



Review

A hitchhiker's guide to assessing young people's motor competence: Deciding what method to use



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ABSTRACT

Objectives: To offer a user's guide to select appropriate measures of motor competence for children and adolescents.

Design: Expert consensus among a working group of the International Motor Development Research Consortium (I-MDRC).

Methods: The guide provides information on objective (motion devices and direct observation) and subjective (self-reports and proxy reports) methods for assessing motor competence among children and adolescents. Key characteristics (age group, sample size, delivery mode, assessment time, data output, data processing) as well as limitations and practical considerations (e.g., cost, sources of error) with regard to each method are included in this paper. We do not recommend specific instruments, rather a guide to assist researchers and practitioners interested in assessing children's motor competence.

Results: A decision flow chart was developed to support practitioners and researchers in selecting appropriate methods for measuring motor competence in young people. Real-life scenarios are presented to illustrate the use of different methods in research and practice.

Conclusions: Policy makers, practitioners and researchers should consider the strengths and limitations of each method when measuring motor competence in children and adolescents. This will allow them to choose the most appropriate instrument(s) that meets their needs.

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1. Introduction

Motor development plays an important role in young people's general health and growth and is also related to cognitive and social aspects of development.¹ A concept within the context of motor development is motor competence, which reflects the degree of proficiency in performing a wide array of motor skills as well as the underlying processes such as coordination, control and quality of movement.^{2,3} Different terminologies (e.g., fundamental motor/movement skills, motor ability, motor proficiency, motor performance, motor coordination) have been used in the literature, that fall under the umbrella of motor competence.⁴ Reviews have shown that motor competence is associated with positive health outcomes including physical activity participation, perceived phys-

ical competence, physical fitness and weight status.^{4–6} Moreover, the associations between motor competence and the aforementioned health outcomes are reciprocal and change over time.^{4,5} As noted by Robinson et al.⁴ and Logan et al.,⁷ research on motor competence has increased across the globe over the past decade, which has helped to better understand the role of motor competence in health behaviours (e.g., physical activity) and outcomes (e.g., weight status). In light of these health benefits, it is important to consider the instruments used to assess and monitor motor competence in young people.

A multitude of assessment methods exist to evaluate children and adolescents' motor competence in both educational and non-educational settings.^{8,9} The accuracy of these instruments is critical to accommodate different purposes including: (1) assessment of motor competence levels in individuals; (2) screening for motor delay; (3) talent identification in sports; (4) design and evaluation of physical activity/education and intervention/training programs; (5) injury prevention and rehabilitation; (6) examination of links

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between motor competence and health outcomes/trajectories; and (7) monitoring of population trends.^{10–12} The choice of instruments depends on the purpose of assessment, administrative properties (e.g., user friendliness, required time, cost), and target group (e.g., age, disability). The psychometric quality of the assessment instrument (e.g., test-retest reliability, construct validity) also needs to be considered on a case by case basis, although it is beyond the scope of this paper to provide this information. There are existing reviews that discuss the characteristics of specific assessments of motor competence used among children and adolescents.^{8,9,13} However, previous reviews have only focused on a few instruments and tend to discuss only one method (e.g., field-based tests) of assessing motor competence in young people. Furthermore, there is no clear guide as to how to decide which instrument to use in specific circumstances. As new instruments are continually being developed, it is challenging to decide which methods are most appropriate within a certain context. Similar to previous user guides for assessing physical activity¹¹ and sedentary behaviour,¹² the purpose of this paper is to provide a guide to support researchers and practitioners in selecting appropriate methods to assess motor competence in children and adolescents.

2. Methods for assessing motor competence

In July 2015, members of the International Motor Development Research Consortium (I-MDRC) met to identify and debate relevant topics related to motor development. A working group was created to identify and review commonly used methods for assessing motor competence in children and adolescents. For each method, we discussed key characteristics, limitations and practical considerations to guide the decision making process for researchers, practitioners and policy makers interested in measuring motor competence in young people.

Motor competence can be evaluated using a variety of test instruments, which can be categorised into objective and subjective methods. Fig. 1 provides an overview of these methods of assessment, and the potential cost and sample size related to each method. Each method/instrument has key features, limitations and practical aspects that are important for researchers and practitioners to consider when deciding which method to use (see Tables 1 and 2). It should be noted that a list of specific instruments are not provided for these assessment methods, rather some examples of widely used assessment tools are mentioned.

2.1. Objective methods

Objective methods include motion devices and observation. These methods capture an individual's movement behaviour directly with minimal bias and measurement error to provide a reasonably accurate estimate of motor competence.

Motion devices. Instrumented movement analysis –through the use of specialised hardware (e.g., high-speed cameras, motion sensors, force plate) and software– allows quantitative assessment of human movement (kinematics, kinetics and neuromuscular activity), with an emphasis on the characterization of motor skills through biomechanical measures; specific ranges of those quantities reflect the actual levels of competence for a given motor skill. Quantitative movement analyses are based on measurements of kinematic (linear and angular displacement, velocity, acceleration), kinetic (force, moment, power) and electromyographic (electrical activity of the muscles) variables that determine performance.¹⁴ These measures are typically constrained to laboratory settings and primarily used to assess motor competence and development in individuals.^{15,16}

