Movement Skills Assessment tool: A validation study using a modified Delphi method

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Abstract

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Physical activity is integrated in preventive health programs due to its health-related benefits. Increasing physical activity levels in children and adolescents is a global objective that focuses in cognitive, affective, and behavioral factors. Physical literacy and models of motor development suggest a positive association between movement competence and physical activity. Poor movement competence is associated with a sedentary lifestyle and is a risk factor for musculoskeletal injury.

Promoting physical activity and sports participation is crucial; however, participating in physical activity and sports has been related to increased risk of musculoskeletal injury. Assessments of physical literacy and movement competence are mainly focused on motor development factors, but injury prevention techniques are not considered in these assessments. Our objective was to establish the face and content validity of four movement skills, each with four evaluation criteria, to create a movement skills assessment tool for 8-12-year-old children to fill the gap between movement competence and injury prevention assessments.

We used a modified Delphi method to survey an international expert panel of clinicians, researchers, and practitioners (n=22). Three rounds of surveys were used to achieve consensus on the validity of four movement skills and evaluation criteria. Consensus was achieved when 75% or more of the experts scored "Agree" or "Strongly Agree" using a 5-point Likert scale. In the first and second Delphi-rounds, the expert panel achieved consensus on the validity of eight movement skills and 53 evaluation criteria. In the third round, the experts ranked the movement skills and evaluation criteria to identify the top four movement skills and top four evaluation criteria per movement skill to create the movement skills assessment tool.

This study provided preliminary validity evidence for the movement skills assessment tool. Future research should evaluate other psychometric properties and assess injury outcomes of a movement-oriented intervention. The movement skills assessment tool will be used to screen movement competence and identify movement patterns that present risk factors for musculoskeletal injury in different settings with minimal equipment.

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Literature Review

Physical Activity

Regular physical activity has positive effects on psychological, musculoskeletal, and physiological health in children and adolescents.[1,2] Conversely, physical inactivity is associated with health problems and leads risk factors for death worldwide as it increases the incidence of noncommunicable diseases, musculoskeletal disorders, and depression.[2-4]

Physical activity levels in children and adolescents have decreased over the past decades. More than 80% of adolescents aged 11-17 years did not meet the minimum goals in daily physical activity in 2010.[3,5,6] According to The World Health Organization (WHO), although obesity is preventable, the number of overweight and obese children and adolescents was over 340 million in 2016.[7] Evidence from the Global Matrix 2.0, a summary report card of physical activity in children and youth from 38 countries, reported an average grade ‘D’ for overall physical activity in Canada. A ‘D’ grade indicates that only 20-39% of our children participate in adequate amounts of physical activity.[11]

The Canadian Society of Exercise Physiology, the WHO, and centers for disease control and prevention have developed evidence-based physical activity guidelines for children.[12-14] Physical activity guidelines specify that children should participate in a minimum of 60 minutes of moderate-to-vigorous physical activity daily.[14-16] These 60 minutes should incorporate aerobic exercise and activities that strengthen muscle and bone at least three days per week.[14-16] Reviews, observational research, and experimental studies focused on the benefits of and strategies to promote physical activity.[6,9,17,18] Researchers hypothesize that children with increased movement competence will potentially adopt lifelong physical activity.[19-21]

Movement Competence

In motor development literature, many terms are used interchangeably with movement competence (e.g., motor competence, motor proficiency, fundamental motor/movement skills proficiency, physical competence, and motor coordination).[20] We use movement competence as a global term to describe goal-oriented proficiency in any movement-based activity as well as the underlying processes of movement, such as coordination and control.[20,33]

Burton and Miller (1998) addressed the ambiguity of the terminology in motor development literature. Terms such as movement and motor are often used interchangeably, but these terms represent different concepts and are context-dependent. Movement is the observable change in the position of the body or any part of the body,[43] and motor, used as an adjective, refers the underlying factors that affect movement and are not directly observable.[58] Movement skills can be measured by observation; while, motor abilities are components of the movement skills that may be inferred by performance.[43] In this study, we used the terms movement competence and movement skill, which are in line with Burton's and Miller's claims.[43] Logan et al. (2018) stated that the terms fundamental motor skill and fundamental movement skill can be used interchangeably only if the term is clearly defined before using it.[58]

Fundamental Movement Skills and Basic Human Movements

Several models of motor development target fundamental movement skills to assess movement competence.[19,21,23,29,49,52] Fundamental movement skills are basic, prerequisite, movements (i.e., building blocks) that are learned and emerge during the period of early (2-3 years) and later (7-10 years) childhood as a part of normal motor development.[23,53] Fundamental movement skills constitute the basis of specialized movement skills, which are complex and integrated movements that are necessary to accomplish everyday activities and participate in physical activity and sports.[23,54,55] Fundamental movement skills are classified into three subsets of skills: object control skills (e.g., catching, throwing, kicking and striking), locomotor skills (e.g., running, hopping, jumping), and stability skills (e.g., balancing, single-leg balancing).[23,43,53,55-57] Locomotor skills are used to move the body from a place to another in relation to a fixed point on the surface and are influenced by the foundations of the movement (e.g., strength, power) and motor abilities (e.g., gross body coordination, balance, stamina).[23,58] Locomotor skills, in advanced stages of motor development, can be refined and combined to become in elaborated movements patterns used in more demanding situations.[23,43]

Tompsett and colleagues (2015) proposed the assessment of basic human movements as a complement to the assessment of fundamental movement skills. Basic human movements are essential movement patterns (e.g., squat, lunge, pull, push) that allow a person to interact with the environment and influence children's motor competence.[173]

Models of Motor Development

Seefeldt (1980) presented the 'sequential model of motor development' which studied developmental motor patterns and their progression across time.[52] Seefeldt's model was further developed and promoted by Gallahue and colleagues (1998), who developed the 'Hourglass of Motor Development.'[23] Clark and Metcalfe (2002) presented their metaphor of the 'Mountain of motor development'.[49] These models assume that reflexes and rudimentary movements provide a neurological basis for the development of movement skills.[23,49,52]

Seefeldt's, Gallahue's, and Clark and Metcalfe's models stated the existence of a fundamental movement phase. The fundamental movement phase is a critical period to learn and master several fundamental movement skills to promote the highest potential for skill transfer to more advanced movement skills and activities.[23,49,52] Children with a stronger fundamental movement base will have more movement skills to transfer and apply in more physical activities and sports.[59] Therefore, transitioning to the most advanced levels in these models supports the sequential nature of skill development across time.[23,49,52]

Clark and Metcalfe's 'Mountain of Motor Development and Gallahue's 'Hourglass Model of Motor Development have a dynamic systems perspective.[63-66] The dynamic systems theory states that motor development not only is non-linear, but it is also a continuous-discontinuous process affected by several factors.[23,63-66] The acquisition of fundamental movement skills or specialized movement skills is age-related, but it is not age-dependent.[20,23,63-66] Different factors, such as environment, the individual characteristics, and the task, affect the processes of acquiring movement skills and phase-shifting from the fundamental movement phase to more advanced movement phases.[23,63-66] In regard to musculoskeletal injury, learning and mastering specialized movement skills with a poor fundamental movement base may lead to early specialization which may cause a higher risk of acute and overuse injuries, burn out, decreased motivation, and limited long-term physical activity participation.[68-70]

Movement Competence and Physical Activity

Movement competence in childhood has been identified as a predictor of physical activity participation in adolescence, and physical activity is hypothesized to promote further development of movement competence.[19,46] Evidence suggests that maintaining adequate levels of movement competence supports functional independence in later life and reduce the risk of both falls and risk of mortality.[50,51]

The Spiral of Engagement-Disengagement Model

Stodden (2008) proposed the spiral of engagement-disengagement model that suggests reciprocal and synergistic associations between physical activity, movement competence, perceived movement competence, health-related fitness, and weight status.[19] Recent studies have supported Stodden's model; however, further research is warranted.[20,25]

Physical activity participation is assumed to increase movement competence levels in early childhood (2-5 years of age). During the transition to middle and late childhood (6-12 years of age), this relationship reverses, and movement competence level is thought to increase physical activity participation.[19] Stodden's model recognizes a bi-directional relationship between physical activity and movement competence. Stodden hypothesized that health-related fitness and perceived movement competence are mediating variables in the proposed movement competence-physical activity relationship. Movement competence, physical activity, perceived movement competence, and health-related fitness promote either a positive (healthy) or a negative (unhealthy) trajectory for weight status.[19]

Physical Literacy

Whitehead (2001) introduced the concept of physical literacy and defined it as " the motivation, confidence, physical competence, knowledge, and understanding to maintain physical activity throughout life."[21,22] Physical competence is "one's ability to move with competence in a wide variety of activities."[21,22] Fundamental movement skills are used to operationalize movement competence and are targeted to develop the physical competence component of physical literacy.[71]

The physical literacy concept is applied in different countries in response to the common problem of declining rates of physical activity,[73] and researchers have become interested in intervening and assessing physical literacy and fundamental movement skills proficiency at different ages.[57,72] Some studies refer the concept of fundamental movement skills and physical literacy as the same construct, but they are not synonyms; indeed, fundamental movement skills exclusively focus in physical abilities, and physical literacy contemplates physical, cognitive, and affective elements.[71]

