSISTÊNCIA INTERNA; FIABILIDADE; VALIDADE FATORIAL; DESEMPENHO MOTOR

Abstract

The Movement Assessment Battery for Children – 2nd is one of the most frequently used tools for clinical research concerning motor skills in children, specifically to identify developmental coordination disorder. The test is divided by age bands (AB1 - 3 to 6 years old; AB2 – 7 to 10; AB3 – 11 to 16 years) and comprises 8 tests within 3 subscales: Manual Dexterity, Aiming and Catching and Balance. To be applied in Portuguese children, MABC-2 psychometric properties have to be previously analysed. AB1 is being validated and AB2 has already been validated, being the AB3 the one missing. The aims of this study were (1) to investigate the internal consistency and test-retest reliability of age band 3, (2) to examine the factorial validity of AB3 through a confirmatory factor analysis (three-factor model) and (3) to analyse the effects of sex and age in motor performance of children between 11 and 16 years old. Two hundred and thirty-one Portuguese children aged 11 to 16 years old (117 boys and 114 girls) were tested with MABC-2 (age band 3) in all studies. In the first one, internal consistency was assessed through Cronbach's α (Manual Dexterity = 0.598, Aiming and Catching = 0.725 and Balance = 0.314) and Pearson's correlation (MD = 0.745, AC = 0.614 and B = 0.489). Test-retest reliability was meaningful, with an ICC = 0.689. Internal consistency had a poor result (Cronbach's α for Balance), but the other results range from meaningful to highly correlated, making AB3 a reliable measure. In the second study, the results of the confirmatory factor analysis suggested a satisfactory fit of the data to the model (χ^2/df =1.813; CFI = .865; GFI = .954; RMSEA = .059, TLI = .811). Accordingly, both studies show that the AB3 is a valid tool to assess motor competence in Portuguese children (11-16 years), with possible movement difficulties. After the validation, the effect of sex and age on motor performance in AB3 was studied. Boys presented statistically significant higher results in MD and AC. As to age, the performance was lower at 11 and 16 years old, in B and AC, respectively.

Keywords: MABC-2; INTERNAL CONSISTENCY; RELIABILITY; FACTORIAL VALIDITY; MOTOR PERFORMANCE

List of Abbreviations

AA – Atirar e Agarrar

AB – Age band

AC – Aiming and Catching

B – Balance

BI – Banda de Idade

BOT – Bruininks-Oseretsky Test of Motor Proficiency

BOT-2 - Bruininks-Oseretsky Test of Motor Proficiency 2

CFI – Comparative Fit Index

DCD – Developmental Coordination Disorders

DM – Destreza Manual

DSM-5 – Diagnostic and Statistical Manual of Mental Disorders

E - Equilíbrio

GFI – Goodness-of-Fit Index

KTK - Körperkoordinationstest Für Kinder

MABC - Movement Assessment Battery for Children

MABC-2 – Movement Assessment Battery for Children – Second Edition

MD – Manual Dexterity

RMSEA – Root Mean Square Error of Approximation

TGMD – Test of Gross Motor Development

TGMD-2 - Test of Gross Motor Development 2

TLI – Tucker-Lewis index

Chapter I – Introduction

Motor coordination

Motor coordination is the capacity to create an integration between separate motor and varying sensory systems, into efficient patterns of movement, commonly referred to as motor skills (Gallahue & Ozmun, 1998). These motor skills, to achieve an efficient performance, must be synchronous, rhythmical and properly sequenced. Visual information integrated with limb action characterize eye-hand and eye-foot performance, which are important to movements evolving external objects, such as bouncing, catching and throwing. Besides that, gross body coordination involves moving the body quickly while carrying out various fundamental movement skills, as hopping, skipping, jumping, galloping, rotations, stabilizations. The ability to maintain the equilibrium of the body in numerous positions is designated balance, often defined as static or dynamic. While static balance concerns the capacity to maintain equilibrium in a stationary position (e.g. balancing on one foot or standing on a balance board), dynamic balance refers to the ability to maintain the same equilibrium mentioned before, but in a moving position, such as walking heel-to-toe backwards (Gallahue & Ozmun, 1998).

Although it is expected that children achieve these coordinated motor skills successfully until the age of 7 years old, some motor difficulties may delay or hamper its acquisition and execution (Higashionna et al., 2017).

Developmental Coordination Disorder

According to American Psychiatric Association (2013), Developmental Coordination Disorder (DCD) is a chronic neurodevelopmental condition characterized by deficits in the acquisition and execution of coordinated motor skills and is manifested by clumsiness and slowness or inaccuracy of performance of motor skills that cause interference with activities of daily living.

Its prevalence is 5%-6% in children from 7 to 11 years old and affects more males than females. Even though there may be enhancement in the longer term, the characteristics may remain through adolescence in an estimated 50%-70% of children (American Psychiatric Association, 2013). Developmental Coordination Disorder's diagnosis is made according to 4 criteria, present in Table 1.

Table 1: The DSM-5 criteria for developmental coordination disorder (American Psychiatric Association, 2013).

A	The acquisition and execution of coordinated motor skills is substantially below that expected given the individual's chronologic age and opportunity for skill learning and use. Difficulties are manifested as clumsiness (e.g., dropping or bumping into objects) as well as slowness and inaccuracy of performance of skills (e.g., catching an object, using scissors or cutlery, handwriting, riding a bike, or participating in sports).
B	The motor skills deficit in Criterion A significantly and persistently interferes with activities of daily living appropriate to chronological age (e.g., self-care and self-maintenance) and impacts academic/school productivity, prevocational and vocational activities, leisure and play.
C	Onset of symptoms is in the early developmental period.
D	The motor skills deficits are not better explained by intellectual disability (intellectual developmental disorder) or visual impairment and are not attributable to a neurological condition affecting movement (e.g., cerebral palsy, muscular dystrophy, degenerative disorder).

Also, the World Health Organization (1992) characterizes specific developmental disorder of motor function as occurring when gross and fine motor coordination is below than expected according to the child's chronological age and IQ and when this motor difficulties interferes with daily living activities. Hence, physical education teachers, sports professionals, physiotherapists, psychologists, and even paediatricians or neurologists need valid and reliable tools to assess motor competence in children or adults, in order to prescribe a re-education motor program (Niemeijer et al., 2015). Through the years, many authors have created, developed and updated different tests to assess motor coordination and motor development, for example, Peabody Developmental Motor Scale (Folio & Fewell, 1983) and its second edition (Folio & Fewell, 2000); the Test of Gross Motor Development (TGMD) (Ulrich, 1985) along with its updated version (TGMD-2) (Ulrich, 2000); the Bruininks-Oseretsky Test of Motor Proficiency (BOT) (Bruininks, 1978) and its second publication (BOT-2) (Bruininks & Bruininks, 2005), the Körperkoordinationstest Für Kinder (KTK) (Kiphard & Schilling, 1974) and the Movement Assessment Battery for Children (MABC) (Henderson & Sugden, 1992) along with the second edition (MABC-2) (Henderson et al., 2007).

Peabody Developmental Motor Scale – Second Edition (Folio & Fewell, 2000) is an instrument used to assess gross and fine motor skills in children since birth until 5 years old. The gross motor scale is constituted by three subtests: reflexes, stationary, locomotion, and object manipulation whereas the fine motor scale includes two subscales: grasping and visual-motor integration. However, due to the later appearance (11 months) of some skills, the reflexes and the object manipulation are only tested after that age.

The Test of Gross Motor Development-2 (Ulrich, 2000) is a revised version of the Test of Gross Motor Development (Ulrich, 1985) and measures common gross motor skills in children aged 3 years old to 10 years and 11 months. This test is divided into two subscales: locomotor, which assesses run, gallop, hop, leap, horizontal jump and slide; and object control, measured through striking a stationary ball, stationary dribble, kick catch, overhand throw and underhand roll.

Bruininks-Oseretsky Test of Motor Proficiency (Bruininks, 1978) evolved to Bruininks-Oseretsky Test of Motor Proficiency-Second Edition (Bruininks & Bruininks, 2005) and is used to examine gross and fine motor skills in children and youths between 4 to 21 years old. This tool has a variety of 53 tests that are comprised in 8 subscales: fine motor precision, fine motor integration, manual dexterity, bilateral coordination, balance, running speed and agility, upper-limb coordination and strength.

The Körperkoordinationstest Für Kinder (KTK) (Kiphard & Schilling, 1974) is a tool developed to simply evaluate motor coordination in children between 5 to 14 years old. It consists of four test items: walking backwards along balance beams; one-legged hopping over an obstacle; two-legged jumping sideways across a wooden slat for 15 seconds as quickly as possible; and moving sideways on wooden boards for 20 seconds. All the four test items include age adjusted scores and a global motor quotient.

As the Movement Assessment Battery for Children-2 is the instrument studied and applied in our study, we proceed to detail more information about it.

