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Review Article

THE EVALUATION OF MOTOR COMPETENCE IN TYPICALLY DEVELOPING CHILDREN: AN INTEGRATIVE REVIEW

AVALIAÇÃO DA COMPETÊNCIA MOTORA EM CRIANÇAS COM UM DESENVOLVIMENTO NORMAL: REVISÃO INTEGRATIVA

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RESUMO
O desenvolvimento da competência motora é essencial na infância. Estudos anteriores encontraram várias associações positivas da CM com a atividade fisica, aptidão cardiorrespiratória, aptidão física e competência motora percebida, bem como uma associação inversa com o peso. A falta de CM durante a infância pode, portanto, comprometer a futura adopção de estilos de vida ativos e saudáveis. Esta revisão tem como objetivo verificar e examinar os diferentes instrumentos que têm sido utilizados para avaliar CM em crianças com desenvolvimento típico, referindo ainda a fraqueza e os pontos fortes do ponto de vista dos professores de Educação Física. Foi realizada uma pesquisa sistemática em seis bases de dados electrónicas. Foram incluídos estudos transversais, longitudinais e experimentais/quasi-experimentais. Quarenta e dois artigos foram identificados de acordo com os critérios de inclusão. A preferência por medidas quantitativas (21 estudos) foi verificada relativamente a uma abordagem mais qualitativa (13 estudos), embora oito estudos utilizaram ambas as medidas. Além disso, descobrimos que 34 estudos usaram protocolos estandardizados e oito estudos protocolos desenvolvidos pelos autores utilizados. Em geral, os protocolos exibiram alguns pontos fortes, no entanto várias deficiências foram apresentadas que podem limitar a sua aplicação em aulas de educação física, tais como a quantidade excessiva de tempo necessário para avaliar, o grande número de tarefas, os efeitos de teto ou de chão, e o facto de que nem todos as componentes da CM são avaliadas simultaneamente. Diferentes instrumentos e metodologias têm sido utilizadas para avaliar a CM, no entanto não parece existir um instrumento ideal. Por fim, é sugerido um protocolo quantitativo padronizado, com fiabilidade e validade adequada, que pode ser usado por profissionais de educação física.
Palavras-chave: Criança. Adolescentes. Competência Motora. Revisão. Educação Física.

ABSTRACT
The development of motor competence (MC) is essential in childhood. In this respect, previous studies have found several positive associations of the MC with physical activity, cardiorespiratory fitness, physical fitness, and perceived physical competence, as well as an inverse association with weight status. The lack of MC during this stage might, therefore, compromise the future adoption of active and healthier lifestyles. This review aimed at listing and examining the different instruments that have been used to evaluate MC in typically developing children, pointing the weakness and strengths from the perspective of Physical Education (PE) teachers. A systematic search of six electronic databases was conducted. Research designs included cross-sectional, longitudinal or experimental/quasi-experimental. Forty-two articles were identified according to the inclusion criteria. A preference for quantitative measures (21 studies) was verified comparatively to a more qualitative approach (13 studies), although eight studies used both measures. Additionally, we have found that 34 studies used standardized protocol tests and eight studies used protocols developed by the authors. In general the protocols exhibited some strong points, however several presented weaknesses that can limit their application in PE classes, such as the excessive amount of time required, the large number of tasks, the ceiling or floor effects, and the fact that not all MC components are simultaneously evaluated. Different instruments and methodologies have been used to evaluate MC. Finally, a quantitative standardized protocol test is suggested, with proper reliability and validity, which can be used by physical education professionals.
KeyWords: Child. Adolescent. Motor competence. Review. Physical education.

Introduction

In general, Motor Competence (MC) can be described as a person's ability to be proficient on an large array of fine and/or gross motor acts or skills[1]. MC is often used in the literature as a concept that entails a wide variety of terms (i.e., fundamental motor skill or movement, motor proficiency or performance, motor ability, motor coordination, agility, and fine motor proficiency). For the purpose of this study, MC is specifically defined as the mastery of human gross movement, which depends of an optimal development of Fundamental Motor Skills (FMS), comprising locomotor (*e.g.*, leaping, galloping or vertical jump), stability (*e.g.*, dynamic and static balance) and manipulative (*e.g.*, catching, throwing and kicking) skills[2,3]. These skills are essential for future acquisition of specialised motor skills (more complex movements) employed in many organized and non-organized physical activities for children and adolescents[4]. For example, the mastery of specific FMS, like kicking and running, allows a child to successfully play soccer and to be more proficient, achieving higher levels of MC. Moreover, a recent systematic review has shown that MC, in childhood, is closely associated with health-related physical fitness, particularly in the components of cardiorespiratory and musculoskeletal fitness[5].

Motor competence during childhood is influenced by a combination of environmental factors, opportunities and experiences, encouragement, and instruction[2], making schools and Physical Education (PE) classes a place of choice to its development. Increasing Physical Activity (PA) levels does not seem to be enough to promote a gradual and positive development of MC[6] therefore, structured practice opportunities should be offered to children[7,8]. Since children spend much of their days at school, and is assumed that these have the necessary equipment, personnel and facilities[9], PE classes are the ideal environment for promoting suitable MC experiences[10].