Assessment of Movement Competence

Assessment of movement competence aims at understanding an individual's motor behavior to reflect the degree of proficiency in performing a wide array of movement skills.[33] Assessing movement competence and identifying children who may be at increased risk of musculoskeletal injury should be one of the first steps to promote physical activity and sports participation.[35,38,39] A valid and reliable assessment of movement competence is necessary to understand children's motor development.[33]

Several movement competence assessment tools for children exist, and most of them are either process- or product-oriented.[41,43] Process-oriented assessment tools determine whether a movement skill is performed according to a set of predefined evaluation criteria; in other words, assess the quality of the movement skill.[41] In process-oriented assessment tools, raters, usually, score an evaluation criterion as '1' criterion performed or '0' criterion not performed. The evaluation criteria are summed to create trial scores. The trial scores are summed to create movement skill scores. The movement skill scores are summed and provide a raw composite score.[74] The Tests of Gross Motor Development 2 (TGMD 2) is a good example of a process-oriented movement competence assessment tool.[74] Product-oriented movement competence assessment tools report quantitative results (e.g., time to complete a task, speed a ball is kicked) and are focused on the outcome of the movement.[41] The Canadian Agility and Movement Skill Assessment (CAMSA) is a good example of a product-oriented assessment tool as it reports the time to complete a circuit with several movement skills.[57]

Previous studies developed and used different movement skill assessment tools to assess movement competence in children at different ages.[53] Some assessment tools do not have a clear and justified age-related progression, which generate either a floor or ceiling effect which compromise their validity.[20,41,78-80] The practicality and feasibility of some assessment tools have been questioned, and a series of logistic constraints were listed (e.g., time to complete, price, materials).[57,72] We could not identify a 'Gold Standard' that captures all aspects of movement competence.[6,33] Bardid et al. (2018) recommended that, in the absence of a 'Gold Standard' in the assessment of movement competence, policymakers, practitioners, and researchers need to identify the purpose of the assessment, the population, and practical aspects to decide which assessment tool to use.[33] Finally, although process-oriented assessment tools account for the quality of the movement,[41] no movement competence assessment tool has been designed with injury strategies in mind.

After reviewing existing movement competence assessment tools, the physical literacy model, and motor development models, we concluded that an additional factor should be included in the assessment of movement competence in 8-12-year-old children. Existing assessment tools aim to assess movement competence at different ages to detect motor impairment, motor development delays, and predict physical activity participation.[23,43,74,77] However, no assessment tool is neither based on nor associated with injury prevention strategies. We aim to bridge the gap between movement competence and injury risk assessment. A movement skill assessment tool could give us information about both movement competence and risk of musculoskeletal injury, under the assumption that children who perform "poor" in a movement skill may be in an increased risk of musculoskeletal injury compared to children who perform "good."[40]

Musculoskeletal injury

Musculoskeletal injury can be defined as any physical state that impairs movement.[93] Although we cannot prevent all injuries, even preventing one injury may help to improve physical condition and performance.[94-96] Injury can cause extended periods of absence from the activity and may impact on individual's involvement in movement skills and physical development activities and participation in organized sports.[35]

Organized sport is the main cause of injury in children and adolescents across many countries.[208-211] The estimated injury incidence proportion is 35 injuries over 100 youth annualy.[212] Lower extremity injuries account for over 60% of the overall injury burden in youth sport.[213] The highest rates of injury for boys and girls are reported in team sports.[212,213] Injury rates range between 0.50 (95% CI 0.29-0.71) per 1000 hours of physical education classes for 10-12-year-old children.[214]

Since musculoskeletal injury is considered a barrier to physical activity participation,[35] coaches, physical education teachers, and researchers should strive to reduce injury rates by implementing injury prevention strategies (e.g., injury prevention programs, integrative neuromuscular training/warm-ups, injury screening).[35,44,45] Injury prevention strategies aim at improving upper and lower extremity biomechanics and decreasing landing impact forces by working on strength, plyometrics, agility, balance, and flexibility.[31,36,39,44,45]

Risk factors for musculoskeletal injury

Risk factors, in health sciences, are environmental, behavioral, or biological factors that are usually used in research as part of a causal chain. If a risk factor is present, the probability of a disease or condition occurring increases; however, if the disease or condition is already present, the removal of a risk factor may not lead to a cure.[97,107] Internal risk factors for musculoskeletal injury include age, sex, body composition, health, physical fitness (e.g., strength, power), skill level (e.g., sport-specific technique, postural stability), and psychological factors.[83] On the other hand, external risk factors for musculoskeletal injury include activity factors (e.g., sport, physical activity), protective equipment, (e.g., specialized equipment), and environmental factors (e.g., weather, obstacles).[83,107]

Internal risk factors	External risk factors	Inciting event
Age (maturation, aging) **Gender** **Body composition** **Health** (e.g., history of previous injury) **Physical fitness** (e.g., muscle strength/power) **Anatomy** **Skill level** (e.g., technique, movement competence) **Psychological factors**	**Human factors** (e.g., team mates, opponents) **Sport factors** (e.g., rules) **Protective equipment** **Sports equipment** **Environment** (e.g., weather, floor and turf type, maintenance)	**Joint motion** (e.g., kinematics, joint forces and moments) **Playing situation** (e.g., skill performed) **Training programme** **Match schedule**

Figure 1. Risk Factors for Injury
This figure shows the risk factors for injuries and possible injury mechanisms.[83,107]

Currently, coaches, physical education teachers, and practitioners find insufficient levels of movement capabilities in children and adolescents.[89] Therefore, either the transition from fundamental movement phase to more advanced movement phases may be happening at a later stage, or the acquisition of fundamental movement skills and specialized movement skills may overlap.[43,76] Children may acquire new complex and structured movements patterns based on pre-existing poor movement patterns, and the quality of movement, in general, could be compromised.[38] This leads to poor technique and might represent increased stress in joints and soft tissues (e.g., ligaments, tendons, and cartilages) that is not only a risk factor for musculoskeletal injury but also compromise muscle activity, which can further compromise mobility and stability.[38]

Children who do not demonstrate proper movement mechanics may utilize compensatory movement strategies. These movement strategies may not only hamper children's athletic performance and movement competence but also increase their risk of musculoskeletal injuries.[38,90] Furthermore, if these inefficient movements patterns are neither corrected nor modified, children will continue using and mastering these sub-optimal movement strategies. From this point, other movement skills may be affected and follow this sub-optimal performance, thus, increasing the risk for musculoskeletal injury.[30]

Injury Screening

In biomechanics and motor development research, screening tools are used to identify any developmental issues or risk factors that may result in a problem in the future. Screening tools are protocols used in healthy, uninjured, people to assess the quality of a movement rather than the outcome and objective of the movements.[48,98] Screening tools can help to synthesize observations of biomechanical measures and movement competence to a common language and objective metrics.[43] Appropriate screening strategies can observe deficits in neuromuscular control and are essential for practitioners to identify individuals who may be at increased risk of musculoskeletal injury.[99-101] Identifying the biomechanical and anatomical limitations that underlie poor movement patterns is essential to guide corrective, targeted, strategies in different contexts.[31,32]

Screening is a method used to identify risk factors for musculoskeletal injuries to develop injury prevention strategies.[102-105] Musculoskeletal screening is the process of systematically looking at an individual's joint range of motion, strength, proprioception, and balance/stability.[103,106,107] These factors are also relevant in movement competence assessment tools; thus, developing a movement skill assessment tool with an injury strategies approach may be feasible and practical. The information obtained from screening tools can be used to establish baseline data and personalize programs and interventions to potentially increase performance and reduce the risk of injury.[102,103,108] Bahr and Holme (2003) suggest that looking for risk factors that can be modified is necessary to prevent injuries.[107] Assessing fundamental movement from a functional perspective allows focussing on movement patterns rather than just specific muscles or joints.[102]

Although there are many valid and reliable injury screening tools, their feasibility and practicability have been questioned;[35] thus, developing a feasible and practical assessment tool to screen a large number of children in a proper amount of time in different contexts is warranted.[35] For example, the 'gold standard' to assess kinematics of the knee to identify multiplanar knee motion is via three-dimensional motion analysis. Three-dimensional (3D) motion analysis requires specialized equipment and labor-intensive data collection. Therefore, it may not be feasible to use 3D motion analysis in large groups of children in different settings (e.g., physical education classes, sports teams) with a limited period of time.[35]

Movement Skills Assessment Tool: Evaluation criteria

We proposed a scoring system based on a series of statements, which are intended to be easy to follow and understand by the raters. The scoring system aims to be related to the process of the movement and movement patterns to identify biomechanical risk factors for musculoskeletal injury. The statements were based on injury prevention literature and were, initially, worded in the form of internal focused cues. Internal focused cues are related to the process of the movement; whereas, external focused cues are related to the outcome of the movement.[204] Although external focused cues are recommended to be used in motor learning processes,[204] we used internal focused cues because they would allow raters to observe specific movement patterns in a movement skill. The internal focused cues did not aim at instructing nor constraining children's movement behavior. In the second Delphi-round, we reworded the internal focused cues in the form of evaluation criteria that describe movement patterns related with musculoskeletal injuries.