Movement Assessment Battery for Children-2

Historical background

Henderson & Sugden (1992) developed the Movement Assessment Battery for Children as a result of a lengthy programme of research and development that started in 1966. This research had two separated aims that were put together to create MABC as a single package with two components: the checklist and the performance test. The purpose of the test was to identify and describe children with movement difficulties, so the vast amount of investigations and the consequent limitations and suggestions proposed by the numerous published studies in this field, led to a natural evolution of the test, culminating in the MABC-2 (Henderson et al., 2007).

Checklist and battery of the Movement Assessment Battery for Children-2

The MABC-2 (Henderson et al., 2007) is divided in two sections: the Checklist and the Performance Test. The Checklist has to be completed by someone who has regular contact with the child, being teacher, parents or therapists. There are three sections to complete, concerning different matters: section A has 15 items about movement in a static and/or predictable environment; section B also has 15 items about movement in a dynamic and/or unpredictable environment and section C has 13 items about non-motor factors that might affect movement. After the application of the Checklist, the results of every question are summed, and the total is rated according to the “Traffic Light” system for the Checklist Total Motor Score (Table 2).

Table 2: “Traffic Light” system for the Checklist Total Motor Score.

	Raw score cut-off values		
Age group	Red zone	Amber zone	Green zone
5 years	≥ 42	≥ 34	≤ 33
6 years	≥ 25	≥ 20	≤ 19
7 years	≥ 17	≥ 12	≤ 11
8 years	≥ 13	≥ 9	≤ 8
9 years	≥ 10	≥ 6	≤ 5
10 years	≥ 7	≥ 4	≤ 3
11 years	≥ 3	≥ 1	0
12 years	≥ 2	≥ 1	0

On the other hand, the Performance Test is divided by band ages: age band 1 (3 to 6 years old), age band 2 (7 to 10 years old) and age band 3 (11 to 16 years old). It assesses three items, Manual Dexterity, Aiming and Catching and Balance, each one with 8 tests (Table 3).

Table 3: Test items included in the Movement Assessment Battery for Children-2 for each component and age band.

	AB1	AB2	AB3
Manual Dexterity	Posting coins Threading beads Drawing trail 1	Placing pegs Threading lace Drawing trail 2	Turning pegs Triangle with nuts and bolts Drawing trail 3
Aiming & Catching	Catching beanbag Throwing beanbag onto mat	Catching with two hands Throwing beanbag onto mat	Catching with one hand Throwing at wall target
Balance	One-leg balance Walking heals raised Jumping on mats	One-board balance Walking heel-to-toe forwards Hopping on mats	Two-board balance Walking heel-to-toe backwards Zig-Zag hopping

However, this model is different from the first one (Henderson & Sugden, 1992). These differences include age extension, because the first version examined from 4 to 12; reduction of age bands from four to three, item revision and addition

of new items and rearrangement of subtests; inclusion of a new score interpretation method and a more representative standardization sample (Wuang et al., 2012). The scoring system of MABC-2 relays on equivalent percentiles that are used to categorise children according to the degree of motor impairment through the Traffic Light system: at or below the 5th percentile is classified as red (a significant movement difficulty), between the 6th and the 15th percentile inclusive as amber (child is "at risk" of having a movement difficulty), at or above the 16th percentile as green (no movement difficulty detected).

Age band 3 of the Movement Assessment Battery for Children-2

The age band 3 of the Movement Assessment Battery for Children-2 (Henderson et al., 2007) is applied to children between 11 years old and 16 years and 11 months old. As presented before, it comprises 8 tests divided in 3 components: Manual Dexterity, Aiming and Catching and Balance. Manual Dexterity is assessed through *turning pegs*, *triangle with nuts and bolts* and *drawing trail 3*. The test *turning pegs* consists in turning 12 pegs placed in a board, as quickly as possible. Both hands are tested in two trials and the score is recorded in seconds. *Triangle with nuts and bolts* is a test where the child has to build a triangle with strips, nuts and bolts as quickly as possible, and where the score is also recorded in seconds. The *drawing trail 3* is a drew route that the child has to fill with a single line. Its score is recorded in errors that the child makes along the drawing. In turn, Aiming and Catching is assessed through *Catching with one hand* and *Throwing at wall target*. Both tests are scored in correctly executed attempts in 10 trials, and the trials are made behind two different marked distances. In the first test, the child has to throw the ball and catch it with one hand without it bouncing on the floor. In the second test, the ball thrown by the child has to hit the red target. Balance is determined with the tests *two-board balance*, *walking heel-to-toe backwards* and *Zig-Zag hopping*. The first one consists in finding balance above the keels of the board, for 30 seconds (the score is recorded in seconds). In the *walking heel-to-toe*, the child has to walk backwards (placing the toe of one foot against the heel of the other with each step) on a line drew on the floor. The number of steps (maximum 15 or the entire line) is recorded. Lastly, in the *Zig-*

Zag hoping, the child has to hop, on one foot, diagonally from one mat to the next until the target mat. Both legs are tested across the 6 mats (5 plus the target one), and the score is recorded in correct consecutive hops.

According to several authors (Hua et al., 2013; Kokstejn et al., 2018; Venetsanou et al., 2011; Wagner et al., 2011), the MABC-2 is the most commonly used tool to assess motor difficulties, namely DCD. Consequently, it is important that the test is valid and reliable in different countries, allowing professionals who work with children with movement difficulties to improve their activity in this field. Several validation studies have been made with each age band: age band 1 (Ellinoudis et al., 2011; Hua et al., 2013; Kokstejn et al., 2018; Psotta & Brom, 2016; Smits-Engelsman et al., 2011), age band 2 (Kita et al., 2016; Wagner et al., 2011) and an experimental version of age band 3 (Chow et al., 2002). Other studies examined the validity of two age bands together (AB2 and AB3), as Psotta & Abdollahipour (2017), and Wuang et al. (2012) with AB1 and AB2. Further studies analyzed all bands (Schulz et al., 2011) and both the checklist and the battery (Capistrano et al., 2015; Schoemaker et al., 2012; Valentini et al., 2014). On the whole of AB1, the validity results were acceptable, indicating that the battery can be applied to this age range. In AB2, the results were similar but Kita et al. (2016) reported that girls were better in Manual Dexterity and Balance. Schulz et al. (2011), when analyzing all three age bands, found evidence for changing the factor structure of the MABC-2 towards differentiation in motor abilities with age. This is directly linked to Malina et al. (2004) theory of growth and maturation that mentions the role of the continuous process of motor development influenced by neuromuscular maturation which takes action in motor skill proficiency variability across age. However, a lack of validation studies regarding AB3 has been found, meaning, there were fewer studies concerning age range 11-16 years old. Furthermore, this age range is favorable to the aforesaid regarding variability in motor performance.

Following this line of thinking, the main goal of this study was to give all the professionals who work with children on which its suspected that they present some kind of movement difficulties, a valid and reliable tool which they can use

to identify and to describe those difficulties. Conjointly, contributing to the research area of these validations, given this gap in AB3.
In addition, it was also aimed to investigate the effect of sex and age in motor performance in accordance to the MABC-2 results.

This dissertation was made according to the Scandinavian model. This model allows the publication of the studies made, which grants a big impulse to the scientific world according this domain. It is divided by six chapters:
Chapter I: comprises the general introduction, with brief description of the state of the art concerning motor coordination, development coordination disorders and the motor tests used to assess motor performance.
Chapter II: composed by the two studies with the validation of age band 3 of the Movement Assessment Battery for Children – Second Edition.
Chapter III: includes the third study, with the investigation regarding the effects of sex and age in MABC-2 performance.
Chapter IV: presents the conclusions of the researches made, along with limitations found and suggestions for future studies.
Chapter VI: presents the attachments.

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Chapter II – Validation

Article I - Movement Assessment Battery for Children-2: Validity and reliability of age band 3 for Portuguese children

Title page

Title

Movement Assessment Battery for Children-2: Validity and reliability of age band 3 for Portuguese children

Authors

Bárbara Fontes Costa de Freitas Vasconcelos[1]

Paula Cristina dos Santos Rodrigues[1,2,3]

Ana Isabel Carita[4]

Maria Olga Fernandes Vasconcelos[1]

Authors Affiliations

[1]Motor Control and Learning Laboratory, Centre of Research, Education, Innovation and Intervention in Sport, CIFI2D, Faculty of Sport, University of Porto

[2]Institute of Intercultural and Transdisciplinary Studies of Almada, Piaget Institute

[3]RECI-Research in Education and Community Intervention

[4]Ciber-Biolad, Faculty of Human Kinetics, University of Lisbon

Corresponding Author

Bárbara Fontes Costa de Freitas Vasconcelos

Faculty of Sport, University of Porto

Rua Dr. Plácido Costa, 91

4200-450 Porto, Portugal

E-mail: fontes.b94@gmail.com

ORCID ID: https://orcid.org/0000-0002-9397-8109

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Structured abstract

The aim of this study was to investigate the internal consistency and test–retest reliability of the Movement Assessment Battery for Children–Second Edition Test (MABC-2), age band 3, a test that has been specifically developed to identify developmental coordination disorder (DCD) in children and to help professionals to overcome children's motor difficulties. Two hundred and thirty-one Portuguese children aged 11 to 16 years old (117 boys and 114 girls) were tested with MABC-2 (age band 3). Internal consistency was assessed through Cronbach's α (Manual Dexterity = 0.598, Aiming and Catching = 0.725 and Balance = 0.314) and Pearson's correlation (MD = 0.745, AC = 0.614 and B = 0.489). Test-retest reliability for the total score was meaningful, with an ICC = 0.689. Overall, even though the internal consistency had a poor result (Cronbach's α for Balance), the other results range from meaningful to highly correlated, making MABC-2 Test a reliable measure to assess motor competence in Portuguese children with possible DCD, between 11-16 years.