For most children, PE is the opportunity they have to engage in structured practice that specifically aims the development of MC, physical fitness, and health-enhancing PA, especially at high-intensity levels[11]. In several countries, PE classes are integrated into the school curriculum from the age of three, with great focus on development of MC[12]. Recent findings have shown that MC can be improved with proper training given by PE teachers or highly trained classroom teachers[13], although the former are recognizably in a unique position to provide and promote PE programs that enhance MC[14].

Given the importance of MC promotion in childhood and the existing possibility of developing it with proper experiences in several contexts (*e.g.*, sports training and PE classes), it becomes vital to be able to systematically evaluate children's MC. These evaluations allow to identify possible motor delays, and to assess the effects of motor experiences, providing adequate information for future interventions[15]. Many different MC assessment instruments have been developed for this purpose; however, their lack of range in terms of assessed competences represents a major challenge for the physical educator. Furthermore, the wide variation of used instruments has hampered the development of longitudinal research and the comparison of results across studies[16].

Motor competence can be assessed through quantitative and qualitative methods[17]. Quantitative methods are generally product-oriented, measuring the performance outcome (*e.g.*, speed, distance) with a more user-friendly approach[17]. Qualitative methods are process-oriented, providing insight into the form or characteristics of the movement and comparing it with a mature model of performance. These methods tend to focus on critical components of the movement and usually require a more advanced knowledge on the movement components. In addition, qualitative approaches can be used to identify developmental changes and children's different levels of performance[18,19]. The data that are generated from these two methods are also different since qualitative methods produce ratio data and qualitative methods tend to be ordinal[20].

Numerous instruments have been developed to assess MC in typical and atypically developing children. In a review, Cools and colleagues[21] looked closely into seven MC assessment instruments, pointing out the weaknesses and strengths of each one of them. However, this review was limited to preschool ages and standardized protocols. Our present work adds to this topic by expanding the age range and the type of instruments used (including non-standardized). The aim of this study was to conduct an integrative review of all different instruments used to assess MC in typically developing children, and to point out the weakness and strengths in respect to the applicability by PE or by elementary classroom teachers.

Methods

The guidelines defined in the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) Statement[22] were used to organize this review.

Eligibility Criteria

Two authors (CL and GA) independently assessed the eligibility of the studies according to the following inclusion criteria: i) articles in which the evaluation of MC was a central goal; ii) studies were the participants age was 6 to 14 years-old, attending primary/elementary school (6–10 years) and middle school (10–14 years); iii) studies were the participants had no health problems or neurodevelopmental disorders (*e.g*., motor disorders, intellectual disability). In some cases, however, research including children with special needs or disabilities was included when the control group included typically developing children; iv) studies where at least two different MC categories of gross motor skills (i.e. stability, locomotor or manipulative, according to original authors) were assessed, either using product (quantitative) or process (qualitative) measures; v) any type of study design (*e.g*., cross-sectional, longitudinal or experimental/quasi-experimental) with the exception of review papers; vi) articles published or accepted for publication in journals with peer review, that is, conference proceedings and abstracts were excluded; and finally vii) studies published in English. It should be stressed that articles with the aim of testing the psychometric characteristics of different instruments or with screening purposes were not considered in this work.

Information Sources and Search

Two strategies were used for collecting information. Firstly, a systematic search of six electronic databases (Science Direct, Web of Knowledge, Pubmed, ERIC, Academic Search and Sport Discus) was conducted, using combinations of the following keywords: ‘child’, ‘adolescent’, ‘assessment’, ‘motor skill performance’, ‘fundamental motor skill’, ‘motor coordination’, and ‘motor competence’ with the *AND or *OR operator according to the database. Secondly, in order to refine the search and reduce the possibility of information loss, a snowballing literature search was used. This strategy consists in identifying additional references in the bibliography of the previously selected studies. The literature search was confined to studies from January 1st, 2000 to October 30th, 2013, since this time frame allows capturing all instruments that have been used more recently.

Study Selection

After the initial search, different stages were followed for selecting the studies for analysis, namely: i) removing all duplicates; ii) screening and removing articles based on the title and abstract. When doubts emerged, or when there was insufficient information the full text was retrieved for further analysis in order to make a proper judgement; iii) screening and removing articles based on full text articles selected on the previous step; iv) screening and removing articles based on full text articles incorporated from the snowballing search. All decisions, in all stages, were made independently by two of the authors (CL and GA). The results were conferred after each stage and the following stage would only initiate when full consensus was reached. Thereby there was a total agreement in all final articles.

Data Collection Process

In this stage, CL organized all the information concerning the participants' characteristics, type and nature of studies, tests and measures of MC and principals findings, and GA checked the information and adjusted the terminology used.

Results

Study Selection

In the first stage, 1606 potentially relevant articles were identified using the keywords combinations. After removing duplicates, 1464 articles remained. After screening the titles and abstracts of potential studies (*n=55*) and with the inclusion of the snowballing literature (*n=12*), 67 full text articles were retrieved. A total of 42 articles met the inclusion criteria and were included in the review for further analysis (Figure 1).