One goal in research and practice is to describe the qualitative changes which occur in a child's movement, as he/she acquires a motor skill.¹⁷ For example, Getchell and Robertson¹⁸ used a force plate to record vertical ground reaction force during hopping and assessed the hop movement using Robertson and Halverson's developmental sequences. The authors found that stiffness of the support leg varies between different developmental sequences for the leg action during hopping, identifying body stiffness as a quantitative parameter related to qualitative changes in children's skill performance.¹⁸ Similarly, Robertson and Konczak¹⁹ examined the changing relationship between qualitative movement descriptions and the ball velocities in overarm throwing in children at ages 6, 7, 8, and 13 years. Skill performance was assessed using Robertson and Halverson's developmental sequences for upper arm, forearm, trunk, and leg action, as well as stride length.²⁰

Developmental transitions may therefore be studied by selecting (collective) biomechanical variables that present a behaviour, which is related to a motor developmental stage. In their study, Whittall and Getchell²¹ compared walking and running in newly running infants by observing several variables likely to be collective including relative stance, estimated pathway of center of mass and segmental/joint action. The authors placed a set of reflective markers on relevant body segments and used a high-speed video camera to record the infants' movement.

Lab-based assessments allow for highly accurate quantitative measures but are not appropriate for assessing large numbers

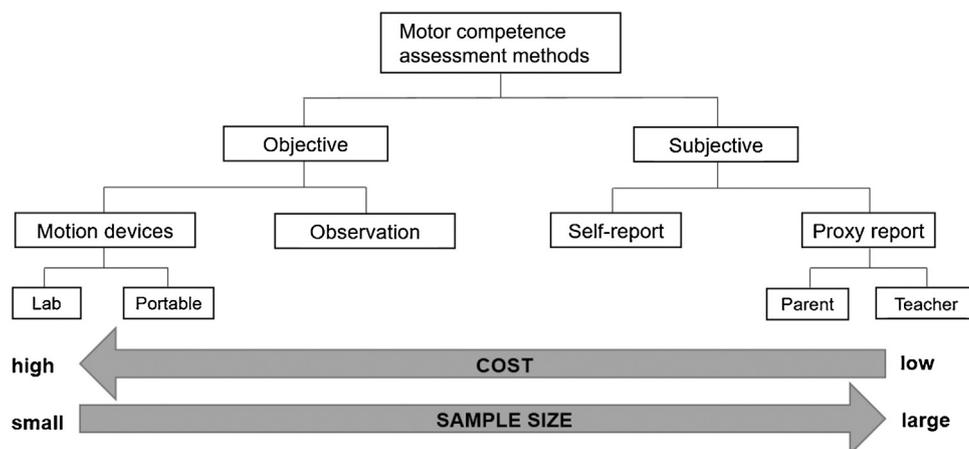


Fig. 1. Flow chart for selecting methods to assess motor competence among young people.

Table 1
Key attributes of common methods for assessing motor competence in young people.

Characteristics	Objective methods		Subjective methods			
	Motion devices		Observation	Self-report	Proxy report	
	Lab	Portable			Parent	Teacher
Population age	>2 years	>2 years	0–21 years	≥4 years	4–15 years	5–18 years
Sample size	Small	Small to large	Small to large	Small to large	Small to large	Small to large
Method	Prospective/current Child free to move. Acquisition volume limited to the camera view. Both in field or lab-based. Most of the FMS allowed	Prospective/current Motion sensors worn at different anatomical levels or at least one monitor on a belt at pelvis level. All FMS allowed.	Prospective/current Naked eye or video/film observation (paper or electronic recording form).	Retrospective Pictorial form (4–8 years)/written form (>8 years).	Retrospective Written	Retrospective Written
Assessment time	One-off	One-off	One-off	One-off	One-off	One-off
Data output	Centre of mass kinematics, joint kinematics. Time and frequency parameters are estimated. Joint kinetics measured using force plates or estimated using inverse dynamics and musculoskeletal models. They allow assessing one skill at a time. Process-oriented assessment.	Body segment acceleration, angular velocity and orientation are available in real time. Time and frequency parameters are estimated. Selected biomechanical parameters can be obtained. They allow assessing one skill at a time. Process-oriented assessment.	Counts of successful movements/trials, distance, time upon completion (product scores). Counts of quality criteria demonstrated during movements/trials (process scores). Method consists of a set of motor skill items, and is product- and/or process-oriented.	Physical self-perception; subdomains (e.g., active play [4–8 years], sports competence [>8 years]). Specific motor skill items	Probable DCD ^a Specific motor skill items	Probable DCD ^a Specific motor skill items
Data entry and reduction	High Complex set-up. Algorithms needed to process data, reduce data volume and extract meaningful parameters	Medium to Low Not so complex set-up. Algorithms needed to process data and extract meaningful parameters. Potential implementation on smartphones could support real-time assessment.	Low – manual data entry. Data reduction is generally conducted using following steps: (1) Raw item scores are changed into standard item scores using an ordinal scale (e.g., 0–2; 0–10). (2) Item scores are summed to total test (and subtest) scores. (3) Total test (and subtest) scores are transformed into standard scores, percentiles and classifications using reference norms.	Low – manual data entry	Low – manual data entry	Low – manual data entry

^a DCD: Developmental Coordination Disorder.

Table 2
Limitations and practical considerations associated with common methods for assessing motor competence in young people.