Keywords

MABC-2; internal consistency; reliability

INTRODUCTION

Developmental coordination disorder (DCD) is a chronical neurologic disorder affecting 5%-6% of the population [1]. DCD is diagnosed through the four criteria of the Diagnostic and Statistical Manual of Mental Disorders, 5th edition, presented in Table 1. It is characterised based on a significant motor coordination impairment, which hampers daily living activities and academic achievement [2], without the presence of any physical, neurologic or intellectual disability. In children with DCD, clumsiness, handwriting complications and fine motor delay or difficulties are also observed [3]. Bernardi, Leonard [4] suggests that these impairments can persist until adulthood, unless there is an early identification and an appropriate intervention [5]. Moreover, according to Wuang, Su [6], early identification and therapeutic intervention are important to enhance motor function and promote success in school and daily life in children with movement

difficulties. Pearsall-Jones, Piek [7] stated that DCD has been associated with a poor psychological well-being, along with anxiety and depression and Cairney, Hay [8] reported that children with DCD perceive themselves to be less competent in basic motor skills and overall physical abilities with results in adopting a more sedentary life. Children with sedentary lifestyles are at increased risk for negative health and psychosocial outcomes. Therefore, an early diagnosis and educational interventions should be treasured in order to improve their motor skills development [9], their quality of life and their well-being, as young people and as future adults.

Regarding the diagnosis of DCD and its criteria, namely criterion A, motor tests can be conducted to assess the extent and severity of movement impairments [2]. There has been an enhancement focus on the diagnosis and assessment [10] which results in a wide range of tests for different purposes [11]. The Movement Assessment Battery for Children - Second Edition (MABC-2) [12] is one of the most commonly used tests to assess motor impairments in children between 3 to 16 years old [13]. This test is an update of the original MABC [14] , specifically changes in the age bands (reduction of age bands from four to three with an extension from 3 to 16 years old), item revision and inclusion of new items together with a rearrangement of subtests, a new score interpretation method, and a more representative standardization sample [6]. The scoring system of MABC-2 relays on equivalent percentiles that are used to categorise children according to the degree of motor impairment through the Traffic Light system: at or below the 5^{th} percentile is classified as red (a significant movement difficulty), between the 6^{th} and the 15^{th} percentile inclusive as amber (child is “at risk” of having a movement difficulty), at or above the 16^{th} percentile as green (no movement difficulty detected) [12].

Although the validity and reliability of the MABC-2 test was already conducted with healthy children, only few studies used the full age range of each band, age band 1 [13, 15], age band 2 [16-18].

To our knowledge, there is no reference to the analysis of the psychometric qualities of MABC-2 in the full age band 3 in healthy children. Therefore, the

purpose of this study was to evaluate MABC-2 Test's internal consistency and test-retest reliability in the age band 3 in Portuguese children.

METHOD

Participants

A total of 231 children (117 boys and 114 girls) from four different Portuguese cities covering north, centre and south regions, and aged 11 to 16 years old (M = 13 years and 11 months, SD = 1 year and 7 months) were enrolled in this study. The inclusion criteria were (1) age between 11 and 16 years old and (2) attendance at the chosen schools. The exclusion criteria met the DSM-5 diagnostic criterion D, which includes intellectual disability, visual impairment and neurologic conditions affecting movement, such as cerebral palsy, muscular dystrophy or degenerative disorder [1]. The parents of all children provided written informed consent for the study. The Review Number of the process assigned by the Faculty of Sport's Ethical Committee was CEFADE 18.2018.

Instruments

The MABC-2 is a standardized tool to assess and describe motor ability and impairment in children. The test encompasses two parts: the Checklist and the Performance Test, and comprises three age bands (AB1 – 3 to 6 years old; AB2 – 7 to 10 years old; AB3 – 11 to 16 years old). This study used only the Performance Test in the age band 3. Within each age band, eight items are grouped under three components: manual dexterity (MD), aiming and catching (A&C) and balance (B). Manual Dexterity is assessed through the tests "Turning pegs", "Triangle with nuts and bolts" and "Drawing trail 3"; Aiming and Catching with "Catching with one hand" and "Throwing at wall target"; and the Balance is measured through "Two-board balance", "Walking heel-to-toe backwards" and "Zig-Zag hopping" [12]. For all of the items, apart from aiming and catching, two trials are granted (if needed) and the best one is used to rate the item. The designated measures (raw scores) are recorded as time taken to complete the task, number of successful throws/catches and the number of failures, and then converted to standard scores (SSs). The scoring system relays on the age-based

standard scores labelled for each individual item, which allows its conversion in Component Scores (CSs) and further calculation into Total Test Score (TTS).

Procedure

Children were individually tested according to the instructions given in the MABC-2 manual, namely age band 3 [12]. Three expert physical activity professionals were fully trained to administer the MABC-2 prior to the study. To assess the test-retest reliability, the MABC-2 was administered twice, two weeks apart, to 40 children (20 boys and 20 girls), under the same conditions.

Data analysis

All data were analysed using Statistical Package for Social Sciences (version 24.0) for Macintosh. The standard scores of the MABC-2 Test were used in the following analyses. To all analysis, the level of significance was established for $p< 0.05$.

Descriptive analysis of the data

To examine the score distribution of the results, namely the standard scores, descriptive statistics was used, such as range, means and standard deviations.

Internal consistency

Internal consistency refers to the degree of interrelatedness among the items. Cronbach's alpha (α) coefficient was calculated for internal consistency of the MABC-2 Test using all children's data, except from the test-retest. Coefficients indicate poor reliability when they are below 0.5, acceptable between 0.50 and 0.70 and good when above 0.7 [19]. Moreover, Pearson's correlation was used to assess the internal consistency (IC) between the subscales and the total standard score. Pestana and Gageiro [20] consider Person's correlation's values very high above 0.90, high from 0.70 to 0.90, moderate from 0.40 to 0.70, poor between 0.20 and 0.40 and very poor lower than 0.2.

Test-retest reliability

The ability of the standard scores to produce consistent results when tested in two different time points (first and second measurement) was determined using the Intra-class Correlation Coefficient (ICC) with a two-way random effects model that allowed results generalization to testing conditions beyond the ones in this study. According to Landis and Koch [21], values are considered slight if less than 0.20, fair from 0.21 to 0.40, moderate from 0.41 to 0.60, meaningful from 0.61 to 0.80 and almost perfect between 0.81 and 1.00.

RESULTS

Descriptive analysis of the data

Descriptive statistics for the standard scores of the first evaluation is presented in Table 2. Means at subscales shows variation, with Balance presenting the highest mean, and Manual Dexterity the lowest.

Internal consistency

The Cronbach's α values for Manual Dexterity, Aiming and Catching and Balance subscales were 0.598, 0.725 and 0.314, respectively, and the value for all the subscales together was 0.299. In Table 3 are presented the Pearson's correlation coefficients between subscales and between each one of them with Total Test Score. No significant correlations were observed between subscales. The values were 0.745 for Manual Dexterity, 0.614 for Aiming and Catching and 0.489 for Balance. Conversely, significant correlations were found between subscales and TTS, being the bivariate association strong between Manual Dexterity and TTS, while Aiming and Catching and Balance correlate moderately with TSS.

Test-retest reliability

The intraclass correlation coefficient (ICC) was calculated to analyse the intra-rater reliability (Table 4). The values for the subscales ranged from 0.686 for Balance and 0.760 for Manual Dexterity, and the ICC of the Total Test Score was 0.689.

DISCUSSION

The aim of this study was to investigate the internal consistency and test–retest reliability of the MABC-2 Test, age band 3. Cronbach's α value for all the subscales together was 0.299, which indicates poor internal consistency. However, the values for each subscale were Manual Dexterity = 0.598, Aiming and Catching = 0.725 and Balance = 0.314. According to Stangor [19], the values for Manual Dexterity and Aiming and Catching are acceptable, although the value for the Balance reveals poor IC. Interestingly, we can verify that the test Aiming and Catching revealed a higher value for internal consistency [15]. These results are similar to those of Ellinoudis, Evaggelinou [15] (MD = 0.51, AC = 0.70 and B = 0.66), which have explained that the observed values might be justified by the short number of items for which the Cronbach's α was calculated. This justification may also explain our values for the internal consistency. Moreover, Batalha [18], although considering a different age band in her investigation (band 2), also verified low values at all subscales (MD = 0.51, AC = 0.49, B = 0.56), supporting this theory. More comparisons considering other studies could not be made due to the lack of similar research data regarding this age band.