The evaluation criteria aim at identifying movement patterns such as knee valgus, hip adduction, limited knee flexion, knee rotation, and hip rotation,[112-114] which are frequently discussed as modifiable risk factors for lower extremity injuries including anterior cruciate ligament (ACL) injury.[39] The evaluation criteria are also based on the process of the movement,[41,43] as we intend to observe specific movement patterns to assess motor competence and modifiable risk factors of musculoskeletal injury. Results on the movement skill assessment tool would be used as a feedback source for children, parents, and practitioners. Feedback on the quality of the movement has been recommended to be used in injury prevention programs to either maintain a proper technique or the correction of movement patterns.[39]

Rationale

Assessing movement competence is important for various motor development models and physical literacy to promote lifelong physical activity. However, no movement competence assessment tool has been developed with injury prevention strategies in mind. Since poor movement competence increases the risk of musculoskeletal injury, and participating in physical activity and sports is associated with increased risk for musculoskeletal injury,[34,44,45] we believe that an evidence gap exists between movement competence assessment and injury risk screening. Identifying the biomechanical and anatomical limitations that underlie poor movement patterns is essential to guide corrective targeted strategies in different contexts and settings, such as physical education class and sports teams.[31,32] For this reason, we used a modified Delphi method to propose a series of movement skills, each with associated evaluation criteria to be validated by an international expert panel to develop a movement skills assessment tool. This movement skills assessment tool aims to assess movement competence and identify movement patterns that present risk factors for musculoskeletal injury in 8-12-year-old children.

Research Question

Are the proposed movement skills and evaluation criteria valid to assess movement competence and identify movement patterns that present risk factors for musculoskeletal injury?

Hypotheses

- The expert panel will achieve consensus on validating four of the proposed movement skills to assess movement competence and identify movement patterns that present risk factors for musculoskeletal injury.
- The expert panel will achieve consensus on validating four of the proposed evaluation criteria associated with each of the accepted movement skill to assess movement competence and identify movement patterns that present risk factors for musculoskeletal injury.

Main objective

- To establish the face and content validity of four movement skills, each with four associated evaluation criteria to develop a movement skill assessment tool. This assessment tool aims to assess movement competence and identify movement patterns that present risk factors for musculoskeletal injury.

Methods

Participants

We invited 70 international experts by email to participate in our study. Out of the 70 experts who were invited, 22 experts (31.4%) participated in our research. The participants were experts with verifiable experience in the selected fields (i.e., Athletic therapy/training, physiotherapy, biomechanics, motor development, physical literacy, children and adolescence).[147] Since defining an expert is mostly subjective, an expert panel does not need to be a representative sample of any particular population.[115] Baker (2006) concluded that the researchers must strive for the 'best options' when choosing and defending the most appropriate expert panel.[147] We used non-probabilistic sampling techniques (i.e., convenience sampling and purposive sampling) in the form of a knowledge resource nomination worksheet (KNRW) with specific inclusion criteria to recruit the experts.[118,122]

Inclusion Criteria

We selected the experts based on fulfillment of at least one of the following inclusion criteria: 1) Being involved in research that uses assessment tools on either movement competence or injury prevention; 2) Being a (co-) author of one or more published articles about assessment tools, movement competence, or injury prevention; 3) Being a lecturer in a health-related program, such as kinesiology, exercise science, physical therapy, biomechanics, and athletic therapy on a recognized academic institution; 4) Being involved in developing an health-related standardized assessment[15]; 5) Working directly with assessment tools, movement skills, injury prevention techniques, or with the target population.

Self-reported professional background and work-experience among the expert panel confirmed that the participants met the inclusion criteria to be considered as experts. The experts were academics, clinicians, and practitioners. Most of the experts had authored, or co-authored peer-reviewed publications investigating in the fields of motor development, biomechanics, injury prevention, physical activity, and physical literacy. Figure 4 presents the flowchart of the invitation and participation process. Confusion regarding panel sizes in Delphi studies exists because established sampling criteria is not available.[147] Many published Delphi studies have used panels consisting of between ten and 100 or more experts, so we aimed to have a panel size above ten experts.[115,139]

Instruments

Knowledge Resource Nomination Worksheet (NRNW)

The modified version of the KRNW consists of four steps: 1) Prepare the knowledge resource nomination worksheet by identifying relevant disciplines, fields, organizations, and literature; 2) search participants using non-probabilistic sampling methods and create a general list of the names of the possible participants; 3) categorize and rank experts based on on a subjective appreciation of their qualifications, publications, and working experience; 4) invite experts in the order of their ranking.[115] Figure 2 shows the headings of the modified KRNW.

Name	Country	Discipline	Institution	Profession	Degree Level	Publications	Years of Experience	Phone	e-mail

Figure 2. Knowledge Resource Nomination Worksheet (KRNW)

5-Point Likert Scale

We used a series of surveys to ask the participants to respond to a 5-point Likert-type questions. Recent studies in the exercise science field have used Likert scales to measure the level of agreement or disagreement of the participants and validate assessment tools.[15] Regarding Likert scales, there is a discrepancy regarding: 1) how to properly use Likert scales; 2) what Likert scales are more suitable for research and Delphi processes (i.e., 3-point, 5-point, 7-point, or 9-point Likert scales); and 3) how to analyze the data obtained from Likert scales.[121,152,156,157]

The 5-point Likert scale is a unidimensional scaling method expressed as a statement with categories of choice.[155] Researchers have suggested that the 5-point Likert scales have feasibility, reliability, and validity to capture an individual's opinions regarding a topic.[157] The five categories of the scale are: 1) Strongly Disagree, 2) Disagree; 3) Neither Agree nor Disagree; 4) Agree; 5) Strongly Agree).[155] Experts expressed their opinion by selecting only one category per statement.

Procedures

Selection of Movement Skills and Evaluation Criteria

We performed a literature review to bridge the gap between movement competence and injury risk assessments. We identified movement skills that are typically used and assessed in motor development, physical literacy, and injury prevention fields. We analyzed models of motor development[19,21-23,49,52] and identified movement skills used to intervene and assess motor competence.[21-23] The assessment tools analyzed included the Canadian Agility and Movement Skill Assessment (CAMSA);[57,75] the Test of Gross Motor Development-Second Edition (TGMD-2);[74,76] the Bruininks-Oseretsky Test of Motor Proficiency-Second Edition (BOT-2);[77] the Movement Assessment Battery for Children-Second Edition (MABC-2);[205] the PLAYfun tool;[207] Get Skilled, Get active;[206] and the Victorian fundamental movement skills assessment.[56,72] We finally explored the injury prevention field where we identified movement skills and movement patterns used in injury prevention programs, integrative neuromuscular training (e.g., the '11+', the 'GAA 15', the 'PEP Program'),[44] and injury screening tools (e.g., LESS, single-leg hop test).[44] The proposed movement skills are usually used in these fields and are in line with current research in physical activity promotion and participation.[159] See the appendix section for the list of the proposed movement skills, descriptions, and evaluation criteria.

Pilot Survey

We completed a pilot survey to obtain verbal feedback on the survey's characteristics and content. We drafted the pilot survey after identifying the movement skills (n=12) and evaluation criteria (n=84) in the literature review. We used 5-point Likert scales to ask raters to indicate their level of agreement with each of the proposed items (i.e., movement skills and evaluation criteria). The raters also had the option to respond to open-ended questions (n=14). Four academics with backgrounds in biomechanics, strength and conditioning, and athletic therapy completed the pilot survey. We received feedback on grammar and language issues, the time to complete the survey, the wording of the statements and descriptions of the movement skills, and the distribution of the statements in the pages of the survey. We used the feedback received from the pilot survey to design the first-round survey. We reworded some questions and descriptions of the movements to solve the language issues. We rearranged the distribution of the questions in the pages within the survey to improve its flow.

The Modified Delphi Process

We obtained ethical approval from Concordia University's human research ethics committee (certification number: 30004928). We created and collected the surveys using the software LimeSurvey (LimeSurvey GmbH, Version 2.65.1+170522, 2017) under Concordia's university license.