Characteristics	Objective methods			Subjective methods		
	Motion devices		Observation	Self-report	Proxy report	
	Lab	Portable			Parent	Teacher
Cost	High	Medium to high	Medium to high	Low	Low	Low
Sources of error and limitations on dimensions of motor competence captured	No standard protocol for data management or reduction. Data collection method can be considered invasive. Environmental constraints. Results could be affected by errors in marker positioning, artefacts and post-processing issues.	No standard protocol for data management or reduction. Data collection method is not invasive. No environmental constraints. Results could be affected by bad sensor positioning, artefacts and post-processing.	Captures specific dimensions of motor competence. Data collection method can be considered invasive. Environmental constraints – smooth/even surface, minimal space required. Require a certain amount of assessment training. Unclear/subjective scoring criteria (e.g., process scores)	Overestimation of own competence to a large (4–8 years) or small extent (>8 years).	Susceptibility to socially desirable responses. Literacy levels can vary.	Potential poor teacher memory, judgement or motivation
Additional considerations	Normative data is required to compare motion signals and estimated, performance parameters. The detection of motor impairments and gait strategies is allowed. The method is time-consuming. The instruments are expensive.	Automatic scoring criteria can be obtained without requiring expert raters.	Some methods focus on specific age groups. Some methods are specifically designed to detect motor problems. Some methods are time consuming. Some methods require specific/expensive equipment. Some methods require sufficient training.			
Tips to improve data quality	Pay attention to marker displacement, skin artefacts and calibration issues	Follow guidelines for sensor sealing and placement	Combine different methods for a more comprehensive assessment of motor competence.			

of individuals because testing is time consuming and expensive, and requires access to specialised equipment, dedicated laboratory set-up and significant data post-processing.²² In addition to the administrative aspects, it is important to consider the validity and reliability of the lab-based assessment, which requires the adoption of valid motion analysis protocols and the use of adequate number of trial repetitions.²³

Advances in quantitative measurement of human movement analysis in different contexts have led to the development of inertial measurement units (IMUs) as an alternative wearable tool for field-based assessment of motor competence, which helps overcome some of the limitations of laboratory-based methods. IMUs have gained popularity in the field of human motion analysis due to their ease of use, robust design, and small dimensions.^{24,25} These devices normally include accelerometers and gyroscopes, which measure three-dimensional accelerations and angular velocities, respectively. IMUs potentially allow measurement of children's movement-related quantities in real-life environments (i.e. schools, playgrounds). The feasibility of using such an instrument to quantify developmental differences has been demonstrated in both locomotor and object control skills patterns of young children.^{26,27}

Observation. Observation methods involve an individual systematically viewing and recording a participant's performance in a set of motor skill tasks; the recording can be conducted live or via video. Live coding is more time efficient than video coding, although it can be difficult to assess some skills (e.g., object control skills) live, especially when evaluating different components of skill performance.²⁸ Observation methods generally follow a standardised procedure in terms of guidelines and conditions, and can be applied in clinical, educational and home settings. These assessments typically comprise product-oriented and process-oriented measures. Product-oriented assessments, such as the Bruininks Oseretsky Test of Motor Proficiency (BOT), the Körperkoordinationstest für Kinder (KTK) and the Motorische Basiskompetenzen test (MOBAK),^{29–31} measure the outcome of movement (e.g., ball speed of kick).⁸ Process-oriented assessments, such as the Test of Gross Motor Development (TGMD)^{32,33} and the Get Skilled Get Active assessment (GSGA)³⁴, focus on the quality of movement (e.g., elongated step before a ball kick) and provide specific information on children's motor competence, which can be useful for the design of interventions. Many observation methods can be considered static, as motor skills are performed following an iterative sequence of instruction and performance. However, circuit-based assessments have recently emerged as a dynamic method to assess motor competence using a sequence of different motor tasks, which children have to complete without interruption. Examples of circuit-based assessments are the Canadian Agility and Movement Skill Assessment (CAMSA),³⁵ the Athletic Skill Track (AST),³⁶ and the Zurich Neuromotor Test.³⁷

A limitation of the observation methods is the focus on specific dimensions of motor competence. For instance, the KTK focuses on gross motor coordination but does not include tasks on fundamental motor skills (especially object control skills). Similarly, the TGMD includes locomotor and object control skills but not stability skills. Further, observation methods tend to provide one type of information; that is, product-oriented measures offer information on movement outcome (e.g., jump distance) whilst process-oriented measures are concerned with movement patterns (e.g., arm movement during jump). As suggested by Robinson et al.,⁴ a combined use of product-oriented and process-oriented measures can provide a more comprehensive assessment of motor competence. Other issues pertain to administrative and feasibility aspects (e.g., assessment training, clarity of instruction and scoring, assessment time, required space) and psychometric aspects (e.g., construct validity, convergent validity, test-retest reliability).

Contemporary research has begun to focus on developing instrumented versions of test batteries (e.g., Bisi et al.³⁸), which integrates motion devices and observation methods for an effective and efficient assessment of young people's motor competence.

2.2. Subjective methods

Subjective measures, including self and proxy reports, may be useful for assessing large numbers of children as they are cheaper than objective assessments and do not require much training to administer. Another advantage of subjective measures is the inclusion of contextual information (e.g., competence in activities of daily living), which is not captured by objective measures.