Pearson's correlation also assessed the internal consistency, presenting a high correlation between the Manual Dexterity and the Total Test Score (0.745) but a moderate correlation between the remaining tests and the TTS. These correlation values suggest that the three sub-scales contribute to the measurement of a coordination factor. Otherwise, the weak correlation values between the subscales suggest that they assess different dimensions of motor coordination, but all contribute to the knowledge of the level of general coordinative proficiency. It will be this general dimension that will inform about the movement difficulties of the child, if he/she has DCD, if he/she is at risk of DCD or if he/she does not have coordinative difficulties.

Regarding consistency in scores over time (first and second measurement), through test-retest reliability, the ICC's results showed meaningful reliability (MD = 0.760, AC = 0.732, B = 0.686 and TTS = 0.689), according to Landis and Koch [21].These values are slightly below the ones mentioned in the MABC-2 manual (MD = 0.77, AC = 0.84, B = 0.73 and TTS = 0.80) [12], and also in more studies

with other age bands as Ellinoudis, Evaggelinou [15] with the AB1 (MD = 0.82, AC = 0.61, B = 0.90 and TTS = 0.85), or Wuang, Su [6] who studied children between 6 to 12 years (MD = 0.97, AC = 0.91, B = 0.97 and TTS = 0.97). Despite the lower values, the reliability can still be considered meaningful. The difference between our results and the ones aforementioned might be explained by the disparity in age. The use of age band 3 comprises children between 11 to 16 years old, which includes very specific ages in what concerns the growth rates. According to Malina, Bouchard [22], these growth rates are presented as velocity curves, which suggests that girls between 11-15 and boys between 14-17 are exposed to bigger changes in their height and weight, especially during the peak height/weight velocity (12 years old at girls and 14 years old at boys). Also, intraindividual variability can be detected in motor performance which can be observed from day to day and even from trial to trial on a given day [22]. Therefore, changes in performance from the first to the second measurement, that resulted in lower test-retest values, can be justified by these peak velocities and this variability.

The results showed that the standard scores during the first measurement were significantly associated with scores during the retest. In any case, the acquiescence bias (positive or negative) did not happened, effectively confirming the test reliability [10]. Given the importance of this issue, and despite our results it is possible the identification of motor difficulties in children of this age band. Therefore, appropriate intervention can be carried out, with programs of motor re-education in order to overcome these difficulties and to prevent their prevalence until and beyond adulthood.

The major limitation of this study was the small sample size (n=231) compared to other validation studies of the MABC-2 [11, 13, 16]. However, so far, this is the first study with Portuguese children in the age band 3.

Besides the poor internal consistency of Manual Dexterity, Aiming and Catching and Balance subscales, tests' results support the reliability of this tool. In addition, the results in repeated measurements over a two weeks interval are also reliable. In conclusion, the MABC-2 Test for Portuguese children between 11-16 years (AB3) is a valid and reliable instrument to assess motor coordination and to

identify DCD in Portuguese children, allowing its application and implementation of an ecological intervention in this age range.

The authors have stated that they had no interests which might be perceived as posing a conflict or bias.

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Table 1: The DSM-5 criteria for developmental coordination disorder [1].

A	The acquisition and execution of coordinated motor skills is substantially below that expected given the individual's chronologic age and opportunity for skill learning and use. Difficulties are manifested as clumsiness (e.g., dropping or bumping into objects) as well as slowness and inaccuracy of performance of skills (e.g., catching an object, using scissors or cutlery, handwriting, riding a bike, or participating in sports).
B	The motor skills deficit in Criterion A significantly and persistently interferes with activities of daily living appropriate to chronological age (e.g., self-care and self-maintenance) and impacts academic/school productivity, prevocational and vocational activities, leisure and play.
C	Onset of symptoms is in the early developmental period.
D	The motor skills deficits are not better explained by intellectual disability (intellectual developmental disorder) or visual impairment and are not

attributable to a neurological condition affecting movement (e.g., cerebral palsy, muscular dystrophy, degenerative disorder).

Table 2: Description of the MABC-2 standard scores (Items, subscales and total test score) at the first moment (n=231).

(n=231)	Min	Max	Mean	Std. Deviation
Items				
Manual Dexterity 1	1	16	8.338	3.195
Manual Dexterity 2	1	17	7.749	2.998
Manual Dexterity 3	1	13	7.874	3.733
Aiming & Catching 1	2	15	8.736	3.236
Aiming & Catching 2	3	17	8.377	3.045
Balance 1	3	13	10.558	2.801
Balance 2	3	12	11.719	1.181
Balance 3	3	11	10.593	1.435
Subscales				
Manual Dexterity	2	16	7.896	2.857
Aiming & Catching	1	18	8.675	3.295
Balance	6	14	11.602	2.433
Total Test Score	2	17	8.961	2.254

Table 3: Pearson's correlations. Subscales and total test score of MABC-2.

(n=231)	Manual Dexterity	Aiming and Catching	Balance
Manual Dexterity	1	.098	.117
Aiming and Catching	.098	1	.171
Balance	.117	.171	1
Total Test Score	.745**	.614**	.489**

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4: Test-retest reliability. Subscales and total test score of MABC-2.

(n=40)	ICC (95%CI)
Subscales	
Manual Dexterity	0.760 (0.547 – 0.873)
Aiming and Catching	0.732 (0.492 – 0.858)
Balance	0.686 (0.407 – 0.834)
Total Test Score	0.689 (0.412 – 0.836)

Article II - Factorial validity of the Movement Assessment Battery for Children-2 (age band 3)

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FACTORIAL VALIDITY OF THE MOVEMENT ASSESSMENT BATTERY FOR CHILDREN-2 (AGE BAND 3)

Bárbara Vasconcelos[1], Paula Rodrigues[1,2,3], Olga Vasconcelos[1]

[1]Laboratório de Aprendizagem e Controlo Motor, CIFI2D, Faculdade de Desporto da Universidade do Porto

[2]*Instituto de Estudos Interculturais e Transdisciplinares de Almada, Instituto Piaget*

[3]*RECI-Research in Education and Community Intervention*

RESUMO

O Movement Assessment Battery for Children – Segunda Edição é um dos testes mais utilizados na investigação da coordenação motora de crianças e jovens. Este instrumento compreende bandas de idade (BI1 – 3 até 6 anos; BI2 – 7 até 10 anos; BI3 – 11 até 16 anos) cada uma incluindo 8 testes agrupados em 3 dimensões: destreza manual, atirar e agarrar e equilíbrio. Para ser aplicado na população portuguesa, a validade do MABC-2 deve ser analisada previamente. Este estudo pretendeu analisar a validade fatorial da BI3 do MABC-2 através de uma análise fatorial confirmatória (modelo trifatorial). Os resultados dos testes aplicados a 231 crianças portuguesas (117 rapazes e 114 raparigas) indicaram um bom ajustamento dos valores ao modelo (χ^2/df =1.813; CFI = .865; GFI = .954; RMSEA = .059, TLI = .811). Concluiu-se que o MABC-2, BI3 é um instrumento válido para avaliar as dificuldades motoras de crianças e jovens entre os 11 e os 16 anos.

Palavras-chave

movement assessment battery for children-2; perturbação do desenvolvimento da coordenação; validade fatorial; análise fatorial confirmatória

Abstract

The Movement Assessment Battery for Children – Second Edition is one of the most frequently used tools assessing motor coordination in children. This test comprises 3 age bands (AB1 – 3 to 6 years old; AB2 – 7 to 10; AB3 – 11 to 16 years) and eight tests into three dimensions: manual dexterity, aiming and catching and balance. To be applied in Portuguese population, the MABC-2 validity has to be previously analysed. This study aimed to examine the factorial validity of the MABC-2 AB3 through a confirmatory factor analysis (three-factor model). The results comprising a sample of 231 Portuguese children (117 boys and 114 girls) suggested a satisfactory fit of the data to the model (χ^2/df =1.813; CFI = .865; GFI = .954; RMSEA = .059, TLI = .811). Consequently, the MABC-2, AB3 for Portuguese children is a valid tool for assessing movement difficulties in children and youths between 11 and 16 years old.

Key-words

movement assessment battery for children-2; development coordination disorder; factorial validity; confirmatory factor analysis

Introduction

Developmental coordination disorder (DCD) is a neurodevelopmental disorder which affects children and, if no early intervention is carried out at this age, may persist in adulthood (1). This disease affects 5%-6% of the population and is characterized by significant motor difficulties which interfere with child's daily activities (such as self-care, school tasks or leisure activities), without a previously explanation by neurologic conditions, intellectual disabilities or visual impairments (2). To identify and describe these movement difficulties, professionals need valid and reliable motor tests (3). The Movement Assessment Battery for Children – Second Edition (MABC-2) (4) is one of the most widely used tests to assess motor impairments in children between 3 and 16 years old. This updated version of the original MABC (5) includes some changes such as age extension, reduction of age bands, item revision and addiction of new items, inter alia (6). Given the importance of this subject, it is fundamental the early identification of motor difficulties in children so that an appropriate intervention can be carried out with programs of motor re-education. Therefore, the aim of this study was to examine the factorial validity of the age band

3 in order to endow Portuguese professionals to apply this age band of the MABC-2 and to have a better understanding of the motor abilities assessed by this test.