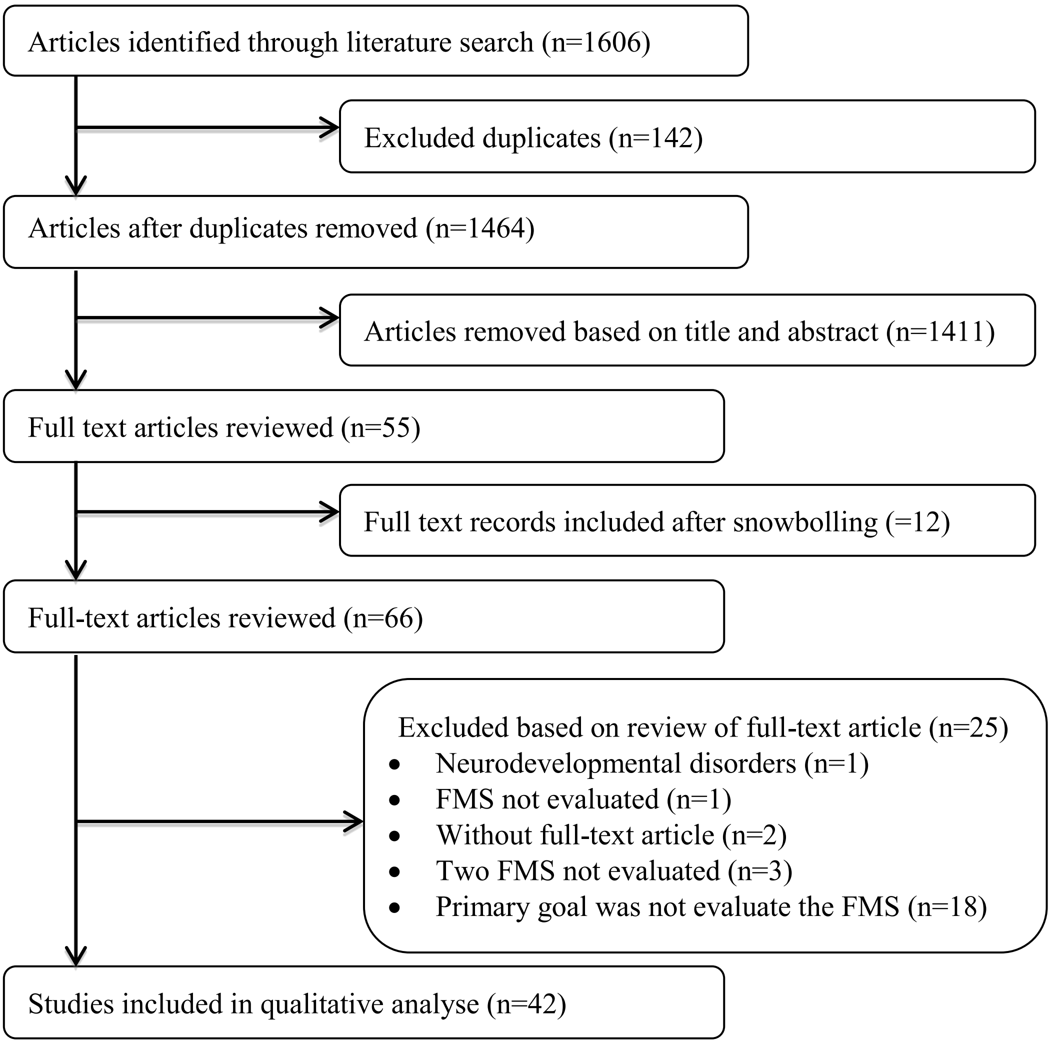

Figure 1. PRISMA flowchart of studies through the review process
Source: Own source.

Studies Characteristics

Europe (*n=23*) and the Oceania (*n=10*) were the continents with more studies included in the systematic review. Studies with 6 to 10 year-olds were the most common (*n=24*); five studies focused on 10 to 14 year-olds, and 13 studies evaluated children with ages between 3 and 14 years. Regarding the study design, eight articles used a longitudinal approach, seven were quasi-experimental, and 27 reported cross-sectional studies. The nature and type of the instruments used for assessing MC in these studies was diverse, however we found six qualitative standardized protocols, 20 quantitative standardized protocols and eight that used both types. Additionally, qualitative and quantitative protocols developed by the authors were used in seven and one studies, respectively (see Table 1).

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Table 1. Summary of included studies.