We used a modified Delphi process to survey the experts. The Delphi method is an iterative[117] and anonymous process that aims to achieve consensus on a subject after multiple rounds of discussion with controlled feedback.[118] The Delphi method has shown to be valid to gather expert's opinions on a specific problem[147] and has been previously used to validate physical-activity-related[15] and clinically-related assessment tools.[122] The Delphi method allowed asynchronous interaction with the international expert panel and the experts could complete the surveys at their convenience.[115] The anonymity feature of the Delphi method allowed free communication without influencing experts' opinions with another expert's reputation or field of expertise.[139]

Many authors claim that the Delphi method provides evidence of face and content validity;[136-138] this belief is based on three key assumptions. First, the results come from group opinion, which is assumed to be more valid than a decision made by a single person. Second, the process is based on expert opinion, which provides confirmative judgments on the subject. Third, the experts can suggest items in the first Delphi-round, and the iterative process allows the opportunity to review and judge the appropriateness of the items. However, it is unclear how the validity of the results from a Delphi method can be established; moreover, like any other judgemental method the Delphi method can produce false accuracy, reflecting errors due to lack of rigor in the Delphi process.[128]

We performed three Delphi-rounds. Each Delphi-round consisted of data collection, data analysis, and controlled feedback.[115] This process can be summarized as 1) formulating surveys and statements, 2) sending surveys to the experts, 3) performing analysis of the surveys' responses, 4) writing a feedback report and sending it to the experts.[122] We included the feedback in both the invitation to the next Delphi-round and within the survey to avoid response fatigue related to the time to complete the Delphi-rounds.[154] Figure 3 summarizes the Delphi process.

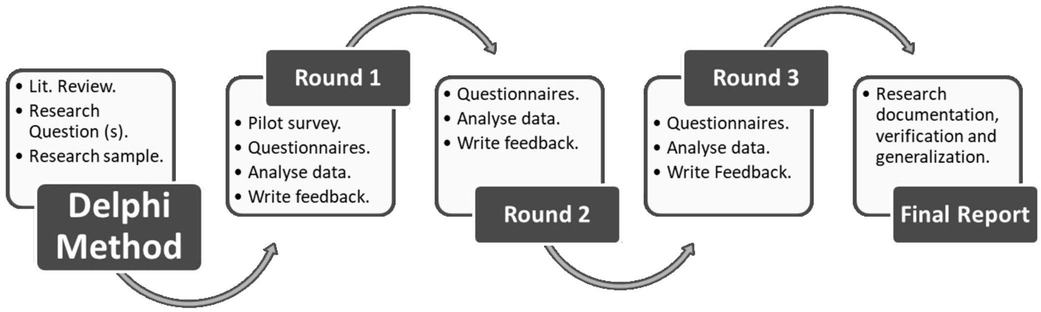

Figure 3. Modified Delphi Method[115]

First Delphi-Round

We invited the experts to participate in the study via e-mail. The e-mail contained information about the study, our objectives, and a link to the first-round survey at the LimeSurvey webpage. The first Delphi-round took 13 weeks to complete. We performed three rounds of invitations due to the low response rate, and we sent reminders each three weeks. The criterion to finish the first-Delphi round was reaching a panel size between ten and 20 experts. We invited 53 experts to participate in the first Delphi-round. Fourteen experts (26.4%) completed the first-round survey, 14 experts (26.4%) either opted out or declined to participate in the Delphi process, and 25 experts (47.2%) did not respond.

The experts accepted our invitation to participate by clicking 'YES' in the consent form, which were at the first page of the first-round survey. We then asked the participants to self-report demographic information and use a 5-point Likert scale to indicate their level of agreement with each of the proposed statements. We asked the participants to indicate if they believed there were missing evaluation criteria or if they felt it necessary to modify any evaluation criterion. Finally, participants were asked to indicate if there were missing movement skills and if the participants indicated yes, they were asked to suggest new movement skills and at minimum seven evaluation criteria for each movement skill. Participants were also given the opportunity to make comments or suggestions regarding the study. We reviewed expert comments and suggestions and made modifications for the second round-survey. We used the following decision rule on the first-round survey results to decide what was the content of the third-round survey.

Table 1. Decision rules for the first Delphi-round.

First Delphi-round results	Action
1. 75% or more of experts scored an item equal or over 4 ("Agree").	The item was not included in the second Delphi-round and was included on a final list for possible ranking.
2. 75% or more of the experts scored an item equal or lower 2 (Disagree).	The item was excluded from the study.
3. 75% or more of experts did not score an item either equal or over 4 ('Agree') or equal or lower 2 ('disagree').	The item was included and re-scored in the second Delphi-round.
4. Experts reported an item as missing.	The item was included in the second Delphi-round, and a new statement is formulated.

Item: a movement skill or evaluation criterion.

We prepared feedback for the experts who completed the first Delphi-round. We included the feedback in both the invitation to the next survey and within the survey. We used this strategy to avoid response fatigue related to the time to complete the next round.[127,161] Feedback within the survey was found on the first page and in the form of percentages and the word 'NEW' in either before or in front of the items. We also indicated what items reached consensus on either being accepted or rejected using the colors green and red respectively.

The first-round feedback consisted of: 1) the group distribution of responses for each item; 2) a report of the movement skills and evaluation criteria included in the final list for possible ranking; 3) a report of the movement skills or evaluation criteria excluded from the study; 4) a report of the movement skills or evaluation criteria suggested by the experts and included in the second-round survey; 5) a report of the modifications made on some aspects of the rationale of the study based on the responses of the open-ended questions. We also prepared individual responses to those experts who have specific questions regarding the study. We gave individual feedback to avoid bias due to participant fatigue product of a large feedback document.[127]

Second Delphi-Round

We performed a second Delphi-round because we did not achieve the objective of reaching consensus on accepting at least four movement skills, each with at least four associated evaluation criteria in the first Delphi-round. We designed the second-round survey to score the movement skills and evaluation criteria that did not achieve consensus on either being accepted or rejected. We updated the evaluation criteria and descriptions and included the new evaluation criteria in the second-round survey. The questions were randomized to avoid any bias in the survey.

The second Delphi-round took in 11 weeks to complete. We performed two rounds of invitations due to the low response rate, and we sent reminders each three weeks. The criterion to finish the second-Delphi round was to at least equalize the panel size (n=14) of the first Delphi-round. We invited 56 experts to participate in the second Delphi-round, and 14 experts (25.0%) completed the second-round survey. First, 39 experts (respondents [n=14] and non-responded [n=25]) were invited, and six experts (15.4%) completed the second-round survey. Second, we identified and invited a new group of experts (n=17), and eight experts (47.1%) completed the second-round survey. Forty-two experts (75.0%) either declined to participate or did not respond.

In the second Delphi-round, we again asked to experts to use a 5-point Likert scale to indicate their level of agreement with each of the proposed. Participants were given the opportunity to make comments or suggestions regarding individual movement skills or evaluation criteria and the study as a whole. We used the following decision rule on the second-round survey results to decide what was the content of the third-round survey.

Table 2. Decision rules for the second Delphi-round.

Second Delphi-round results	Action
1) The expert panel achieved consensus on accepting four movement skills, each with four evaluation criteria.	The objective was accomplished, and the study is completed.
2) The expert panel achieved consensus on accepting four movement skills, each with more than four evaluation criteria.	A new survey is created to rank and establish the top four evaluation criteria.
3) The expert panel achieved consensus on accepting more than four movement skills, each with at least four evaluation criteria.	A new survey is created to rank and establish the top four movement skills and/or criteria.
4) The expert panel achieved consensus on accepting at least four movement skills, but they did not achieve consensus on accepting at least four evaluation criteria associated with each of the accepted movement skills.	A new survey is created following the decision rules used in the first Delphi-round to create the second-round survey.
5) The expert panel did not achieve consensus on accepting at least four movement skills.	A new survey is created following the decision rules used in the first Delphi-round to create the second-round survey.

We prepared feedback for the experts who completed the second Delphi-round. We included the feedback in both the invitation to the next survey and within the survey. We used this strategy to avoid response fatigue related to the time to complete the next round. Feedback within the survey was found on the first page. [127,161]

The second-round feedback was included within the third-round survey and consisted of: 1) a report of the movement skills and evaluation criteria included in the final list for ranking; 2) a report of the movement skills or evaluation criteria excluded from the study. We also prepared individual responses to those experts that have specific questions regarding the study. We gave individual feedback to avoid bias due to participant fatigue product of a large feedback document.[127]

Third Delphi-Round

We performed the third Delphi-round to rank the movement skills and evaluation criteria to identify the top four movement skills and top four evaluation criteria associated with each movement skill. The third Delphi-round took four weeks to complete. We invited 22 experts in the third Delphi-round, and 15 experts (68.2%) completed the third-round survey. We only invited the experts that agreed to participate in the study by clicking 'YES' in the consent form and did not opt-out of the study. We sent reminders at the third and fourth weeks. The criterion to finish the third-Delphi round was to at least equalize the panel size of the first Delphi-round.

In the third round the experts ranked the movement skills and the evaluation criteria, and categorized the accepted movement skills. Experts were asked to categorize the movement skills into four categories: 'locomotor,' 'balance/stability,' 'both,' and 'other.' When an expert categorized a movement skill as other, she/he had a text box to justify her/his response.

The third Delphi-round and final feedback document consisted of 1) a summary of the changes made either in terms, content, or rationale product of experts' comments or suggestions; 2) the list of the movement skills, their descriptions, and the evaluation criteria to establish the movement skills assessment tool.

Trustworthiness in the Delphi Method.