Method

Participants

This investigation used a sample of 231 children (117 boys and 114 girls) between 11:0 and 16:11 years old (M = 13.45, SD= 1.71) from north, centre and south of Portugal. All the children had an informed consent for the study written by their parents. To be chosen, the students had to meet inclusion criteria, such as not being previously diagnosed with intellectual disability, visual impairment or neurologic conditions affecting movement, as cerebral palsy, muscular dystrophy or degenerative disorder, which establish the criterion D of DSM-5 for the diagnostic of DCD (2). The Review Number of the process assigned by the Faculty of Sport's Ethical Committee was CEFADE 18.2018.

Instruments

The Movement Assessment Battery for Children – Second Edition is a standardized tool specifically developed to assist professionals responsible for helping children with movement difficulties. It comprises two parts: the Checklist and the Performance Test, and includes three age bands (AB1 – 3 to 6 years old; AB2 – 7 to 10 years old; AB3 – 11 to 16 years old). This study used only the Performance Test in the age band 3. Within each age band, eight items are grouped under three components: manual dexterity (MD), aiming and catching (A&C) and balance (B). In this age band, Manual Dexterity is assessed through the tests "Turning pegs" (Manual Dexterity 1), "Triangle with nuts and bolts" (Manual Dexterity 2) and "Drawing trail 3" (Manual Dexterity 3); Aiming and Catching, with "Catching with one hand" (Aiming & Catching 1) and "Throwing at wall target" (Aiming & Catching 2); and the Balance is measured through "Two-board balance" (Balance 1), "Walking heel-to-toe backwards" (Balance 2) and "Zig-Zag hopping" (Balance 3). (4). For all of the items, apart from Aiming and Catching, two trials are granted (if needed) and the best one is used to rate the item. The designated measures (raw scores) are recorded as time taken to complete the task (MD), number of successful throws/catches (A&C) and the number of

failures (B), and then converted to standard scores (SSs). The scoring system relays on the age-based standard scores labelled for each individual item, which allows its conversion in Component Scores (CSs) and in Total Test Score (TTS).

Procedure

The sample was tested with AB3 of the MABC-2, following the instructions and guidelines specified in the Examiner's Manual (4). The application of the test was conducted by three physical activity professionals, who were fully trained in advance. To simplify the procedure, the datasheets and guidelines used were those translated and adapted culturally to the Portuguese language (7).

Data analysis

All data were analysed using Statistical Package for Social Sciences (version 24.0) for Macintosh, and the confirmatory factor analysis was performed using AMOS (version 24.0) for Windows. The following analysis used the standard scores of the MABC-2 Test.

Descriptive analysis of the data

To examine the score distribution of the results, namely the standard scores, descriptive statistics measures was used, such as range, means and standard deviations.

Confirmatory Factor Analysis

We performed confirmatory factor analysis to examine the factorial validity of the AB3 of the MABC-2, using the SSs of the eight test items. This analysis tested a postulated model whereby each of the three components correlated with each other, but the errors did not correlate. Multiple fit indices were used to evaluate the model fit: chi square statistic to Degree of Freedom ratio [$\chi^2/df < 5$ (8)] , the Comparative Fit Index [CFI > 0.95 (8)], the Goodness-of-Fit Index [GFI (0.95-1) (9)], the Root Mean Square Error of Approximation [RMSEA < 0.05 (10)] and the Tucker-Lewis Index [TLI > 0.95 (11)].

Results

Descriptive statistics for the standard scores is presented in Table 1. Means at subscales shows variation, with Balance presenting the highest mean, and Manual Dexterity the lowest.

Table 1: Description of the MABC-2 standard scores for tests, subscales and TTS (n=231).

	Min	Max	Mean	Std. Deviation
Items				
Turning Pegs	1	16	8.338	3.195
Triangle with nuts and bolts	1	17	7.749	2.998
Drawing trail 3	1	13	7.874	3.733
Catching with one hand	2	15	8.736	3.236
Throwing at wall	3	17	8.377	3.045
Two-board balance	3	13	10.558	2.801
Walking heel-to-toe backwards	3	12	11.719	1.181
Zig-Zag hopping	3	11	10.593	1.435
Subscales				
Manual Dexterity	2	16	7.896	2.857
Aiming & Catching	1	18	8.675	3.295
Balance	6	14	11.602	2.433
Total Test Score	2	17	8.961	2.254

In Figure 1, we can see the values of the MABC-2 three-domain model, adjusted to a sample of 231 children aged 11 to 16 years. The values obtained, $\chi 2$ / df = 1,813; CFI = .865; GFI = .954; RMSEA = .059, TLI = .811, indicate a good quality of adjustment.

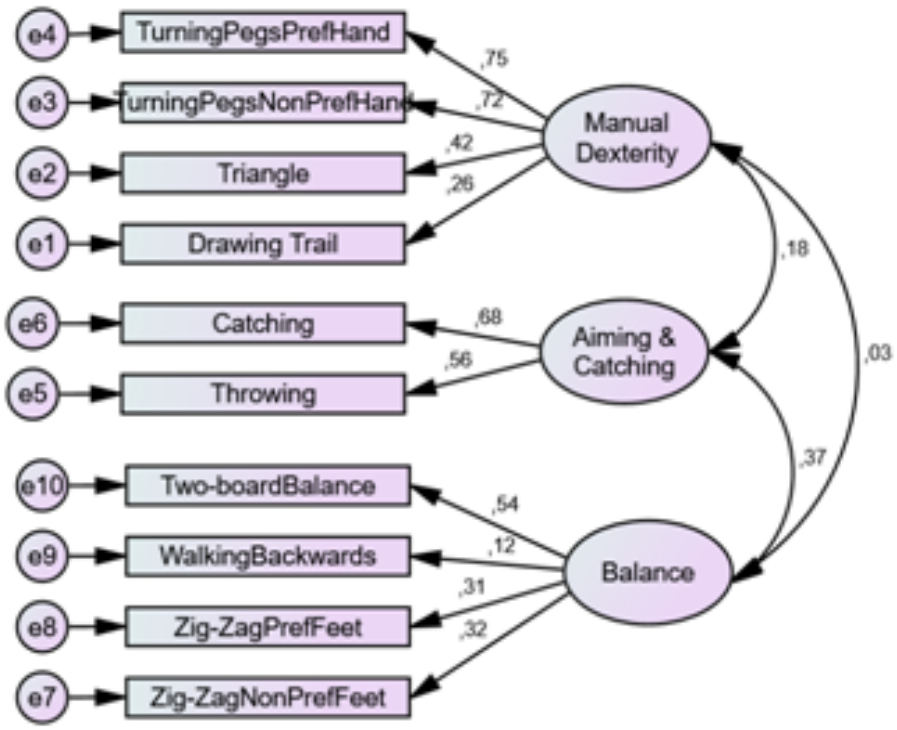

Figure 1: Three-specific factor model of the MABC-2 test—age band 3 for 11- 16-year old children.

Discussion

The aim of this investigation was to examine the factorial validity of the AB3 of the Movement Assessment Battery for Children – Second Edition. A confirmatory factor analysis was performed to test the goodness-of-fit of the items and the results for the three-domain model were similar to the structure proposed by Henderson, Sugden (4). Also, the goodness-of-fit indices suggested the data have a good fit to the model considering the GFI (0.954) is over than 0.95 (8). We can still consider that the AB3 of the MABC-2 can be used in Portuguese children, although it may need further refinement for enhancing its psychometric quality, contrary to Ellinoudis, Evaggelinou (12) whose results of the CFI approached the desirable level 0.90. Hua, Gu (13) analysed AB1 factorial validity and suggested an adjustment or an item revision to apply this age band in Chinese children. Their results suggested the data did not have a satisfactory fit to three-domain model due to the factor loading of “Drawing trail” and “Walking heels raised” tests.

These slightly lower results can be explained because of the differences between the aspects of movement that are assessed through the three subscales. If the correlations were too high, the same characteristics would certainly be measured across the three subscales. Considering the

MABC-2, it is supposed that the subscales Manual Dexterity, Aiming and Catching and Balance evaluate separate abilities.

The major limitation of this study was the small sample size, compared with other validation studies (13-15). In future studies, we suggest increasing the sample.

Conclusions

In conclusion, this investigation verified that the AB3 of the MABC-2 can be used in clinical research in order to identify motor difficulties, even though it may need adjustments in the number of items as suggested Hua, Gu (13). This motor coordination test is important to provide an early identification of motor difficulties in children so that an appropriate intervention can be carried out with programs of motor re-education.