References (Authors, year, country)	Objective	Type of study	Test and measures of motor development	Nature	Psychometric characteristics	Comments about the test used
Qualitative standardized protocols						
Akbari et al. (2009) Iran	a) Examine the influence of a program in FMS development; b) Compare the effective traditional games with daily activities on FMS	Quasi-experimental	TGMD-2 (locomotor: run, gallop, hop, leap, horizontal jump, slide; object control: strike, dribble, catch, kick, throw, roll)	Qualitative	NR	NR
Bonifacci et al. (2004) Italy	Examine perceptual, visual-motor abilities and intellectual skills in children with low, average and above average motor abilities	Cross-sectional	TGMD (locomotor: run, hop, jump, slide, gallop, skip, leap; object control: dribble, kick, throw, catch, strike)	Qualitative	NR	NR
Karabourniotis et al. (2002) Greece	Investigate the effect of self-testing activities on the development of FMS in children	Quasi-experimental	TGMD (locomotor: run, hop, jump, slide, gallop, skip, leap; object control: dribble, kick, throw, catch, strike)	Qualitative	NR	TGMD is sensitive in the evaluation of FMS of children 3-10 years
Mitchell et al. (2013) New Zealand	Describe the efficacy of one intervention on improving FMS	Quasi-experimental	TGMD (locomotor: run, hop, jump, slide, gallop, skip, leap; object control: dribble, kick, throw, catch, strike)	Qualitative	NR	NR
Pang and Fong (2013) China	Investigated the fundamental motor skill proficiency of 76 female Hong Kong children ages 6–9	Cross-sectional	TGMD-2 (locomotor: run, gallop, hop, leap, horizontal jump, slide; object control: strike, dribble, catch, kick, throw, roll)	Qualitative	NR	Missing studies reporting normative data from different countries
Spessato et al. (2002)	Compared the fundamental motor status of Brazilian boys and girls	Cross-sectional	TGMD-2 (locomotor: run, gallop, hop, leap, horizontal jump, slide; object control: strike, dribble, catch, kick, throw, roll)	Qualitative		Missing studies reporting normative data from different countries
Quantitative standardized protocols						
D'Hondt et al. (2010) Belgium	Investigate differences in MC with different BMI levels in children of different ages	Longitudinal	KTK (dynamic balance, hop, jump and stability)	Quantitative	The reliability and validity was reported by the original authors	NR
D'Hondt et al. (2011) Belgium	Evaluated the short-term effectiveness of a multidisciplinary program in BMI, related measures, and MC	Quasi-experimental	KTK (dynamic balance, hop, jump and stability)	Quantitative	The reliability and validity was reported by the original authors	Limitation of the KTK to assess manipulative skills and/or fine motor skill performance
D'Hondt et al. (2013) Belgium	Investigate the evolution in MC according to children's BMI and identify predicting factors	Longitudinal	KTK (dynamic balance, hop, jump and stability)	Quantitative	Highly reliable - 0.90 and 0.97. Construct validity: **r.**0.60–0.81	NR
Frasen et al. (2012) Belgium	effect of sampling various sports and of spending many or few hours in sports on fitness and MC	Cross-sectional	KTK (dynamic balance, hop, jump and stability)	Quantitative	NR	NR

Table 1 (continued)

Graf (2004) Germany	Examines the association between BMI, motor abilities and leisure habit	Cross-sectional	KTK (dynamic balance, hop, jump and stability)	Quantitative	NR	NR
Hebestreit et al. (2008) Germany	Assess the difference between head circumference and MC in born prematurely and typical children	Cross-sectional	KTK (dynamic balance, hop, jump and stability)	Quantitative	The reliability and validity was reported by the original authors	NR
Hands (2008) Australia	Report the results of a subsample of children participating in a longitudinal study tracking fitness and skill levels of children	Longitudinal (5 years)	MC screening test (SiS): balance, hop; run; catch. Other measures: throw; horizontal jump	Quantitative	Test-retest reliability for each item ranging between .87 to.90. The validity was reported by the original authors	NR
Lopes et al. (2011) Portugal	Relationships among MC, physical fitness and PA in children from 6 to 10 years.	Longitudinal (5 years)	KTK (dynamic balance, hop, jump and stability)	Quantitative	NR	NR
Lopes et al. (2012) Portugal	Examine the influence of MC, physical fitness and PA on the development of subcutaneous adiposity in children	Longitudinal (5 years)	KTK (dynamic balance, hop, jump and stability)	Quantitative	The reliability and validity was reported by the original authors	
Lopes et al. (2012) Portugal	Analyze the association between MC and BMI	Cross-sectional	KTK (dynamic balance, hop, jump and stability)	Quantitative	The reliability and validity was reported by the original authors	A more comprehensive MC assessment may provide a clearer picture
Lopes et al. (2013) Portugal	Evaluate the relationship between MC and academic achievement in children aged 9–12 years	Cross-sectional	KTK (dynamic balance, hop, jump and stability)	Quantitative	The reliability and validity was reported by the original authors	NR
Martins et al. (2010) Portugal	Investigate the association between PA, 1-mile run/walk, MC and BMI	Longitudinal (5 years)	KTK (dynamic balance, hop, jump and stability)	Quantitative	The reliability and validity was reported by the original authors	NR
Nourbakhsh (2006) Iran	Study the perceptual-motor abilities of fifth grade elementary school female pupils.	Cross-sectional	BOTMP (Fine Manual Control, Manual Coordination, Body Coordination, Strength & Agility)	Quantitative	Reliability = 0.99 Validity = 0.88	NR
Ratzon et al. (2000) Israel	Examine the effects of diabetes during pregnancy on the long-term MC and to study correlations between glycemic control and MC	Cross-sectional	BOTMP (Fine Manual Control, Manual Coordination, Body Coordination, Strength & Agility)	Quantitative	NR	NR

Table 1 (continued)