Researchers in traditional hierarchies of evidence consider expert opinion as low evidence (Level 5).[132] For this reason, we aimed to enhance the rigor throughout the Delphi process.[133] There are no standardized guidelines to conduct a Delphi method, and the researchers can modify this method to suit their needs.[129] Some features, such as the number of experts participating, the consistency of knowledge and understanding, the participant self-interest, and ambiguous and imprecise surveys, may affect the results of a Delphi method.[128,130]

In conventional science, criteria such as validity and reliability are used to determine the rigor of a method.[128,130] The Delphi method combines both quantitative (e.g., Likert-scale scores) and qualitative (e.g., opinions) research processes.[128,130] Data from Delphi studies are subjective and qualitative, and personal bias can influence the results.[116,117] Thus, different expert panels could generate different results when responding to the same survey. Experts' judgments can be influenced by the level of experience, qualification, and exposure to the problem being investigated. This can affect the reliability of reporting and the confidence placed in the outcome.[128] Published literature indicates that it is not possible to determine reliability as each Delphi-round (or Delphi method) requires the creation of a new measuring instrument.[115,135] The validity of the Delphi method may depend on the specificity of the research question, who and how many experts can answer it, the inquiry system (e.g., empiricist inquiry system), and the rigor of the sampling criteria.[130] Any detail of methodological and analytical decisions made in the Delphi process must be tracked to increase the validity and reduce criticism.[128-131,139] We used rigorous sampling criteria to ensure consistency in the level of knowledge and understanding of the experts to invite them to participate in the Delphi process.[115]

For interpretative studies, trustworthiness is a more frequent feature. Trustworthiness is when a study findings and conclusions are credible, transferable, confirmable, and dependable.[128,130,131] We aimed to enhance the rigor throughout the Delphi process by using[133] 1) ongoing iteration and feedback to increase credibility;[143] 2) rigorous sampling methods, a detailed description of the experts' participation, and inclusion criteria to increase dependability;[133] 3) a detailed description of the data collection and analysis processes to increase confirmability;[128] and 4) we plan to perform further research to validate and refine the findings to increase transferability.[128]

Statistical Analysis

Quantitative data from the Delphi process was analyzed using descriptive statistics. Consensus on accepting a movement skill or evaluation criterion was achieved when 75% of the expert panel scored an item equal to or higher than 4 ("Agree"). Consensus on discarding a movement skill or evaluation criterion was achieved when 75% of the expert panel scores an item equal to or lower than 2 ("Disagree").[15,122] Expert's responses to the open-ended questions were analyzed to identify the movement skills and evaluation criteria proposed by the expert panel and common ideas regarding the study. In the third round, we assigned inverted point values to the rankings made by the experts. For example, if there were 10 items to be ranked, the first ranked item received 10 points, the second ranked item received nine points and so on. The expert's rankings were added to determine the final ranking and used to establish the most important movement skills to be included in the movement skill assessment tool.

We had missing data in the first Delphi-round. No measure was taken to manage the missing data because the items were independent of each other, and any value did not change the items' status regarding consensus on being accepted or rejected. Literature suggests that simple techniques can be used to replace missing data in Likert type surveys;[160] for example, either median or mean have been used to replace a missing value. However, we performed the data analysis without considering the missing data. The missing value was removed, and the distributions were calculated only with the respondents' inputs.

Results

We proposed 12 movement skills and 84 evaluation criteria based on relevant literature. The expert panel scored the movement skills and evaluation criteria in the first and second Delphi-rounds. In the third Delphi-round, the experts ranked and classified the accepted movement skills and ranked the evaluation criteria. At the end of the Delphi process, four movement skills and 16 evaluation criteria were selected to develop the movement skills assessment tool.

The expert panel

We invited 70 experts, and 22 experts (31.4%) participated in the Delphi process. Fourteen (63.6%), 14 (63.6%), and 15 (68.2%) of the 22 experts participated in the first, second, and third Delphi-rounds respectively. Not all the experts (n=22) completed each round. Six experts (27.3%), completed only the first-round survey. Two experts (9.1%) completed the first- and second-round surveys. One expert (4.5%) completed only the second-round survey. Seven experts (31.8%), completed the second- and third-round surveys. Six experts (27.3%) completed all three surveys. Figure 4 presents the flowchart of the invitation and participation process.

Demographic Characteristics

The most common primary field of expertise was athletic therapy/training (31.8%) followed by motor development (18.2%) with professor (27.3%) as the most common primary affiliation. More than half of the experts had a doctorate (54.5%) and were from Canada (59.1%). The location of the participants included United States of America (18.2%), United Kingdom (13.6%), Australia (4.5%), and Switzerland (4.5%). Table 3 shows the demographic characteristics of the expert panel.

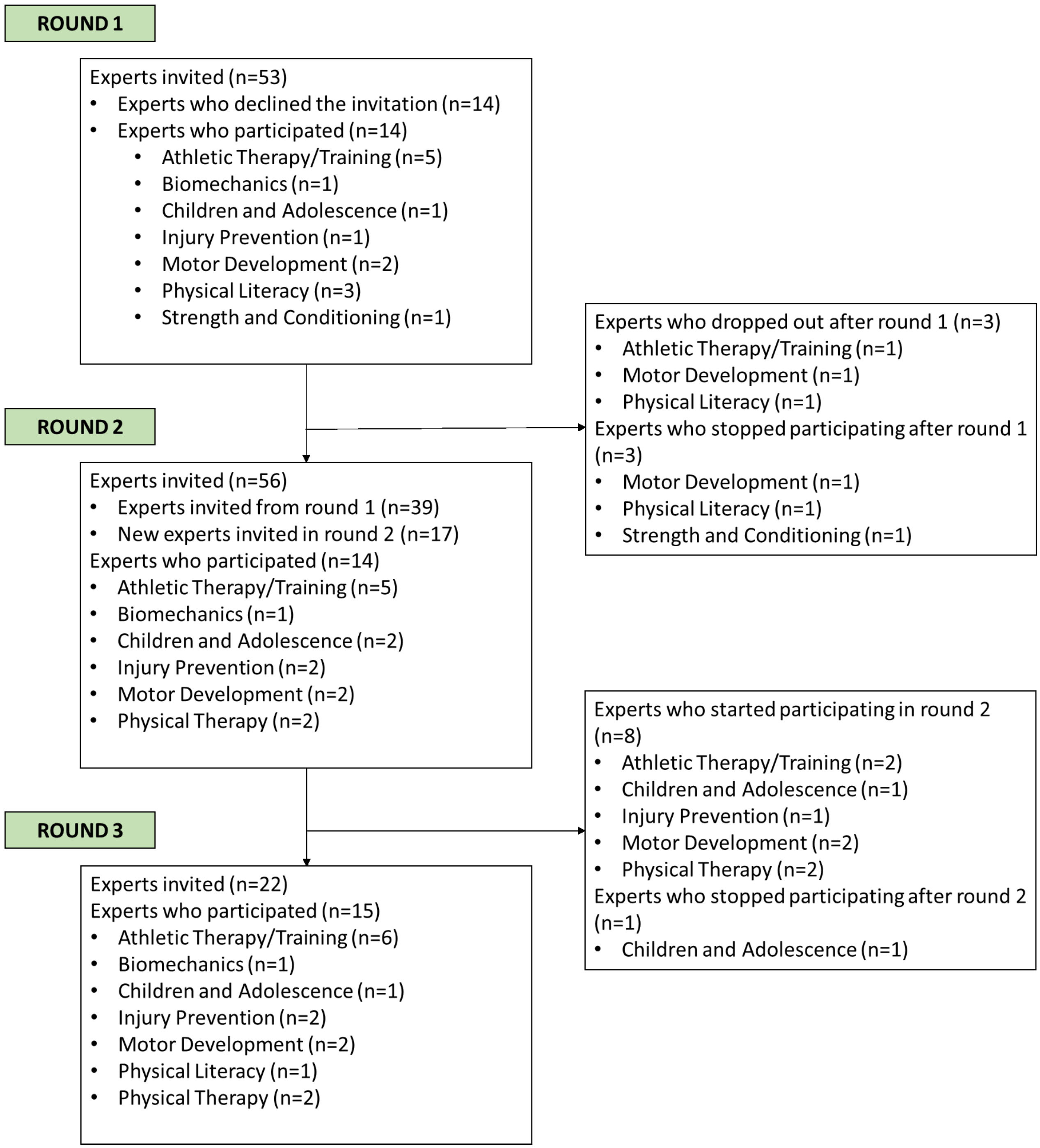

Figure 4. Invitation process used in the modified Delphi method.

Table 3. Demographic characteristics of the panel experts.