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Chapter III - Motor proficiency

Article III - Motor performance gender and age variation in Movement Assessment Battery for Children-2

Title page

Title

Motor performance gender and age variation in Movement Assessment Battery for Children-2

Authors

Bárbara Fontes Costa de Freitas Vasconcelos[1]

Maria Olga Fernandes Vasconcelos[1]

Paula Cristina dos Santos Rodrigues[1,2,3]

Authors Affiliations

[1]Motor Control and Learning Laboratory, Centre of Research, Education, Innovation and Intervention in Sport, CIFI2D, Faculty of Sport, University of Porto

[2]Institute of Intercultural and Transdisciplinary Studies of Almada, Piaget Institute

[3]RECI-Research in Education and Community Intervention

Corresponding Author

Bárbara Fontes Costa de Freitas Vasconcelos

Faculty of Sport, University of Porto

Rua Dr. Plácido Costa, 91

4200-450 Porto, Portugal

E-mail: fontes.b94@gmail.com

ORCID ID: https://orcid.org/0000-0002-9397-8109

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Motor performance gender and age variation in Movement Assessment Battery for Children-2

Abstract

Motor coordination is the ability to perform motor skills through the integration of separate motor and sensory systems. However, delays or hampers in the acquisition of these motor skills may result in Developmental Coordination Disorders. To assess motor performance, various tools have been designed, namely Movement Assessment Battery for Children-2. The literature is not consensual about the differences in motor competence regarding sex and age, regardless of the existence of any disturbance. Therefore, the aim of this study was to investigate the effect of sex and age of 231 Portuguese children between 11 and 16 years old on motor competence, using the MABC-2. Regarding the sex effect, independent t-test showed that boys performed statistically significant better than girls in Manual Dexterity and Aiming and Catching and there were no differences between sexes in Balance and in the TTS. Concerning the age effect, statistically significant differences were found in Aiming and Catching and in Balance, where children with 11 and 16 years old presented worse performance, respectively, compared to their counterparts. Summarizing, the findings of this study suggests that motor performance is affected by sex and age, and that more specific analyses regarding these effects should be took in consideration to further investigations.

Key-words

Motor coordination; DCD; MABC-2; age band 3.

1. Introduction

By definition, motor coordination is the capacity to create an integration between separate motor and varying sensory systems, into efficient patterns of movement, commonly referred to as motor skills (Gallahue & Ozmun, 1998). Motor skills vary from gross body coordination, eye-hand coordination, static and dynamic balance, inter alia. In order to perform a wide range of goal-directed actions, children need to coordinate successfully their body moves (Chagas & Batista, 2017). Although it is expected that children achieve these coordinated motor skills profitably, some motor difficulties may delay or hamper its acquisition and execution (Higashionna et al., 2017). These difficulties frequently entail in medical conditions such as Developmental Coordination Disorder (DCD). DCD is a neurological chronic disorder that is characterised based on a significant motor coordination impairment, which hampers daily living activities and academic achievement (Schoemaker, Niemeijer, Flapper, & Smits-Engelsman, 2012). Also, in children with this condition, it is possible to observe clumsiness, complications in handwriting and the above-mentioned motor delay or difficulties (Farmer, Echenne, & Bentourkia, 2016). The diagnosis is made through four criteria present in Diagnostic and Statistical Manual of Mental Disorders, 5th edition (American Psychiatric Association, 2013). However, it is important that the motor skills deficits are not better explained by intellectual disability, visual impairment or other neurological condition affecting movement (criterion D) (American Psychiatric Association, 2013). These conditions put children at risk for other health problems such as overweight/obesity (Lee, Psotta, & Vagaja, 2016), or even have a negatively impact on their self-efficacy and limit their performance in school as well as in leisure activities, decreasing their levels of physical activity (Engel-Yeger & Hanna Kasis, 2010). Throughout the years, there has been a growth of interest in these children (Venetsanou et al., 2011) since tools to diagnose these disorders are required in many research fields such as neurology, psychology, physiotherapy or sports' science (Ludvik, Psotta, & Abdollahipour, 2016). One of the most commonly used is the Movement Assessment Battery for

Children-2 (Henderson, Sugden, & Barnett, 2007), an upgrade from Movement Assessment Battery for Children (Henderson & Sugden, 1992). It has been specifically developed to assist professionals responsible for helping children with movement difficulties.

Concerning motor performance in children and adolescents, the effect of sex reported in the investigations varies according the authors, the subscales and the age. Ludvik et al. (2016) showed that girls outperformed boys in activities requiring fine motor coordination, such as the ones in Manual Dexterity. In turn, Butterfield, Angell, and Mason (2012) state that boys are usually better in Aiming and Catching. In Balance and in Total Test Score, Kokstejn, Musalek, and Tufano (2017) find no sex differences. In terms of age, Gallahue and Ozmun (1998) affirm that both sexes level off in performance of Balance at age 12. Besides, gross body coordination (where we can insert the test “Zig-Zag hopping” from the subscale Balance) and eye-hand coordination (items assessed in Aiming and Catching) appear to increase with age in a roughly linear fashion. However, motor development is a continuous process involving factors such as neuromuscular maturation, body composition, growth and maturation (Malina, Bouchard, & Bar-Or, 2004). Understanding stability of motor skill performance across developmental time is crucial when aiming to intervene and improve its proficiency (Barnett, van Beurden, Morgan, Brooks, & Beard, 2010). To address this issue, the aim of this investigation was to examine whether performance in the different subscales of the MABC-2 – AB3 was affected by sex and age.

2. Materials and Methods

2.1 Participants

A total of 231 children (117 boys and 114 girls) from four different Portuguese cities covering north, centre and south regions, between 11 and 16 years old (M = 13 years and 11 months, SD = 1 year and 7 months) were enrolled in this study. The inclusion criteria were (1) age range 11 to 16 years old and (2) attendance at the chosen schools. The exclusion criteria met the DSM-5 diagnostic criterion D of DCD, which includes intellectual disability, visual impairment and neurologic

conditions affecting movement, such as cerebral palsy, muscular dystrophy or degenerative disorder (American Psychiatric Association, 2013). All participants had an informed consent for the study provided by their parents or caregivers. The Review Number of the process assigned by the Faculty of Sport's Ethical Committee was CEFADE 18.2018.

2.2 Instruments

The MABC-2 is a standardized tool to assess and describe motor ability and impairment in children. The test encompasses two parts: the Checklist and the Performance Test, and comprises three age bands (AB1 – 3 to 6 years old; AB2 – 7 to 10 years old; AB3 – 11 to 16 years old). This study used only the Performance Test in the age band 3. Within each age band, eight items are grouped under three components: manual dexterity (MD), aiming and catching (AC) and balance (B). Manual Dexterity is assessed through the tests "Turning pegs", "Triangle with nuts and bolts" and "Drawing trail 3"; Aiming and Catching with "Catching with one hand" and "Throwing at wall target"; and the Balance is measured through "Two-board balance", "Walking heel-to-toe backwards" and "Zig-Zag hopping". For all of the items, apart from aiming and catching, two trials are granted (if needed) and the best one is used to rate the item. The designated measures (raw scores) are recorded as time taken to complete the task, number of successful throws/catches and the number of failures. In other words, in Manual Dexterity, a higher score involves a worst motor performance. On the other hand, in Aiming and Catching, Balance and Total Test Score, higher scores mean better motor performance. Then, the raw scores are converted to standard scores (SSs). The scoring system relays on the age-based standard scores labelled for each individual item, which allows its conversion in Component Scores (CSs) and further calculation into Total Test Score (TTS). At last, percentiles are used to categorise children according to the degree of motor impairment through the Traffic Light system: at or below the 5^{th} percentile is classified as red (a significant movement difficulty), between the 6^{th} and the 15^{th} percentile inclusive as amber (child is "at risk" of having a movement difficulty),

at or above the 16th percentile as green (no movement difficulty detected) (Henderson et al., 2007).

2.3 Procedure

Children were individually assessed on the MABC-2 (age band 3) according to the test manual instructions (Henderson et al., 2007). Three expert physical activity professionals were fully trained to administer the battery prior to the beginning of the study. To facilitate testing, the datasheets and the guidelines used were the translated ones purchased from (Batalha, 2015).

2.4 Data analysis

The Kolmogorov-Smirnov test was used to analyse data normality distribution succeeding an independent t-test to understand whether scores in MABC-2 components differs based on sex. A multivariate ANOVA was performed to investigate the age impact on motor performance, along with a Bonferroni post hoc to confirm possible outcomes. The level of significance was set at $p<0.050$. To perform all tests, the CSs were used, as the TTS. All the analyses were carried out using Statistical Package for Social Sciences (version 24.0) for Macintosh.

3. Results

3.1 Effect of sex

Table 1 presents the effect of sex in the subscales and TTS.

Table 1: Differences in components and TTS according to sex. Mean, standard deviation, t and p values (2-tailed).