Vandendriessche et al. (2011) Belgium	Examine variance in MC by morphological and fitness characteristics	Cross-sectional	KTK (dynamic balance, hop, jump and stability)	Quantitative	NR	NR
Vandendriessche et al. (2012) Belgium	Examined the relationship between SES, sport participation, morphology, fitness and MC	Cross-sectional	KTK (dynamic balance, hop, jump and stability)	Quantitative	The reliability and validity was reported by other authors	NR
Vandorpe et al. (2011) Belgium	a) Produce current gender- and age-specific reference values for MC of Flemish children b) Compare the raw scores and MQ values with the norms of the original sample	Longitudinal	KTK (dynamic balance, hop, jump and stability)	Quantitative	NR	NR
Vandorpe et al. (2012) Belgium	Examined the relationship between MC and organized sports participation over time	Longitudinal	KTK (dynamic balance, hop, jump and stability)	Quantitative	The reliability and validity was reported by the original authors	NR
Wrotniak et al. (2006) United States	Examine the relationship between motor proficiency and PA in 8- to 10-year-old children	Cross-sectional	BOTMP short form (Fine Manual Control, Manual Coordination, Body Coordination, Strength & Agility)	Quantitative	The reliability and validity was reported by the original authors	The potential for accurately detecting specific aspects or components of motor skill difficulties and determining where improvement needs to occur is limited
Wrotnick et al. (2009) United States	Examine the relations of motor abilities among siblings using a comprehensive measure of motor proficiency	Cross-sectional	BOTMP short form (Fine Manual Control, Manual Coordination, Body Coordination, Strength & Agility)	Quantitative	Reliability coefficient range from .84 to .87	Comprehensive measure of MC. Limitations: overall measures of MC were the sum of 14 items; this test does not provide specific information on procedural skills
Quantitative and qualitative standardized protocols						
Ekornås et al. (2010) Norway	Compare MC and self-perceived competence between children with and without anxiety disorders	Cross-sectional	MABC	Quantitative and qualitative	NR	NR
Gabbard et al.(2012) United States	Examine the association between children's ability to mentally represent action and general MC	Cross-sectional	MABC -2 - manual dexterity, aiming and catching, and balance.	Quantitative and qualitative	The reliability and validity was reported by other authors	NR

Table 1 (continued)

Haga (2008) Norway	Test physical fitness in children with movement difficulties and a comparison group without movement difficulties	Cross-sectional	MABC PF: jumping; throwing; climbing; running	Quantitative and qualitative	The MABC has a inter-rater reliability of 0.70. PF - The construct validity - 0.93 (girls); 0.89 (boys).	PF test - activities that are naturally included in everyday play activities. The test situation is characterised by a game-style atmosphere that may facilitate children's motivation to participate and perform
Hands et al. (2009) Australia	Examine the interrelationships among PA, physical fitness and MC and compare with high and low levels participants.	Cross-sectional	McCarron Assessment of Neuromuscular Development (fine motor and gross motor tasks - Finger–Nose–Finger, Jumping for Distance, Heel– Toe–Walk, and Standing on One Foot)	Quantitative and qualitative	The reliability and validity was reported by the original authors	NR
Livesey et al. (2011) Australia	Examined the link between motor performance and peer relations	Cross-sectional	MABC-2 - manual dexterity, aiming and catching, and balance.	Quantitative and qualitative	NR	Does not distinguish well the highest of the typical performances
Rigoli et al. (2012) Australia	Examine whether the association between MC and emotional functioning is mediated by self-perceptions	Cross-sectional	MABC - manual dexterity, aiming and catching, and balance.	Quantitative and qualitative	Reliability coefficient of 0.80 for total test score and coefficients ranging from 0.73 to 0.84 for the individual component scores	NR
Schurink et al. (2012) Netherlands	Examine whether the association between MC and emotional functioning is mediated by self-perceptions	Cross-sectional	MABC - manual dexterity, aiming and catching, and balance.	Quantitative and qualitative	The reliability and validity was reported by other authors	More variety in motor skill performance are needed
Zhu et al. (2011) Taiwan	Investigate the associations between obesity and MC in children with and without DCD	Cross-sectional	MABC - manual dexterity, aiming and catching, and balance.	Quantitative and qualitative	The reliability and validity was reported by the original authors	NR
Non standardized qualitative protocols						
Beurden et al. (2002) Australia	Describe the proportion of children from 18 schools who achieved MC mastery.	Cross-sectional	Stability: static balance, vertical jump; locomotor: sprint run, side gallop, hop; object control: kick, catch, overhand throw	Qualitative	The reliability and validity was reported by the original authors	NR
Boyle-Holmes et al. (2010) United States	Describes a comparative evaluation of Michigan's Exemplary Physical Education Curriculum in elementary schools	Quasi-experimental	Locomotor (leap), posture (lift and carry), and manipulative skills (forehand strike)	Qualitative	No psychometric properties	Vigilance and attention to detail over the entire test; fatigue may have affected scoring

Table 1 (continued)