Characteristics	Round 1 (n=14)	Round 2 (n=14)	Round 3 (n=15)	Total (n=22)
	n (%)	n (%)	n (%)	n (%)
Gender				
Female	4 (28.6)	6 (42.9)	6 (40.0)	8 (36.4)
Male	10 (71.4)	8 (57.1)	9 (60.0)	14 (63.6)
Age				
22-29	3 (21.4)	3 (21.4)	3 (20.0)	5 (22.7)
30-39	4 (28.6)	3 (21.4)	3 (20.0)	6 (27.3)
40-49	4 (28.6)	3 (21.4)	4 (26.7)	5 (22.7)
50-59	3 (21.4)	4 (28.6)	4 (26.7)	5 (22.7)
60-69	0	1 (7.1)	1 (6.7)	1 (4.5)
Degree				
Bachelor	6 (42.9)	4 (28.6)	6 (40.0)	6 (27.3)
Masters	2 (14.3)	2 (14.3)	1 (6.7)	4 (18.2)
Ph.D., Ed.D., or equivalent	6 (42.9)	8 (57.1)	8 (53.3)	12 (54.5)
Primary field of expertise				
Athletic Therapy	4 (28.6)	3 (21.4)	4 (26.7)	4 (18.2)
Athletic Training	1 (7.1)	2 (14.3)	2 (13.3)	3 (13.6)
Biomechanics	1 (7.1)	1 (7.1)	1 (6.7)	1 (4.5)
Children and Adolescence	1 (7.1)	2 (14.3)	1 (6.7)	2 (9.1)
Injury Prevention	1 (7.1)	2 (14.3)	2 (13.3)	2 (9.1)
Motor Development	2 (14.3)	2 (14.3)	2 (13.3)	4 (18.2)
Physical Literacy	3 (21.4)	0	1 (6.7)	3 (13.6)
Physical Therapy	0	2 (14.3)	2 (13.3)	2 (9.1)
Strength and Conditioning	1 (7.1)	0	0	1 (4.5)
Institution				
University	5 (35.7)	8 (57.1)	8 (53.3)	12 (54.5)
Sports club or team	3 (21.4)	2 (14.3)	2 (13.3)	3 (13.6)
Clinic	2 (14.3)	2 (14.3)	2 (13.3)	2 (9.1)
Government Institution	1 (7.1)	0	0	1 (4.5)
Private (non-profit)	2 (14.3)	1 (7.1)	2 (13.3)	2 (9.1)
Other	1 (7.1)	1 (7.1)	1 (6.7)	2 (9.1)
Primary Affiliation				
Professor (Full professor, associate professor, assistant professor)	3 (21.4)	4 (28.6)	4 (26.7)	6 (27.3)
Lecturer or instructor	2 (14.3)	0	0	2 (9.1)
Research associate or postdoctoral associate	2 (14.3)	4 (28.6)	4 (26.7)	5 (22.7)
Athletic Therapist	3 (21.4)	3 (21.4)	3 (20.0)	3 (13.6)
Other	4 (28.6)	3 (21.4)	4 (26.7)	6 (27.3)
Years of experience				
Under 5	1 (7.1)	1 (7.1)	1 (6.7)	2 (9.1)
5-9	3 (21.4)	3 (21.4)	3 (20.0)	5 (22.7)
10-14	2 (14.3)	2 (14.3)	2 (13.3)	3 (13.6)
15-19	5 (35.7)	5 (35.7)	5 (33.3)	7 (31.8)
20-24	0	1 (7.1)	1 (6.7)	1 (4.5)
25-29	1 (7.1)	1 (7.1)	1 (6.7)	2 (9.1)
30 and over	2 (14.3)	1 (7.1)	2 (13.3)	2 (9.1)

First Delphi-round

We invited 53 experts to participate in the first Delphi-round, and 14 experts (26.4%) completed the first-round survey. Each expert scored 96 items (12 movement skills and 84 evaluation criteria). The expert panel (n=14) scored 1325 of 1344 items. The expert panel achieved consensus on accepting 25 items, six movement skills and 19 evaluation criteria. Consensus was not reached to reject any item. The accepted movement skills were: leaping, single-leg hop, horizontal jump, vertical jump, walking lunge, and bodyweight squat. We received 95 answers to the open-ended questions, 85 answers were related to a movement skill or evaluation criterion, and ten answers were related to the rationale of the study or recommendations for future Delphi-rounds. Table 5 shows the distribution of the results in the second-round survey.

Missing Data

The first Delphi-round missed 19 (1.41%) of the 1344 values. The distribution of the missing data was as follows: Seventeen items (17.8%) had missing data. Two items (2.1%) missed two (14.29%) of the 14 values, and 15 items (15.7%) missed one (7.14%) of the 14 values. We removed the missing data and distributions were calculated only with the respondents' inputs.

Changes made from results of the first Delphi-round

At first, we proposed a scoring system for the movement skills assessment tool based on internal focused cues. The expert panel stated their concern about using instructional cues to evaluate movement competence. After analyzing and discussing the comments, we reworded so that the internal focused cues were in the form of evaluation criteria. Table 4 shows both the internal focused cues and the evaluation criteria.

One expert suggested that 'Sliding' should be renamed to 'Lateral shuffle.' After reviewing the literature and discussing the feasibility and acceptability of the change, we renamed this movement skill. The evaluation criteria and the description remained the same. This new name was intended to fit in various contexts, including sports and fitness.

The expert panel made some comments regarding the descriptions of the movement skills. The descriptions were modified to make them uniform in wording and format. The new descriptions aimed to increase the understanding and consistency of the movement skill, evaluation criteria, and the objective of the movement skill.

The expert panel suggested a series of evaluation criteria for the movement skill assessment tool. We analyzed the suggested evaluation criteria to determine their relationship with movement competence and movement patterns that present risk factors for injury. After discussing and deciding to include the suggested evaluation criteria, we reworded the new evaluation criteria to make it uniform with the previous evaluation criteria and included them in the second-round survey.

Table 4. First Delphi-round quantitative results.

Movement Skills	Internal Focused Cues	Evaluation Criteria	Agreement (%)
Running			71.4
	Keep your head up Keep your chest up	Upper-body straight and eyes focused in the direction travelled	50.0
	Swing bent arms in opposition to the legs	Swing bent arms in opposition to legs	64.3
	Lift your knees	Knee drives upward and forward to lift the foot off the ground	64.3
	Do not let your knees come in	Knees do not come in	64.3
	Keep your Toes pointing forward	Toes pointing forward	50.0
	Land on your heels	Land on the heels	21.4
Leaping			**78.6**
	Keep your head up Keep your chest up	Upper-body straight and eyes focused in the direction travelled	50.0
	Take off from one foot, land on the opposite foot	Take off from one foot, land on the opposite foot	92.3
	Bend the knee when landing	Knee and hip bend to land softly in a controlled fashion	85.7
	Keep your Toes pointing forward	Toes pointing forward	71.4
	Do not let your knees come in	Knees do not come in	64.3
	Do not let your knee go too far in front of your toes	Knees do not go too far in front of the toes	50.0
Single-Leg Hop			**92.9**
	Keep your head up Keep your chest up	Upper-body straight and eyes focused in the direction travelled	50.0
	Take off from one foot, land on the same foot	Take off from one foot, land on the same foot	84.6
	Swing your arms to assist the movement	Swing arms to assist the movement	57.1
	Bend the knee when landing	Knee and hip bend to land softly in a controlled fashion	69.2
	Keep your Toes pointing forward	Toes pointing forward	85.7
	Do not let your knee come in	Knees do not come in	64.3

The items that achieved consensus are in indicated with green color.

Table 4. First Delphi-round quantitative results. Continued.

Movement Skills	Internal Focused Cues	Evaluation Criteria	Agreement (%)
Vertical Jump			**100.0**
	Keep your head up	Upper-body straight and eyes focused forward	42.9
	Swing your arms to assist the movement	Swing arms to assist the movement	78.6
	Bend your knees when landing	Knees and hips bend to land softly in a controlled fashion	85.7
	Do not let your knees come in	Knees do not come in	71.4
	Land in both feet at the same time	Land in both feet at the same time	78.6
	Keep your Toes pointing forward	Toes pointing forward	57.1
	Do not let your knees go too far in front of your toes when landing	Knees do not go too far in front of the toes when landing	57.1
Horizontal Jump			**92.9**
	Keep your toes pointing forward or slightly outward	Toes pointing forward	50.0
	Keep your head up	Upper-body straight and eyes focused forward	46.2
	Swing your arms to assist the movement	Swing arms to assist the movement	78.6
	Bend your knees when landing	Knees and hips bend to land softly in a controlled fashion	85.7
	Land on both feet at the same time	Land on both feet at the same time	85.7
	Do not let your knees come in	Knees do not come in	78.6
	Do not let your knees go too far in front of your toes when landing	Knees do not go too far in front of the toes when landing	57.1
Skipping			**71.4**
	Keep your head up Keep your chest up	Upper-body straight and eyes focused in the direction travelled	57.1
	Alternate step-hop pattern	Alternated step-hop pattern	57.1
	Lift your knees	High knee lift	71.4
	Swing bent arms in opposition to the legs	Swing bent arms in opposition to legs	64.3
	Keep your Toes pointing forward	Toes pointing forward	71.4
	Do not let your knees come in	Knees do not come in	64.3

The items that achieved consensus are in indicated with green color.

Table 4. First Delphi-round quantitative results. Continued.