		M	SD	t	p
Manual Dexterity	M	22,38	7,241	-3,582	0,000
	F	25,57	6,222		
Aiming and Catching	M	19,49	4,847	7,620	0,000
	F	14,76	4,567		
Balance	M	32,66	3,589	-0,929	0,354
	F	33,11	3,724		
Total Test Score	M	74,51	10,856	0,784	0,434
	F	73,44	9,922		

Table 1 shows the differences between sexes in motor performance of each component. Manual Dexterity ($t_{(229)}$ = -3,582; p<0.001) and Aiming and Catching ($t_{(229)}$ = 7,620; p<0.001) present statistically significant differences in motor performance (p<0.050). Regarding these abilities, boys outperformed girls.
In Table 2 it can be observed the differences between sexes in the participants who present no movement difficulties (90 boys and 84 girls).

Table 2: Traffic Light Scores: green. Differences between sexes to those participants with no movement difficulties. Mean, standard deviation, t and p values (2-tailed).

		M	SD	t	p
Manual Dexterity	M	24,61	6,270	-3,834	0,000
	F	27,86	4,732		
Aiming and Catching	M	20,86	4,257	7,449	0,000
	F	16,07	4,208		
Balance	M	33,29	3,156	-1,566	0,119
	F	34,02	3,026		
Total Test Score	M	78,73	7,667	0,711	0,478
	F	77,95	6,743		

Table 2 shows that children classified as “no movement difficulties” presented statistically significant differences in Manual Dexterity and Aiming and Catching (p<0,050), and in both components, boys outperformed girls.
Table 3 presents the differences between sexes in the 22 boys and 24 girls who were classified as at risk of having movement difficulties.

Table 3: Traffic Light Scores: amber. Differences between sexes to those participants at risk of having movement difficulties. Mean, standard deviation, t and p values (2-tailed).

		M	SD	t	p
Manual Dexterity	M	16,41	4,043	-3,186	0,003
	F	20,42	4,452		
Aiming and Catching	M	15,36	3,646	3,833	0,000
	F	11,29	3,557		
Balance	M	31,68	3,242	0,449	0,655
	F	31,21	3,845		
Total Test Score	M	63,45	2,874	0,605	0,548
	F	62,92	3,134		

The results showed in Table 3 are similar to the ones in Table 2, since Manual Dexterity and Aiming and Catching also present statistically significance (p<0,050), being boys better than girls in these components.
In Table 4 it can be observed the differences between sexes in the 11 children who present significant movement difficulties (five boys and six girls).

Table 4: Traffic Light Scores: red. Differences between sexes to those participants with significant movement difficulties. Mean, standard deviation, t and p values (2-tailed).

		M	SD	t	Sig. (2-tailed)
Manual Dexterity	M	8,60	3,782	-1,710	0,121
	F	14,17	6,369		
Aiming and Catching	M	13,00	4,472	1,180	0,268
	F	10,33	3,011		
Balance	M	25,60	4,506	-0,739	0,479
	F	27,83	5,345		
Total Test Score	M	47,20	7,791	-1,408	0,193
	F	52,33	4,082		

In Table 4 it can be seen that red zone results present no differences regarding sex (p > 0,050).

3.2 Effect of age

Table 5 presents the results of the multivariate ANOVA calculated to verify age effects.

Table 5: Differences between ages. Degrees of freedom, Mean Square, F test, p and Partial Eta Squared values.

	df	Mean Square	F	p	η_p^2
Manual Dexterity	5	59,892	1,254	,285	,027
Aiming and Catching	5	79,454	2,993	,012	,062
Balance	5	36,471	2,839	,017	,059
Total Test Score	5	49,232	,450	,813	,010

In Table 5 it can be observed the effects between age in motor performance. As it is observed, age presented a statistically significant effect in Aiming and

Catching ($F_{(5, 225)}$ = 2,993; p = 0,012; η_p^2 = 0,062) and in Balance ($F_{(5, 225)}$ = 2,839; p = 0,017; η_p^2 = 0,059).

Fig. 1 presents the box plot of the results of Aiming and Catching in each age group.

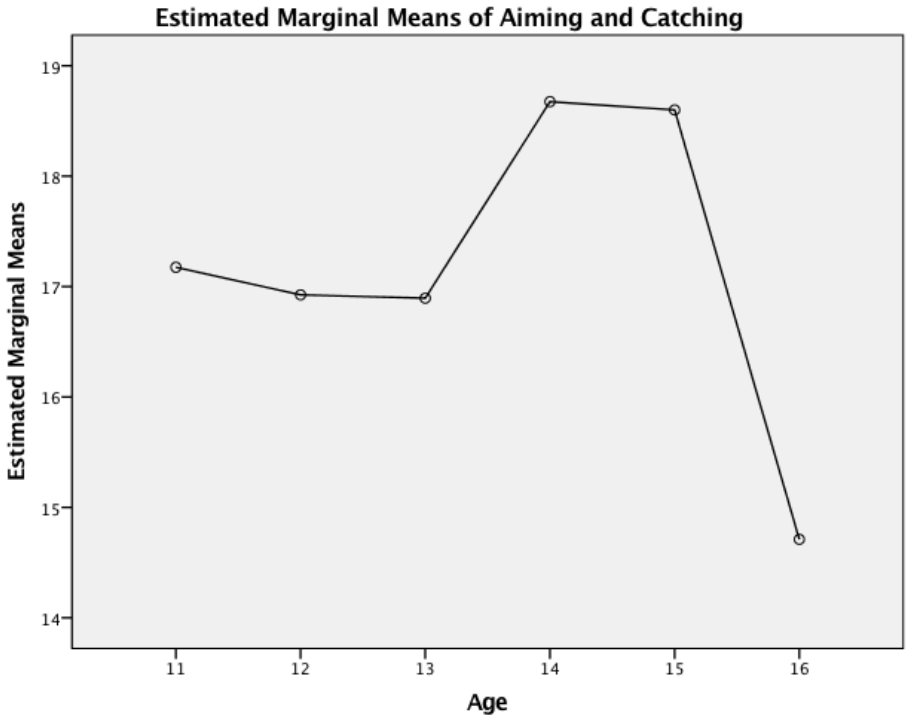

Figure 1: Scores in Aiming and Catching in each age group.

Observing Figure 1, we can see that children aged 16 years old had lower scores compared to the other ages, being the differences statistically significant, confirmed by the Bonferroni post-hoc (p <0.050).

In Fig 2. it can be observed the box plot for the Balance results in each age group.

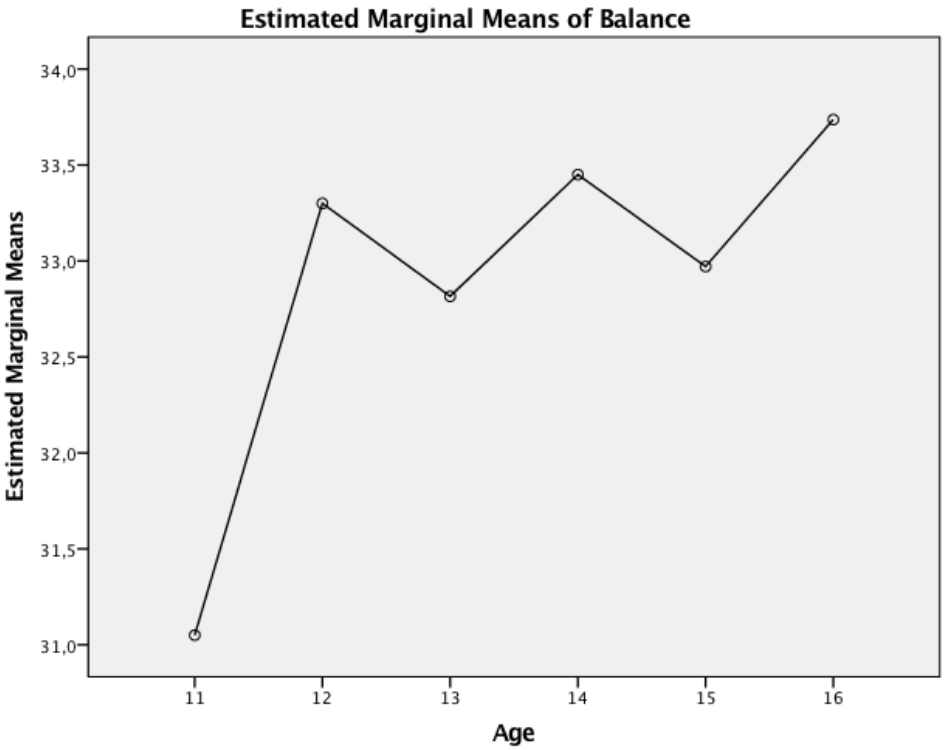

Figure 2: Scores in Balance in each age group.

Figure 2 shows the lower scores in this test obtained by children with 11 years old, when compared with the other ages. These differences are statistically significant and confirmed by the post-hoc Bonferroni ($p < 0.050$).