Foweather et al. (2008) England	Examine the efficacy of an after-school multiskill club designed to increase FMS proficiency	Quasi-experimental	Stability: vertical jump, static balance; locomotor: sprint run, leap; Object control: kick, catch, throw	Qualitative	The reliability and validity was reported by the original authors	NR
Hume et al. (2008) Australia	Describe the relationship (a) among MC, PA, and BMI, and (b) among MC, PA and gender	Cross-sectional	Locomotor: run, vertical jump, dodge; Object control: overhand throw, two-handed strike, kick	Qualitative	NR	Strength: inclusion of five FMS commonly used in children's games, sports, and physical activities
Okely et al. (2001) Australia	Examine the relationship between cardiorespiratory endurance and FMS proficiency	Cross-sectional	Six-item Fundamental Movement Skills Battery (Locomotor (run and jump) and object-control (catch, throw, kick, and strike) skills)	Qualitative	The reliability and validity was reported by the original authors	NR
Okely et al. (2004) Australia	Examine associations of FMS with measures of body composition among children and adolescents	Cross-sectional	Six-item Fundamental Movement Skills Battery (Locomotor (run and jump) and object-control (catch, throw, kick, and strike) skills)	Qualitative	Other authors have established the reliability (.75) and validity (content validity was assessed by a panel of 52 FMS experts)	Process-oriented ("expert" performer) assessments of FMS were used, because they more accurately identify specific topographical aspects of the movement
Okely and Booth (2004) Australia	Examine the prevalence and socio-demographic distribution of skill mastery and near-mastery for boys and girls in Years 1 through 3	Cross-sectional	Six-item FMS - hop, skip, side gallop, over arm throw, kick (stationary ball), leap, two- hand strike, dodge, sprint run, catch, static balance and vertical jump.	Qualitative	The reliability and validity was reported by the original authors	Instrument are more accurately in identify specific topographical aspects of the movement
Non standardized quantitative protocols						
Kalaja et al. (2011) Finland	Investigate whether students' MC and self-reported PA increase through specific intervention	Quasi-experimental	Stability: flamingo standing test, rolling test, rope jumping test; locomotor: shuttle run test, leaping test; object control: accuracy throwing test, figure-8 dribbling test	Quantitative	The reliability was reported by other authors and showed moderate to good reliabilities (.46 - .95)	Not all of the tests have been proven as reliable in previous studies

BMI – Body Mass Index; BOTMP - Bruininks-Oseretsky Test of Motor Proficiency; DCD – Developmental Coordination Disorder; FMS – Fundamental Motor Skills; KTK - Körperkoordinationstest für Kinder; Movement Assessment Battery for Children – MABC; MC – Motor Competence; NR – Not Reported; PA – Physical Activity; PE – Physical Education; PF - Physical Fitness; SiS – Step in Step; TGMD - Test of Gross Motor Development

Source: Own source.

Measurement of MC

As mentioned earlier, the nature of the measure used to evaluate MC proficiency, as well as the tests or protocols used, differed among the studies.

Qualitative standardized protocols

With regard to qualitative instruments, the Test of Gross Motor Development (TGMD - 1st or 2nd edition)[23,24] was the only standardized protocol found in the literature, having been used in 6 studies[25-30]. The main goal of the TGMD is to identify children, in the age range from 3 to 10 years, which are significantly behind their peers in gross motor performance. This battery includes locomotor and manipulative skills and takes about 15 to 20 minutes per participant. Comparing the two editions of this protocol, it was found that the revised edition has several improvements concerning reliability (minimum of .85) and validity aspects. In addition, a new manipulative skill (underhand roll) was added and a locomotor skill (skip) was excluded. Age norms for both subtests are presented divided into half-year increments. The discrimination of skill level (below or above), the good reliability and validity presented, and the assessment of manipulative skills are the strong points of this battery. **However, stability skills are not evaluated, the results tend to have ceiling or floor effects, and** the existence of cultural biases in some skills are considered weaknesses of this test battery, **since this test was normed on a sample of 1,208 north american children**[21]. Moreover, for PE professionals it is too time consuming to assess all twelve tasks of the TGMD in a PE class.

Quantitative standardized protocols

The Bruininks-Oseretsky Test of Motor Proficiency (BOTMP)[31] or its short form was used in four studies[32-35]. The BOTMP and the BOT-2[36] evaluate fine and gross movement skill development in children and adolescents and are used for screening, evaluation, research, and program planning. In addition, they support diagnoses of motor impairments in individuals with ages between 4 to 14.5 years for the BOTMP, and 4 to 21 years for the BOT-2 (1520 north American Children)[36,37]. Both instruments exhibit good validity and reliability, and both assess four major components: fine manual control, manual coordination, body coordination, and strength and agility. BOTMP and BOT-2 have 46 and 58 items, respectively. A short form of BOT-2, consisting of 14 items, was developed for a fast screening of overall motor proficiency. This short form presents a high correlation (.80) with BOT-2 and takes about 15 to 20 minutes to apply. The evaluation with the entire BOT-2 takes 45 to 60 minutes. The strengths pointed by the authors include: the possibility of using the short form for screening for possible motor coordination problems, the existence of separated gross and fine motor composite scores that allow comparisons, and the fact that this instrument covers a wide age range. However, there are also some weaknesses. As examples, age equivalent scores are based on extrapolations, scoring can be time-consuming, and several sessions with the same participant may be required due to participant's fatigue (for more information see[37,38]. Another important disadvantage is that the goal of the instrument is to identify possible motor coordination problems and not to assess MC specifically, so it is mostly used for clinical assessment and not as an ideal instrument for PE professionals.