Self-report. Self-reports focus on individuals' perceived competence and can be used as an indicator of actual motor competence. There is some emerging evidence that the strength of association between perceived and actual competence increases over time.^{39,40} Children are considered to not be able to report on their own competence until around 8 years of age.⁴¹ In the younger age group, it is more typical to have high levels of perceived motor competence; however, it can still be useful to investigate perceptions in young children to identify those who are experiencing low perceptions. Whilst it is challenging to compare findings across studies (due to the use of different constructs and instruments),⁴ it is also apparent that children in preschool and the first years of school (i.e., age <8 years), have limited insight into their motor competence. Perceived competence in this age group is either not related or only weakly related to their actual competence.^{42–45}

It is important to consider the developmental age of the child in relation to the construct of interest and whether the assessment needs to be administered in a pictorial or written format.⁴⁶ In the 1980s, Harter developed scales for self-report of physical competence with different content, and in distinct formats, depending on the individuals' age.^{46–48} Recently, Barnett et al.^{49,50} have developed a more comprehensive pictorial scale for young children to self-perceive their motor and active play skills. The motor skill items in the pictorial scale match the items of a widely used observation method (i.e., TGMD)³³ so that perception is linked to the construct of interest.^{49,50}

In older children (approximately 8–12 years), there appears to be more evidence of a significant positive association between actual and perceived motor competence; although not consistently.⁵¹ The Adolescent Motor Competence Questionnaire (AMCQ) was recently developed with the purpose of identifying motor competence level and suspected motor difficulties among adolescents (age 12–18 years).⁵² The instrument assesses a range of skills including fine and gross motor tasks relevant to adolescents, and other aspects related to sports, schooling, self-care, and daily living. Scores from the AMCQ were shown to have a moderate positive correlation with the McCarron Assessment of Neuromuscular Development ($r=0.49$).⁵²

Associations between measures of actual and perceived motor competence, even into adolescence, are generally low-to-moderate, which might suggest that self-report is not a useful way to estimate motor competence levels. Despite this limitation, low-to-moderate correlations between self-report and more objective measures of physical activity are commonplace (i.e., mean of 0.37 and a range of -0.71 to 0.98).⁵³ Therefore, for older children (age >8 years) and adolescents, self-report of motor competence may be sought as an indicator of actual motor competence, although it should not be used as a replacement for actual motor assessment. In contrast, for younger children (age <8 years), objective methods or proxy reports are recommended.

Proxy report. Historically, when attempting to understand an individual's level of motor competence, proxy reports were

developed to be able to identify children who are atypical in their motor development. Early identification of children with Developmental Coordination Disorder (DCD) is considered important to prevent further compounding issues with regard to academic, emotional and social issues associated with DCD.⁵⁴ Proxy reports are considered an additional source of information, as multiple sources of assessment (i.e., objective and subjective) are recommended to identify issues such as DCD in order to provide a complete picture.⁵⁴ The Developmental Disorder Coordination Questionnaire 2007 (DCDQ'07) was developed to identify children (age 5–15 years) with DCD⁵⁵ and the Movement Assessment Battery for Children Checklist (M-ABC Checklist) was developed for teachers but can also be used by parents.^{29,55} Both assessments include functional skills required in activities of daily living, and the M-ABC also refers to the ability of children to perform self-care skills (e.g., dressing without help).

The Children's Activity Scales for Parents and Teachers,⁵⁴ were also developed to identify children at risk for DCD but developed to be more comprehensive than previous questionnaires and to target younger children (age 4–8 years). In addition to the items on gross and fine motor skills, items in these scales cover children's organisation in space and time whilst completing daily living and self-care skills, mobility, play activities and (pre)school activities. Concurrent validity shows moderate to strong correlations between M-ABC scores and the total scores for the parent ($r=0.51$) and the teacher ($r=0.75$) versions.⁵⁴

Some other scales have been developed particularly for teachers such as the Teacher Estimation of Activity Form,⁵⁶ and the Motor Observation Questionnaire for Teachers (MOQ-T).⁵⁷ The MOQ-T contains 18 items that cover both fine and gross motor skills. Performance on the MOQ-T was compared to performance on the Movement Assessment Battery for Children (M-ABC) and the Developmental Coordination Disorder Questionnaire (DCD-Q). Concurrent validity shows moderate to strong correlations between the MOQ-T and the DCD-Q ($r=-0.63$), and the MOQ-T and the M-ABC ($r=0.57$).⁵⁷

A few recent studies have investigated the relationship between proxy report of motor competence (using teacher and/or parent), child self-report and children's actual motor competence. Liang et al.⁴² found in young children (5–8 year olds) that parent proxy report was more strongly associated with actual motor skill than child self-report. This might be expected in terms of the young age of the sample. In older children (age 6–11 years), Estevan et al.⁵⁸ also found that parents were better than children in terms of reporting on their motor competence, although physical education teachers were even more accurate. In contrast, Lalor et al.⁵⁹ found that, among children aged 8–12 years, self-report scores showed higher correlations with actual motor competence scores compared to teacher and parent report scores. The studies by Liang et al.⁴² and Estevan et al.⁵⁸ both used a proxy report instrument that matched the skill items being assessed in the actual motor skill assessment (TGMD-2) whereas the study by Lalor et al.⁵⁹ completed a questionnaire specifically developed for the purpose of distinguishing children with DCD (i.e., the Developmental Coordination Disorder Questionnaire, DCDQ; Wilson et al.).⁶⁰ These questionnaires may not have been sensitive enough to detect motor competence in a typically developing sample.