Movement Skills	Internal Focused Cues	Evaluation Criteria	Agreement (%)
Dodging			**71.4**
	Look where you are going	Eyes focused in the direction travelled	78.6
	Keep your chest up	Upper-body straight	50.0
	Plant one foot and bend the knee to stop	Plant one foot and bend the knee to stop	64.3
	Push off from the external foot to quickly change direction	Push off from the external foot to quickly change direction	71.4
	Swing bent arms in opposition to the legs	Swing bent arms in opposition to legs	46.2
	Lower the body during the change of direction	Knees and hips bend to lower the body during the change of direction	78.6
	Do not let your knees come in	Knees do not come in or out	57.1
Sliding (Lateral Shuffle)			**42.9**
	Keep your head up Keep your chest up	Upper-body straight	53.8
	Bend slightly your knees	Knees are slightly bent	69.2
	Keep your weight on the balls of the feet	Weight on balls of the feet	61.5
	Lead-foot steps in the direction of travel, free foot follows quickly behind	Lead-foot steps in the direction of travel, free foot follows quickly behind	66.7
	Keep your Toes pointing forward	Toes pointing perpendicular to the direction travelled	33.3
	Do not let your knees come in	Knees do not come in or out	53.8
Tuck Jump			**50.0**
	Do not let your knees go too far in front of your toes when landing	Knees do not go too far in front of the toes when landing	64.3
	Bend your knees when landing	Knees and hips bend to land softly in a controlled fashion	84.6
	Immediately jump after landing	Immediately jump after landing	71.4
	Land on both feet at the same time	Land on both feet at the same time	92.9
	Thighs are parallel to the ground while you are in the air	Knees lifted during the flight phase	35.7
	Do not let your knees come in	Knees do not come in	64.3
	Keep your Toes pointing forward	Toes pointing forward	57.1

The items that achieved consensus are in indicated with green color.

Table 4. First Delphi-round quantitative results. Continued.

Movement Skills	Internal Focused Cues	Evaluation Criteria	Agreement (%)
Bodyweight Squat			**92.3**
	Keep your head up Keep your chest up	Upper-body straight and eyes focused forward	64.3
	Keep the heels down all the time	Keep the heels down all the time	85.7
	Lower the body until your thighs are parallel with the ground	Push the hips back and bend the knees until the thighs are approximately parallel with the ground	71.4
	Do not let your knees come in	Knees do not come in	92.9
	Do not let your knees go too far in front of your toes	Knees do not go too far in front of the toes	57.1
	Keep your toes pointing slightly outward	Toes pointing slightly outward	57.1
Walking Lunge			**92.9**
	Keep your head up Keep your chest up	Upper-body straight and eyes focused in the direction travelled	64.3
	Keep the toes and knees in line with the hips	Toes and knees in line with the hips	78.6
	Do not let your knees come in	Knees do not come in	64.3
	Keep the front heel down	Front-heel down	71.4
	Do not let your knees go too far in front of your toes	Front-knee does not go too far in front of the toes	50.0
	Keep your Toes pointing forward	Toes pointing forward	78.6
Forward Roll			**53.8**
	Adopt a squat position with knees between arms	Start in a squat position with knees between arms	64.3
	Keep your chin tucked onto the chest	Chin and knees tucked onto the chest	71.4
	Place your hands on the ground, shoulder width support	Hands placed on the ground, shoulder width apart	57.1
	Extend legs equally to push off the ground	Legs extend simultaneously to push off the ground	50.0
	Roll onto the back of head and shoulders	Roll forward onto the back of shoulders and length of the back	61.5
	Remain in a flexed position to land on feet	Landing on both feet by maintaining a flexed position	57.1
	Roll in a straight line	Roll in a straight line	71.4

The items that achieved consensus are in indicated with green color.

Second Delphi-round

We invited 56 experts to participate, 14 experts (25.0%) completed the second Delphi-round. Each expert scored 98 items, six movement skills and 92 evaluation criteria, we had no missing data in the second Delphi-round. The expert panel achieved consensus on accepting 36 items; two movement skills and 34 evaluation criteria. Consensus on rejecting an item was not achieved. The accepted movement skills were: running and skipping. Table 5 shows the distribution of the results in the second-round survey.

We received 24 answers to the open-ended questions, 20 answers were related to a movement skill or evaluation criterion, and four answers were related to the rationale of the study or recommendations for future Delphi rounds. The experts neither suggested movement skills nor evaluation criteria in the second Delphi-round. We did not modify any item based on the expert's comments in the second Delphi-round.

Table 5. Second Delphi-round quantitative results.

Movement Skill	Evaluation Criteria	Agreement (%)
Dodging		**71.4**
	Upper-body straight	35.7
	Plant one foot and bend the knee to stop	64.3
	Push off from the external foot to quickly change direction	92.9
	Swing bent arms in opposition to legs	42.9
	Knees do not come in or out	42.9
	No twisting nor bending back	28.6
	Hips and shoulders inside feet	57.1
	Clear change in pace and direction	71.4
	Internal foot and hips point on the direction of travel	64.3
Running		**85.7**
	Upper-body straight and eyes focused in the direction travelled	78.6
	Swing bent arms in opposition to legs	100.0
	Knee drives upward and forward to lift the foot off the ground	85.7
	Knees do not come in	71.4
	Toes pointing forward	57.1
	Land on the heels	7.1
	Knee and hip bend slightly to land softly	78.6
	Knee and hip extend to take off	71.4
	Hips do not drop	14.3
	No reaching forward with the foot	14.3
	Free-knee bends in the recovery phase	50.0
Walking Lunge		
	Upper-body straight and eyes focused in the direction travelled	92.9
	Knees do not come in	85.7
	Front-heel down	78.6
	Front-knee does not go too far in front of the toes	85.7
	No twisting nor bending back	85.7
	Shoulder to back-knee in-line	50.0
	Arms move in opposition to legs	57.1
	Weight in the middle of the front-foot	35.7
	High foot lift when stepping	7.1
	Back-knee does not touch the ground	78.6

The items that achieved consensus are in indicated with green color.

Table 5. Second Delphi-round quantitative results. Continued.

Movement Skill	Evaluation Criteria	Agreement (%)
Lateral Shuffle		**57.1**
	Upper-body straight	57.1
	Knees are slightly bent	92.9
	Weight on balls of the feet	78.6
	Lead-foot steps in the direction of travel, free foot follows quickly behind	71.4
	Toes pointing perpendicular to the direction travelled	42.9
	Knees do not come in or out	42.9
	Hips do not drop	21.4
	Hips and shoulders inside feet	50.0
Tuck Jump		**42.9**
	Knees do not go too far in front of the toes when landing	85.7
	Immediately jump after landing	78.6
	Knees lifted during flight phase	78.6
	Knees do not come in	64.3
	Toes pointing forward	57.1
	Knees together during the jump	64.3
	Toes pointing down during the jump and pointing forward during the landing	35.7
	Upper-body straight and eyes focused forward	64.3
	Arms swing forward and upward to assist the movement	92.9
Horizontal Jump		
	Toes pointing forward	42.9
	Upper-body straight and eyes focused forward	50.0
	Knees do not go too far in front of the toes when landing	64.3
	Body extension during flight phase	57.1
Single-Leg Hop		
	Upper-body straight and eyes focused in the direction travelled	71.4
	Swing arms to assist the movement	92.9
	Knee and hip bend to land softly in a controlled fashion	92.9
	Knees do not come in	71.4
	Hips do not drop	35.7
	Knee bends and moves slightly forward when springing	28.6
	Arms up for balance	35.7
	Hip, knee, and toes aligned	78.6
Skipping		**92.9**
	Upper-body straight and eyes focused in the direction travelled	71.4
	Alternated step-hop pattern	92.9
	High knee lift	71.4
	Swing bent arms in opposition to legs	92.9
	Toes pointing forward	78.6
	Knees do not come in	50.0

Table 5. Second Delphi-round quantitative results. Continued.

Movement Skill	Evaluation Criteria	Agreement (%)
Forward Roll		**42.9**
	Start in a squat position with knees between arms	78.6
	Hands placed on the ground, shoulder width apart	78.6
	Chin and knees tucked onto the chest	85.7
	Legs extend simultaneously to push off the ground	57.1
	Roll forward onto the back of shoulders and length of the back	78.6
	Landing on both feet by maintaining a flexed position	71.4
	Arms reach forward to stand up	42.9
	Roll in a straight line	71.4
Bodyweight Squat		
	Upper-body straight and eyes focused forward	71.4
	Push the hips back and bend the knees until the thighs are approximately parallel with the ground	92.9
	Knees do not go too far in front of the toes	78.6
	Toes pointing slightly outward	42.9
	Knees and toes aligned	92.9
	Weight in the middle of feet	57.1
	Feet are shoulder width apart	71.4
Vertical Jump		
	Upper-body straight and eyes focused forward	57.1
	Knees do not come in	85.7
	Toes pointing forward	64.3
	Knees do not go too far in front of the toes when landing	71.4
	Body extension during flight phase	71.4
Leaping		
	Upper-body straight and eyes focused in the direction travelled	57.1
	Toes pointing forward	78.6
	Knees do not come in	64.3
	Knees do not go too far in front of the toes	64.3
	Swing bent arms in opposition to legs	92.9
	Knee bends and moves slightly forward to leap forward	71.4
	Hip, knee, and toes aligned	92.9

The items that achieved consensus are in indicated with green color.