The Stay in Step (SiS)[39] was solely used in one study[40] and it is a validated gross motor screening test to identify children with poor motor development. This test has a good test-retest reliability for each item, ranging between r= .87 to r= .90, and can only be used with 5 to 7 year-olds. The SiS consists in the evaluation of four motor skills including stability, manipulative, locomotor and velocity. The narrow age range makes this a limited instrument to apply in the school context.

The Körperkoordinationstest für Kinder (KTK)[41] was the most used protocol to assess MC, with 15 studies. This test uses a quantitative method that refers to a norm and assesses gross body control through locomotor and stability outcomes. It can be used with typically developed children as well as with children with brain damage, behavioral problems or learning difficulties[19,21]. The KTK protocol presents four motor tests with construct and content validity[42]. Additionally, it presents good intra-rater reliability (≥.80) and test-retest reliability (>.85), and it can be used in children with ages between 5 and 14 years[21]. Few and easy motor tasks, with a good reliability, and a fast assessment procedure, are considered major strengths of this protocol. However, some weaknesses can be mentioned, as the fact that this instrument only uses four motor tests to assess MC, it does not evaluate manipulative skills, and it uses old normative data (1128 German children). In fact, the absence of a manipulative component assessment represents a large fragility, since these skills are believed to be the best indicators to explain the association between MC and cardiovascular fitness, across childhood and into adolescence[43,44].

Quantitative and qualitative standardized protocols

Eight studies used a mixed quantitative and qualitative approach. The McCarron Assessment of Neuromuscular Development (MAND)[45] was used in one study[46], and the Movement Assessment Battery for Children (MABC) 1st edition[47] or 2nd edition[47,48] was employed in five[49-53] and two studies[54,55], respectively.

The McCarron Assessment of Neuromuscular Development[56] was developed as a tool for health professionals, to screen and evaluate 3.5 to 18 year-old children. The MAND is an individually administered, norm-referenced assessment tool comprising quantitative and qualitative measures of five fine motor and five gross motor skills. Raw scores for each item are converted to scaled scores based on the participant's age. A measure of overall motor skills (Neuromuscular Developmental Index) is given through the sum of the ten-scaled scores. The MAND presents a good reliability ranging between .67 and .98[56], and has showed good concurrent validity[57]. It has many advantages, for example, it has a large age range of application and it includes both qualitative and quantitative components. However, the absence of manipulative skills, an important MC component, and the lack of similarity between most of the tests and the activities or sports that children are familiar with, can be seen as disadvantages.

The Movement Assessment Battery for Children (M-ABC) 1st edition[47] permits to identify delays in the development of MC in 4 to 12 year-old children, divided by four age bands. This test is composed by eight motor tasks per age band that evaluate three movement categories: fine motor skills (manual dexterity), manipulative skills (aiming and catching), and stability (static and dynamic). The skills are evaluated in a 6-point rating Likert scale, where 5 is the weakest and 0 the best performance. The M-ABC 2st edition[48] presents the same objective with also eight motor tasks (same categories), however this edition allows the assessment of 3 to 16 year-old children divided by three age bands. The total test score is given by the sum of the eight item standard scores (range 8–152). Both editions show good validity and sufficient reliability[47,48,57,58] and take about 20 to 30 minutes per participant. One of the major advantages is the simple test administration that allows the collection of a large sample in a short period of time. On the other hand, the ratio between the number of tasks and the time required is inadequate[38], and the lack of assessment of locomotor skills is also a disadvantage.

Non-standardized qualitative protocols

Qualitative protocols specifically developed for the study using a process-based approach with stability, locomotor and manipulative skills were used in seven studies[59-65]. These protocols have similarities, in the sense that all decomposed each movement skill in various components and scored each of the components as present or absent in four or five trials. For all the mentioned studies, the components of each movement skill protocol were established based on the Get Skilled: Get Active program and FMS assessment[66]. Three of the studies[61-64] did not evaluate any stability skills, two used solely one stability task, and only two studies used two tasks (static balance, vertical jump). The tasks used for the assessment of locomotor (*e.g.,* sprint run, hop, side gallop, skip and dodge) and manipulative skills (kick, catch, overhand throw and forehand strike) were identical in all 7 studies; however, the number of tasks used differed among the studies. All locomotor and manipulative tasks used in these studies, with the exception of run and leap, presented a good reliability (≥.70) and the content validity was established by 52 experts[64,67]. The use of several locomotor and manipulative skills that are similar to activities or sports that students are familiar with[64], is considered the greatest advantage of these protocols. However, the time-consuming data collection, the need of expert evaluators, the lack of age referenced standardization, and the undervaluation of the stability skills represent important weaknesses for the use of these protocols in a school context.

Non-standardized quantitative protocols

Only one study used a specifically developed quantitative protocol[68]. Here, several tasks were used to assess all components of MC. These tasks showed moderate to high reliabilities. The use of at least two tasks to evaluate each MC component and the short time required for data collection are two of the strengths of this protocol. The lack of tasks related to some MC components (*e.g.*, catch), and the lack of similarity between some of the tasks (*e.g.*, the rolling test) and familiar sport activities, can be considered as limitations of this protocol.