Few proxy report measures have been designed to report on motor competence specifically with regard to fundamental motor skills in typically developing populations. Nevertheless, it appears that available proxy reports of motor competence tend to be at least moderately correlated with children's actual competence scores, indicating they can be used as a source of information regarding motor competence.

3. Scenarios

We have selected the following scenarios to represent a scope of contexts (i.e., clinical, education, population screening and monitoring, sport) in which motor assessment can take place. These scenarios should be read in conjunction with Fig. 1 as well as Tables 1 and 2. In each scenario, information is presented to guide researchers and practitioners on selecting the most appropriate method(s) of assessment according to their context.

Scenario A: School-based fundamental motor skill intervention. Researchers want to evaluate a school-based 12-week fundamental motor skill program involving 5- to 8-year-old children. They have recruited six schools that will be randomly assigned to the intervention program ($n=200$) or control condition ($n=200$), and plan to conduct motor assessments at baseline and post-intervention. The goal of the research is to determine if the intervention is effective in developing children's fundamental motor skills and improving their motor competence.

In this scenario, researchers are assessing changes in motor competence levels over a three-month period using a randomised controlled trial design. Key considerations for selecting appropriate methods include age, sample size, assessment time and available budget. Self-reports may not be appropriate for children who do not yet have the cognitive skills to accurately assess their own motor competence. Proxy reports by teachers (especially, physical education specialists) can provide more accurate assessments but may place a significant burden upon teachers. Observation (i.e., process-oriented or product-oriented) may then be the most appropriate assessment method to use in this context. Process-oriented measures can provide valuable, qualitative information on children's motor skills but are typically used with video-recording (which increases time and costs associated with the post-hoc analysis of video data) and require a certain amount of assessment training.

An alternative would be to use product-oriented measures, especially in the case of limited resources. Product-oriented measures provide quantitative information on children's motor skills, are less time consuming and require less training, although they do not provide information on the quality of movement in children. It should be noted that both product- and process-oriented measures shed a different light on children's motor skills.⁴ As such, if sufficient resources are available, researchers should use both types of observation measures in order to have a more complete picture of children's motor competence and to evaluate the effectiveness of fundamental motor skill interventions more thoroughly.

Scenario B: Identification of children with motor delay. Typical development is marked by well-observed patterns of motor behaviours, including reflexes, voluntary movements, and goal-directed actions. For example, disappearance of selected reflexes and the emergence of sitting, reaching, and walking are all associated with typical development. As a child progresses from infancy through early childhood, parents, teachers, and clinicians serve the important role of identifying children with motor deficits. Parents and teachers are in the best position to evaluate a child's motor competence due to their regular and ongoing interactions with them on a daily basis. Parents or teachers can identify a child with a potential motor impairment, who can then be referred to a clinician for further assessment and, if needed, remediation/intervention. Or, parents or teachers may aid clinicians and researchers in assessing and monitoring motor competence as part of a research study or intervention program.

In this scenario, an early childhood learning center is interested in assessing motor competence as part of their quarterly outcomes to screen for children with motor impairments. The center currently assesses cognition, language, and social skills through developmental assessments. The center is trying to decide which

motor assessment is most appropriate to screen children for motor delay. Key considerations in the selection of an appropriate motor assessment include the purpose of assessment (screening), the age of the participants, feasibility to train staff members to administer the assessment, and time-constraints to complete the assessment (from administration to scoring). It is also important to choose an assessment that does not require clinical expertise and is appropriate for early childhood educators to administer. As such, a proxy report is an appropriate method when screening young children for motor delay. Those with a potential delay could then be referred to a clinician for more (objective) assessment. Regardless of the results of a proxy report, parents, teachers, and researchers are encouraged to refer children to the appropriate healthcare expert at any sign of atypical development.

Scenario C: Prevalence survey of adolescents. Given the low physical activity during adolescence,⁶¹ it is becoming increasingly important to include the assessment of motor competence as an adjunct measure of physical activity in adolescent health surveys. As the relationship between physical activity and motor competence is reciprocal,⁴ including motor assessment provides useful epidemiology on the prevalence, patterns and distribution of adolescent's motor competence levels. This information contributes to policy decisions of stakeholders in adolescent health and guides interventions to ensure adolescents have adequate levels of motor competence, which supports physical activity participation.

In this scenario, the prevalence of adolescents' motor competence levels has been requested by the state government. Around 3000 adolescents are required and these adolescents are randomly recruited through an appropriate school sampling frame to provide generalisable prevalence estimates. Prevalence estimates should be stratified by sex and age. The provision of socio-demographic characteristics can be useful for targeted intervention.

Ideally, prevalence needs to be estimated objectively; as such, observation using validated and reliable instruments is recommended. Observation may include trained personnel doing live assessment or videoing each adolescent demonstrating various motor skills and coding later. The latter is less time consuming but has several key considerations including ethics approval for videoing, cost of videoing, and the time required to code following collection. Decisions regarding the need for process-based and/or product-based information will guide the selection of observation instruments. Circuit-based assessments (which are largely product based) may provide a quick and valid way of assessing groups of children for large studies. If direct observation is not feasible, adolescents can self-report on their motor competence levels using validated and reliable questionnaires. However, it should be noted that, while they give an indication of motor competence levels, self-reports do not tend to correlate strongly with actual assessment.