4. Discussion

The aim of this study was to investigate whether performance in MABC-2 – AB3 components was affected by sex and age. Hands, McIntyre, and Parker (2018) claim that even though several studies have identified different biological structures between males and females in motor skills assessments, the effect of sex on motor performance is still ignored in clinical research. Therefore, in the analysis of sex effect, the results showed statistically significant differences between boys and girls in Manual Dexterity and Aiming and Catching, where boys outperformed girls. These results run contrary to Ludvik et al. (2016), where girls presented better results in activities requiring fine motor coordination, namely Manual Dexterity. Environmental influences, namely sociocultural influences in play opportunities, can explain these differences in Aiming and Catching, since usually boys tend to perform better than girls in gross motor measures (such as

the aforementioned component), but are contrary for fine motor skills (such as Manual Dexterity), where normally girls tend to present better scores (Hands et al., 2018).

Furthermore, when analysing the differences in the Traffic Light System, where children in the green zone have no movement difficulty, in the amber zone are “at risk” of having movement difficulties and in the red zone have significant movement difficulties, the red zone presents no differences regarding sex, meaning boys and girls, have both equally difficulties.

Regarding age, the statistically significant differences were observed in Aiming and Catching, where children aged 16 presented the worst results, and in Balance, where children with 11 years old were outperformed by the other ages. The results of Aiming and Catching may be explained by the lack of eye-hand coordination which, according to Gallahue and Ozmun (1998) should improve from 6 years old. However, the pick of grown that adolescents with 16 years old are susceptible to, influences their body perception and, consequently, their motor performance in tasks requiring strength and coordination, such as “Catching with one hand” and “Throwing at wall target” (Malina et al., 2004). These prompt changes in adolescents’ bodies may interfere negatively in their motor proficiency, before they adjust their body perception and eye-hand coordination, explaining the bad results Aiming and Catching in this age.

At the age of 11, the motor skill Balance is not optimally developed, since it only levels off from 12 years old and on (Malina et al., 2004).

The current study brought evidences that motor performance of the MABC-2 by children between 11 and 16 years old (age band 3) was influenced by sex and age. Generally analysing, boys seem to have better motor performance in Manual Dexterity and Aiming and Catching, and children with 11 and 16 years old tend to have worst results in Aiming and Catching and Balance, respectively, in this motor assessment tool. The major limitation of this study was the sample size (n=231). Future studies should consider analysing the effect of sex and age in each item of the MABC-2, for further consideration into developing a scoring system adapted by gender.

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Chapter IV - Conclusions

Conclusions

The three studies accomplished in the scope of the present dissertation intend to (1) investigate the internal consistency and test–retest reliability of the Movement Assessment Battery for Children–Second Edition Test (MABC-2), age band 3; (2) examine the factorial validity of the MABC-2 AB3 through a confirmatory factor analysis (three-factor model); and (3) investigate the effect of sex and age in motor performance of the components and Total Test Score of MABC-2 (age band 3).

After the investigations that we have carried out, corresponding to the objectives established, we can conclude that, besides the poor internal consistency of Total Test Score and Balance components obtained in the first study, tests' results support the reliability of age band 3 of the Movement Assessment Battery for Children - 2. In addition, the results in repeated measurements over a two weeks' interval are also reliable, which allows its application in Portuguese children between 11-16 years.

Concerning the second study about the factorial validity of the AB3, it also was verified that this age band can be used in clinical research in order to identify motor difficulties, even though it may need adjustments in the number of items. Therefore, after the application of this age band and resulting diagnosis, an appropriate intervention can be and should be carried out, with programs of motor re-education in order to overcome these difficulties and to prevent their prevalence until and beyond adulthood.

Within this framework of thought, the third investigation about the effect of sex and age on motor performance enabled us to conclude that sex has a statistically significant effect on motor performance in the AB3 of MABC-2, namely in Manual Dexterity and Aiming and Catching, with boys outperforming the girls. In turn, age was a statistically significant factor in Aiming and Catching and in Balance, where children with 16 and 11 years old had lower scores, respectively, compared to 12, 13, 14 and 15 years old children.

The major limitation of this study was the small sample size (n=231). It is also important to refer that the score system of MABC-2 does not distinguish sexes.

Since this is the first study with Portuguese children concerning the age band 3, so far, our suggestion for future investigations is to study possible rearrangements in the age ranges. The variation between bands is not the same, since AB1 and AB2 comprise an age range of 4 years (3 to 6 years old and 7 to 10 years old, respectively), but AB3 comprises an age range of 6 years old (11 to 16 years old). This variance may influence results when converting the raw and component scores into standard scores.

On the other hand, since we found differences in motor performance between sexes, it would be interesting to develop new normative data tables that take into account sex, to classify children according to their Total Test Score.

Also, it would be interesting to study, in more detail, the effect of sex and age in each task of the MABC-2 – AB3, and its future implications beyond aging.

Chapter V - Attachments

Attachment I - Authorizations

Exma. Sr.ª Diretora

Do Agrupamento de Escolas ...

Assunto: Pedido de autorização para realização de um estudo no âmbito das Perturbações do Desenvolvimento da Coordenação em jovens nas faixas etárias dos 11 aos 16 anos.

Bárbara Fontes Costa de Freitas Vasconcelos, Licenciada em Ciências do Desporto pela Universidade de Trás-os-Montes e Alto Douro, e Mestranda em Atividade Física Adaptada, na Faculdade de Desporto da Universidade do Porto, sendo orientada pela Professora Doutora Olga Vasconcelos, vem por este meio, pedir a Vossa Excelência, o consentimento para a participação dos alunos do Ensino Básico da vossa instituição, para a avaliação do nível coordenativo motor, através da aplicação da Bateria de Avaliação de Movimento - Versão 2, Banda de idade 3 (Anexo 1): para crianças dos 11 aos 16 anos de idade. Tendo em conta o número de alunos disponíveis para a realização deste estudo, proceder-se-á a uma seleção, de forma a obter semelhante número de discentes do sexo feminino e masculino.

As escolas ou o Agrupamento não terão quaisquer custos monetários pela aplicação desta Bateria nos seus alunos. Serão enviadas as devidas minutas aos Encarregados de Educação, para que concedam a autorização do seu educando na participação deste estudo (Anexo 2). A avaliação será realizada na própria instituição, e o tempo de teste por aluno pode variar entre os 20 - 40 minutos.

O tratamento dos dados será realizado segundos protocolos éticos.

Encontro-me ao seu inteiro dispor, para o esclarecimento de qualquer dúvida, através dos seguintes contactos: telemóvel – 934209360 ou e-mail fontes.b94@gmail.com.

Estou certa que Vossa Excelência contribuirá com o seguimento deste estudo, concedendo a sua autorização.

Porto, Novembro de 2017

A diretora: Com os melhores cumprimentos

_____ _____

Bárbara Vasconcelos

Anexo 1

A Bateria de Avaliação de Movimento - Versão 2 é composta por 3 Bandas, sendo que para esta avaliação só será utilizada a Banda número 3 (11 aos 16 anos). As provas deste método de avaliação estão categorizadas em *Destreza Manual (*3 atividades), *Destreza com bolas* (2 atividades) e *Equilíbrio Estático e Dinâmico* (3 atividades).

Destreza Manual:

- Virar os pinos;
- Montar um triângulo com porcas e parafusos;
- Desenhar um traçado.

Destreza com bolas:

- Lançar a bola com uma mão;
- Atirar a bola para um alvo na parede.

Equilíbrio estático e dinâmico:

- Equilíbrio sobre dois suportes;
- Caminhar em calcanhar-pontas para trás;
- Saltar ao pé coxinho em ziguezague.

Anexo 2

Ex.mo (a) Encarregado de Educação

Assunto: Pedido de autorização para realização de um estudo no âmbito da Coordenação Motora em jovens nas faixas etárias dos 11 aos 16 anos.

Eu, Bárbara Fontes Costa de Freitas Vasconcelos, Licenciada em Ciências do Desporto pela Universidade de Trás-os-Montes e Alto Douro, e Mestranda em Atividade Física Adaptada, na Faculdade de Desporto da Universidade do Porto, sendo orientada pela Professora Doutora Olga Vasconcelos, venho solicitar a colaboração do seu educando na realização de um teste de coordenação motora, sendo a participação do aluno imprescindível para a realização da minha tese de Mestrado intitulada *Perturbação do desenvolvimento da coordenação: validação da banda 3 do MABC-2 para a população portuguesa*.

A atividade realizar-se-á numa data a combinar com o Professor de Educação Física e nas instalações escolares, que o seu educando frequenta.

Todos os dados serão recolhidos e tratados segundo protocolos éticos.

Ser-lhe-á entregue a avaliação geral e individual do seu educando, no caso da sua participação.

Os melhores cumprimentos

____

Bárbara Vasconcelos

- -

Eu ____, Encarregado/a de Educação do aluno/a ____, autorizo / não autorizo, (riscar o que não interessa), a participação do meu educando na avaliação da coordenação motora, a realizar na sua escola.

Encarregado de Educação

____