Discussion

The main goal of this systematic review was to collect and synthesize existing protocols developed to evaluate MC in typically developing children, which can be used by PE professionals. Of the 42 eligible studies, 13 used qualitative protocols, 21 preferred a quantitative approach and 8 studies used protocols including both qualitative and quantitative procedures, so a preference of quantitative (product-oriented) methodologies over qualitative (process-oriented) methodologies was found. It is interesting to note that, comparative to other continents, the use of quantitative methods are preferred in Europe. Both methodologies have advantages and disadvantages. The quantitative instruments found in the review process have several weaknesses concerning their implementation by PE professionals, namely: i) there is a limited range of motor tasks; ii) they do not evaluate all MC components; ii) they screen motor coordination problems instead of MC; iii) limited age range; iv) lack of similarity between some of the tasks and principal sport activities.

Qualitative methods allow to distinguish more accurately between different stages of specific skill performance and, therefore, provide sensitive information that grants the teacher with the knowledge of the specific components of a skill a student should practice[15]. This allows for a better organization of PE classes. However, the qualitative tests also have some important disadvantages concerning their use by PE professionals. Some examples are the needed expertise and training of the evaluator, the time necessary to assess each participant, usually in the form of video recording observation, and the obligation of parental consent for video footage. Although a trained PE teacher is expected to be able to administer the assessment without the need of video recording, in many countries primary school teachers are responsible for PE administration and they do not have the necessary knowledge or expertise to assess movement skills[69,70]. Another disadvantage is the fact that an ideal performance pattern may not exist. Traditionally, the mastering of specific motor tasks (expertise) has been described as the capacity to consistently replicate a specific movement pattern, increasing the automaticity of movement[71] and eliminating movement patterns that are considered detrimental for the correct movement. However, it is known that even elite athletes are unable to reproduce invariant movement patterns, despite years of practice[72], showing that the exact repetition of the same movement is impossible to achieve.

For the reasons stated above, knowing that qualitative and quantitative measures are correlated (low to moderate)[18,73-75], and that quantitative methods generally ensure a high level of reliability over time and between evaluators[76], it is natural that quantitative tests would be a good option for assessment in PE classes or in other sport contexts.

Our results also show that 34 studies used standardized protocol tests (KTK was the most used), while in eight studies the authors developed the protocols. The use of standardized protocols has several advantages, such as the guarantee of previously tested reliability and validity[77]. The lack of statistically robust psychometric properties (reliability, validity) and the impossibility of comparing the results to normative data are pointed as the major weaknesses of using specifically developed protocols. Despite the potentialities of using standardized tests, it is important to mention some disadvantages that might limit the use of the protocols we have found, from the point of view an of school implementation: i) the acquisition cost of standardized protocols tests; ii) the need to evaluate the three components of MC, which are not included in all standardized protocols tests; iii) time constraints, since standardized protocols usually have several tests and might be time consuming.

The greatest strength of our study is the correct application of the different steps suggested by the PRISMA statement and the determination of the risk of bias for the eligible studies. However, some limitations can be mentioned such as the date range for the eligible studies, and the fact that only English language studies were used.

The studies analysed in this review used different instruments for assessing MC. All the found protocols exhibited particular weaknesses and strengths, and were targeted to specific goals and populations. Considering that a practical and easy to administer instrument that encompasses the full MC spectrum does not seem to exist, the need for a quantitative standardized protocol test using the three MC components is warranted for both PE and research settings.

Other research studies[3,78], published after the data range considered in this review, have proposed new test batteries to assess MC. The study by Sigmundsson and colleagues[78] is simple to administer but still does not consider the three components of MC (it tests two fine and two gross motor tasks). On the other hand, the study by Luz and colleagues[3] proposes six quantitative motor tasks to assess MC, two for each motor category (i.e. locomotor, stability and object control). The authors found that MC could be objectively measured with a good structural and measurement reliability. The stability category was assessed by the shifting platforms (moving sideways for 20s using two wooden platforms) and jumping laterally (jumping sideways with two feet together over a wooden beam as fast as possible for 15s) tests. The locomotor category was measured using Shuttle Run (running at maximal speed 4x10 meters) and standing long jump (jumping with both feet simultaneously as far as possible) tests. Finally, the manipulative category was evaluated through a throwing velocity test (throwing a baseball at a maximum speed against a wall using an overarm action) and a kicking velocity test (kicking a soccer ball nº4 at a maximum speed against a wall using a kicking action). The authors also found that these three categories are closely related to each other. This is an important finding especially for physical educations teachers who have to frequently assess their students.

Conclusions

In this study, a systematic review of the presented methodologies to evaluate MC in typically healthy children was conducted. MC has been assessed through qualitative or quantitative methodological approaches using several standardized protocol tests, or protocols have been developed according to the objectives of the evaluation. Given the existence of positive associations between MC and health benefits[79] and the important role that PE plays in the development of MC[13], it would be of great interest to create a standardized protocol test to evaluate MC in its full spectrum. Such instrument does not seem to exist but we believe that it would be of paramount importance for both PE and research related settings.

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