Scenario D: Performance assessment in sports. Common team or individual sport activities involve children and adolescents divided in age-categories following sport-specific training periods and participating in regular competitions/matches. In this scenario, motor assessment is to be conducted in a sport club to evaluate athlete performance. Youth sport coaches can have different reasons for administering assessments: (i) initial screening to test each athlete about his/her potential role in the team (talent identification); (ii) examination of the current health status of each athlete; (iii) evaluation of the effectiveness and the specificity of the planned training program; (iv) development of possible personalised interventions (return to sport). Key considerations in the selection of appropriate measurement tools include: type (individual/team) and level of sport (competitive/non-competitive); the age of the participants; time-constraints about the required assessment; the need to differentiate a single athlete from the team (e.g., injury or particular role in the team); feasibility due to the different context (training vs competition).

In this context, motion devices and observation measures are considered the most appropriate assessment methods. On the one hand, lab-based measurements can be performed by scientific/technical staff to support kinematic/dynamic assessment of sports movement, to enhance training design and to assess biomechanical fatigue, which will also facilitate the development of appropriate injury prevention programs. On the other hand, observation can be performed by coaches through the adoption of in-field performance tests and video analysis for direct in-field assessment. Nowadays, the two approaches can be combined through inertial sensing,³⁸ bringing the accuracy of motion devices to the field and opening the use of motion devices to non-specialist professionals. Inertial sensors capture kinematic/dynamic quantities, can be worn during matches or prolonged activity without capture volume constraints, and allow real-time monitoring.

4. Concluding remarks

Motor competence is a complex concept that pertains to an individual's proficiency in executing motor skills. In view of its role in young people's overall health and development,⁴ it is important to use an appropriate assessment. However, there is no gold standard measure that captures all aspects of motor competence and some instruments are not always feasible to use due to logistic constraints. Objective methods, such as motion devices and observation measures, provide an accurate and direct estimate of motor competence. Moreover, emerging research on integrating motion devices and observation measures appears to be a promising approach to provide a more holistic assessment of children's motor competence. Subjective methods include self-reports and reports by others (e.g., parents, teachers), and provide an efficient and indirect estimate of motor competence. Policy makers, practitioners and researchers need to consider the purpose of assessment, population characteristics and a range of practical aspects when deciding which instrument to use.

Practical implications

- Motor competence among young people can be assessed in various ways using objective and/or subjective methods. Each method has key features and limitations, and involves practical considerations for the user.
- The choice of assessment method depends on a range of aspects including the purpose of assessment, population characteristics, administrative aspects and measurement quality.
- Researchers, practitioners and policy makers should understand the strengths and limitations of each assessment method in order to select an appropriate instrument.

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References

1. Gallahue DL, Ozmun JC, Goodway JD. *Understanding Motor Development: Infants, Children, Adolescents, Adults*, 7th ed. New York, NY, McGraw-Hill, 2012.
2. Gabbard CP. *Lifelong Motor Development*, 5th ed. San Francisco, CA, Pearson Benjamin Cummings, 2008.
3. Utesch T, Bardid F. Motor competence, in *Dictionary of Sport Psychology: Sport, Exercise, and Performing Arts*, Dieter Hackfort, Schinke R, Bernd Strauss, editors, Amsterdam, Elsevier, 2018, (in press).
4. Robinson LE, Stodden DF, Barnett LM et al. Motor competence and its effect on positive developmental trajectories of health. *Sport Med* 2015; 45(9):1273–1284.

5. Barnett LM, Lai SK, Veldman SLC et al. Correlates of gross motor competence in children and adolescents: a systematic review and meta-analysis. *Sport Med* 2016; 46(11):1663–1688.
6. Lubans DRR, Morgan PJJ, Cliff DPP et al. Fundamental movement skills in children and adolescents: review of associated health benefits. *Sport Med* 2010; 40(12):1019–1035.
7. Logan SW, Ross SM, Chee K et al. Fundamental motor skills: a systematic review of terminology. *J Sports Sci* 2016; 2017:1–16. <http://dx.doi.org/10.1080/02640414.2017.1340660>.
8. Cools W, De Martelaer K, Samaey C et al. Movement skill assessment of typically developing preschool children: a review of seven movement skill assessment tools. *J Sports Sci Med* 2009; 8(2):154–168.
9. Hands B, Licari M, Piek J. A review of five tests to identify motor coordination difficulties in young adults. *Res Dev Disabil* 2015; 41–42:40–51. <http://dx.doi.org/10.1016/j.ridd.2015.05.009>.
10. Burton AW, Miller DE. *Movement Skill Assessment*, Champaign, IL, Human Kinetics, 1998.
11. Dollman J, Okely AD, Hardy L et al. A hitchhiker's guide to assessing young people's physical activity: deciding what method to use. *J Sci Med Sport* 2009; 12(5):518–525. <http://dx.doi.org/10.1016/j.jsams.2008.09.007>.
12. Hardy LL, Hills AP, Timperio A et al. A hitchhiker's guide to assessing sedentary behaviour among young people: deciding what method to use. *J Sci Med Sport* 2013; 16(1):28–35. <http://dx.doi.org/10.1016/j.jsams.2012.05.010>.
13. Wiart L, Darrah J. Review of four tests of gross motor development. *Dev Med Child Neurol* 2001; 43(4):279–285.
14. Cappozzo A, Della Croce U, Leardini A et al. Human movement analysis using stereophotogrammetry. *Gait Posture* 2005; 21(2):186–196. <http://dx.doi.org/10.1016/j.gaitpost.2004.01.010>.
15. Guarrera-Bowlby PL, Gentile AM. Form and variability during sit-to-stand transitions: children versus adults. *J Mot Behav* 2004; 36(1):104–114. <http://dx.doi.org/10.3200/JMBR.36.1.104-114>.
16. Strohmarmann C, Labruyère R, Gerber CN et al. Monitoring motor capacity changes of children during rehabilitation using body-worn sensors. *J Neuroeng Rehabil* 2013; 10(1):83. <http://dx.doi.org/10.1186/1743-0003-10-83>.
17. Robertson MA, Halverson LE. The development of locomotor coordination: longitudinal change and invariance. *J Mot Behav* 1988; 20:197–241.
18. Getchell N, Robertson MA. Whole body stiffness as a function of developmental level in children's hopping. *Dev Psychol* 1989; 25(6):920–928. <http://dx.doi.org/10.1037/0012-1649.25.6.920>.
19. Robertson MA, Konczak J. Predicting children's overarm throw ball velocities from their developmental levels in throwing. *Res Q Exerc Sport* 2001; 72(2):91–103.
20. Robertson MA, Halverson LE. *Developing Children—Their Changing Movement*, Philadelphia, Lea & Febiger, 1984.
21. Whitall J, Getchell N. From walking to running: applying a dynamical systems approach to the development of locomotor skills. *Child Dev* 1995; 66(5):1541–1553. <http://dx.doi.org/10.1111/j.1467-8624.1995.tb00951.x>.
22. Masci I, Vannozzi G, Getchell N et al. Assessing hopping developmental level in childhood using wearable inertial sensor devices. *Motor Control* 2012; 16:317–328.
23. Benedetti MG, Beghi E, De Tanti A et al. SIAMOC position paper on gait analysis in clinical practice: general requirements, methods and appropriateness. Results of an Italian consensus conference. *Gait Posture* 2017; 58:252–260. <http://dx.doi.org/10.1016/j.gaitpost.2017.08.003>.
24. Camomilla V, Bergamini E, Fantozzi S et al. Trends supporting the in-field use of wearable inertial sensors for sport performance evaluation: a systematic review. *Sensors* 2018; 18(3):873. <http://dx.doi.org/10.3390/s18030873>.
25. Kavanagh JJ, Menz HB. Accelerometry: a technique for quantifying movement patterns during walking. *Gait Posture* 2008; 28(1):1–15. <http://dx.doi.org/10.1016/j.gaitpost.2007.10.010>.
26. Grimpampi E, Masci I, Pesce C et al. Quantitative assessment of developmental levels in overarm throwing using wearable inertial sensing technology. *J Sports Sci* 2016; 0414:1–7. <http://dx.doi.org/10.1080/02640414.2015.1137341>.
27. Masci I, Vannozzi G, Bergamini E et al. Assessing locomotor skills development in childhood using wearable inertial sensor devices: the running paradigm. *Gait Posture* 2013; 37(4):570–574. <http://dx.doi.org/10.1016/j.gaitpost.2012.09.017>.
28. Barnett LM, Minto C, Lander N et al. Interrater reliability assessment using the Test of Gross Motor Development-2. *J Sci Med Sport* 2014; 17(6):667–670. <http://dx.doi.org/10.1016/j.jsams.2013.09.013>.
29. Henderson SE, Sugden DA. *Movement Assessment Battery for Children*, London, Psychological Corporation, 1992.
30. Henderson SE, Sugden DA, Barnett A. *Movement Assessment Battery for Children*, 2nd ed. London, Harcourt Assessment, 2007.
31. Herrmann C, Heim C, Seelig H. Construct and correlates of basic motor competencies in primary school-aged children. *J Sport Heal Sci* 2017. <http://dx.doi.org/10.1016/j.jsms.2017.04.002>.
32. Ulrich DA. *Test of Gross Motor Development*, Austin, TX, PRO-ED, 1985.
33. Ulrich DA. *Test of Gross Motor Development*, Second, 2nd ed. Austin, TX, PRO-ED, 2000.
34. New South Wales Department of Education and Training. Get Skilled: Get Active. A K-6 resource to support the teaching of fundamental movement skills. Sydney, 2000.
35. Longmuir PE, Boyer C, Lloyd M et al. Canadian Agility and Movement Skill Assessment (CAMSA): validity, objectivity, and reliability evidence for children 8–12 years of age. *J Sport Heal Sci* 2015. <http://dx.doi.org/10.1016/j.jsms.2015.11.004>.
36. Hoeboer J, Krijger-Hombergen M, Savelsbergh G et al. Reliability and concurrent validity of a motor skill competence test among 4- to 12-year old children. *J Sports Sci* 2017:1–7. <http://dx.doi.org/10.1080/02640414.2017.1406296>.
37. Largo RH, Fischer JE, Caffisch JA. *Zürich Neuromotor Assessment*, Zurich, AWE Verlag, 2002.
38. Bisi MC, Pacini Panebianco G, Polman R et al. Objective assessment of movement competence in children using wearable sensors: an instrumented version of the TGMD-2 locomotor subtest. *Gait Posture* 2017; 56:42–48. <http://dx.doi.org/10.1016/j.gaitpost.2017.04.025>.
39. Stodden DFF, Goodway JDD, Langendorfer SJJ et al. A developmental perspective on the role of motor skill competence in physical activity: an emergent relationship. *Quest* 2008; 60(2):290–306.
40. True L, Brian A, Goodway J et al. Relationships between product- and process-oriented measures of motor competence and perceived competence. *J Mot Learn Dev* 2017; 5(2):319–335. <http://dx.doi.org/10.1123/jmld.2016-0042>.
41. Harter S. *The Construction of the Self: A Developmental Perspective*, New York, Guilford, 1999.
42. Liong GHE, Ridgers ND, Barnett LM. Associations between skill perceptions and young children's actual fundamental movement skills. *Percept Mot Skills* 2015; 120(2):591–603. <http://dx.doi.org/10.2466/10.25.PMS.120v18x2>.
43. Masci I, Schmidt M, Marchetti R et al. When children's perceived and actual motor competence mismatch: sport participation and gender differences. *J Mot Learn Dev* 2017:1–33. <http://dx.doi.org/10.1123/jmld.2016-0081>.
44. Lopes V, Barnett L, Rodrigues L. Is there an association among actual motor competence, perceived motor competence, physical activity, and sedentary behavior in preschool children? *J Mot Learn Dev* 2016; 4(2):129–141. <http://dx.doi.org/10.1123/jmld.2015-0012>.
45. Brian A, Bardid F, Barnett L et al. Actual and perceived motor competence levels of Belgian and US preschool children. *J Mot Learn Dev* 2017. <http://dx.doi.org/10.1123/jmld.2016-0071>. Ahead of print.
46. Harter S, Pike R. The pictorial scale for perceived competence and social acceptance for young children. *Child Dev* 1984; 55(6):1969–1982.
47. Harter S. *The Self-Perception Profile for Children: Revision of the Perceived Competence Scale for Children*, Denver, CO, University of Denver, 1985.
48. Harter S. *Self-Perception Profile for Adolescents: Manual and questionnaires*, Denver, CO, University of Denver, 1988.
49. Barnett LM, Ridgers ND, Zask A et al. Face validity and reliability of a pictorial instrument for assessing fundamental movement skill perceived competence in young children. *J Sci Med Sport* 2015; 18(1):98–102. <http://dx.doi.org/10.1016/j.jsams.2013.12.004>.
50. Barnett LM, Vazou S, Abbott G et al. Construct validity of the pictorial scale of Perceived Movement Skill Competence. *Psychol Sport Exerc* 2016; 22:294–302. <http://dx.doi.org/10.1016/j.psychsport.2015.09.002>.
51. Barnett L, Lubans D, Salmon J et al. What is the contribution of actual motor skill fitness, and physical activity to children's self-perception of motor competence? *J Mot Learn Dev* 2017:1–21. <http://dx.doi.org/10.1123/jmld.2016-0076>.
52. Timler A, McIntyre F, Cantell M et al. Development and evaluation of the psychometric properties of the Adolescent Motor Competence Questionnaire (AMCQ) for Adolescents. *Res Dev Disabil* 2016; 59:127–137. <http://dx.doi.org/10.1016/j.ridd.2016.08.005>.
53. Prince SA, Adamo KB, Hamel M et al. A comparison of direct versus self-report measures for assessing physical activity in adults: a systematic review. *Int J Behav Nutr Phys Act* 2008; 5(1). <http://dx.doi.org/10.1186/1479-5868-5-56>, p56.
54. Rosenblum S. The development and standardization of the Children Activity Scales (CHAS-P/T) for the early identification of children with Developmental Coordination Disorders. *Child Care Health Dev* 2006; 32(6):619–632. <http://dx.doi.org/10.1111/j.1365-2214.2006.00687.x>.
55. Wilson BN, Crawford SG, Green D et al. Psychometric properties of the revised developmental coordination disorder questionnaire. *Phys Occup Ther Pediatr* 2009; 29(2):182–202. <http://dx.doi.org/10.1080/01942630902784761>.
56. Faught BE, Cairney J, Hay J et al. Screening for motor coordination challenges in children using teacher ratings of physical ability and activity. *Hum Mov Sci* 2008; 27(2):177–189. <http://dx.doi.org/10.1016/j.humov.2008.02.001>.
57. Schoemaker MM, Flapper BCT, Reinders-Messelink Ha et al. Validity of the motor observation questionnaire for teachers as a screening instrument for children at risk for developmental coordination disorder. *Hum Mov Sci* 2008; 27(2):190–199. <http://dx.doi.org/10.1016/j.humov.2008.02.003>.
58. Estevan I, Molina-García J, Bowe SJ et al. Who can best report on children's motor competence: parents, teachers, or the children themselves? *Psychol Sport Exerc* 2018; 34:1–9. <http://dx.doi.org/10.1016/j.psychsport.2017.09.002>.
59. Lalor A, Brown T, Murdolo Y. Relationship between children's performance-based motor skills and child, parent, and teacher perceptions of children's motor abilities using self/informant-report questionnaires. *Aust Occup Ther J* 2016; 63(2):105–116. <http://dx.doi.org/10.1111/1440-1630.12253>.
60. Wilson BN, Kaplan BJ, Crawford SG et al. Reliability and validity of a parent questionnaire on childhood motor skills. *Am J Occup Ther* 2000; 54:484–493.
61. Hallal PC, Andersen LB, Bull FC et al. Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet* 2012; 380(9838):247–257. [http://dx.doi.org/10.1016/S0140-6736\(12\)60646-1](http://dx.doi.org/10.1016/S0140-6736(12)60646-1).