Third Delphi-round

The third-round survey included the items that achieved consensus in both the first and second Delphi-rounds. The expert panel achieved consensus on eight movement skills, each with at least four associated evaluation criteria. One movement skill (skipping) was accepted, but it had only three accepted evaluation criteria, so we discarded it.

Each expert ranked seven movement skills and a series of evaluation criteria. The expert panel (n=15) ranked 450 items. Four movement skills (leaping, walking lunge single-leg hop, and bodyweight squat) had more than four evaluation criteria. The expert panel ranked 23 evaluation criteria associated to these five movement skills to establish the top four evaluation criteria per movement skill. Table 6 shows the results of the third Delphi-round. Additionally, the expert panel categorized the movement skills. The categories were 'locomotor,' 'balance/stability,' 'both,' and 'other.' Figure 5 shows the categorization of the accepted movement skills.

Some experts expressed that the movement skills bodyweight squat, horizontal jump, and vertical jump should be considered as strength and conditioning exercises rather than locomotor, stability/balance, or both.

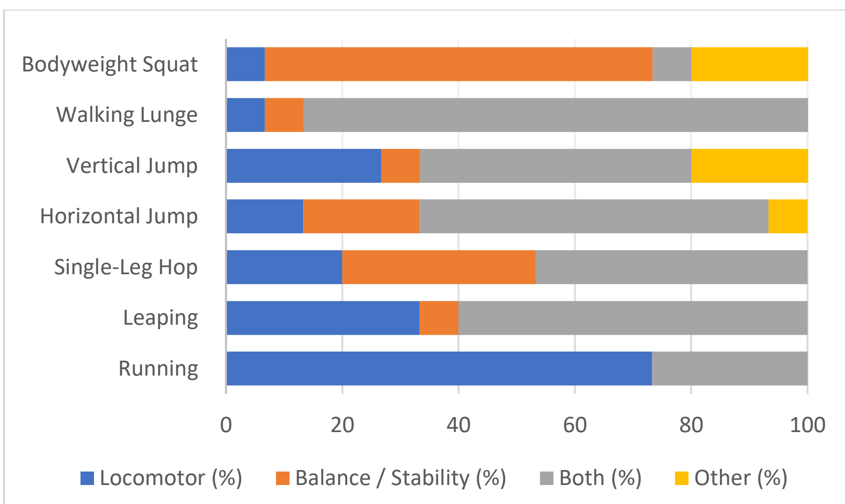

Figure 5. Distribution of categories of the movement skills.

After the third Delphi-round the expert panel reached consensus on accepting four movement skills, each with associated evaluation criteria. The top four movement skills were: 1) bodyweight squat, 2) single-leg hop, 3) running, and 4) horizontal jump. Table 7 shows the final list of movement skills and evaluation criteria.

Table 6. Final ranking of movement skills and evaluation criteria.

Movement Skills	**Score**	**Rank**
Bodyweight Squat	110	1
Single-Leg Hop	96	2
Running	95	3
Vertical Jump	93	4
Horizontal Jump	91	5
Walking Lunge	90	6
Leaping	58	7
Evaluation Criteria (Walking Lunge)	**Score**	**Rank**
Toes and knees in line with the hips	92	1
Upper-body straight and eyes focused in the direction travelled	89	2
Knees do not come in	88	3
Front-knee does not go too far in front of the toes	69	4
No twisting nor bending back	63	5
Toes pointing forward	55	6
Front-heel down	53	7
Back-knee does not touch the ground	31	8
Evaluation Criteria (Single-Leg Hop)	**Score**	**Rank**
Hip, knee, and toes aligned	53	1
Take off from one foot, land on the same foot	51	2
Knee and hip bend to land softly in a controlled fashion	50	3
Swing arms to assist the movement	43	4
Toes pointing forward	28	5
Evaluation Criteria (Bodyweight Squat)	**Score**	**Rank**
Push the hips back and bend the knees until the thighs are approximately parallel with the ground	60	1
Knees and toes aligned	47	2
Knees do not come in	46	3
Knees do not go too far in front of the toes	38	4
Keep the heels down all the time	34	5
Evaluation Criteria (Leaping)	**Score**	**Rank**
Take off from one foot, land on the opposite foot	49	1
Knee and hip bend to land softly in a controlled fashion	48	2
Hip, knee, and toes aligned	48	3
Swing bent arms in opposition to legs	46	4
Toes pointing forward	34	5

Table 7. List of accepted movement skills, descriptions, and evaluation criteria.

Bodyweight Squat	**Evaluation Criteria**
Description: Squatting involves flexing the knees and hips allowing the hips to move back while lowering the center of gravity. The feet are in a comfortable distance apart and the hands are placed either crossed on the chest or extended out in front of the body. The movement should be smooth, and the child will have three trials.	Push the hips back and bend the knees until the thighs are approximately parallel with the ground
	Knees and toes aligned
	Knees do not come in
	Knees do not go too far in front of the toes
Single-Leg Hop	**Evaluation Criteria**
Description: Single-Leg Hop is performed by small forward jumps taking off from one foot and landing on the same foot. The movement should be smooth, and performed equally on both sides. Single-Leg Hop will be evaluated on a 10-meter space marked by cones, and the child will have two trials on each side.	Hip, knee, and toes aligned
	Take off from one foot, land on the same foot
	Knee and hip bend to land softly in a controlled fashion
	Swing arms to assist the movement
Running	**Evaluation Criteria**
Description: Running is faster than walking, but it is not sprinting. It will present the pattern of heel strike-midfoot-forefoot and a flight phase. The movement should be smooth. Running will be evaluated over 20 meters marked by cones where the child will run and come back.	Upper-body straight and eyes focused in the direction travelled
	Swing bent arms in opposition to legs
	Knee drives upward and forward to lift the foot off the ground
	Knee and hip bend slightly to land softly
Vertical Jump	**Evaluation Criteria**
Description: Vertical jump is the action of propelling the body up into the air from the ground using both legs and landing with both feet. The child will have three trials.	Swing arms to assist the movement
	Knees and hips bend to land softly in a controlled fashion
	Land on both feet at the same time
	Knees do not come in

Discussion

This study established the face and content validity of four movement skills with four associated evaluation criteria to be included in a movement skills assessment tool. We proposed 12 movement skills including locomotor skills,[43] basic human movements[30] (e.g., squat), and fundamental movement patterns[162,163] (e.g., lunge) to develop the movement skill assessment tool. The proposed movement skills aimed to be in line with the motor development and injury prevention literature and were expected to be valid and used to assess movement competence in 8-12-year-old children. We explored different models of motor development and identified movement skills, in which 8-12-year-old children should be proficient, to compare them with the movement skills used in injury prevention strategies.

We used the modified Delphi method because gathering the experts to meet face to face was not feasible for this study, for we invited experts from different countries (e.g., Canada, United States, Australia) and movement-related fields (e.g., motor development, athletic therapy, athletic training, physical therapy, physical literacy). We avoided common problems in 'face to face' meetings, such as dominant personalities or the 'focusing effect' where groups go through a single idea during a long period rather than considering the 'larger picture.'[126] The Delphi method allowed asynchronous interaction with the expert panel,[115] for the experts could complete the surveys at their convenience within a defined period of time. The anonymity feature of the Delphi method allowed free communication without influencing experts' opinions by another expert's reputation or field of expertise.[116] Thus, the decisions and conclusions are more likely to be based on the merit of our proposal rather than how a specific expert scored our proposal.

The Delphi method has inherent uncertainties including the meaning of consensus, the applicability of the method to a specific problem, the criteria for defining an expert, the design and administration of the surveys, the feedback, and the different types of Delphi techniques used in research.[128] We defined consensus of 75% of agreement based on existing literature.[75] The experts were identified using the Knowledge Resource Nomination Worksheet,[115] and we used a modified Delphi method after identifying and proposing the movement skills and evaluation by performing a literature review.

Movement Skills Assessment Tool

The accepted movement skills may give us a broad picture of children's movement competence and injury risk profile. The movement skills included in the movement skills assessment tool aim to complement each other and are used in both motor development and injury prevention fields. The movement patterns of the bodyweight squat and the walking lunge are related to other fundamental movement skills.[31,163] The Jumping tasks aim to assess jump-landing mechanics.[35,175] Leaping and Single-Leg Hop aim to detect lower limb imbalances and asymmetries.[35]

The movement skills assessment tool aims to identify movement patterns that lead to increased stress in joints and soft tissues and may compromise muscle activity, mobility, and stability.[38] We performed this modified Delphi process to bridge the gap between laboratory identification of injury risk factors and in-field assessment of movement competence. The movement skills assessment tool aims to be a guide for practitioners, clinicians, and academics to identify and target corrections for biomechanical deficits before participation in more advanced and intense physical activities and sports. The movement skills assessment tool can provide an alternative option to: 1) expensive and sophisticated laboratory evaluation (e.g., motion analysis) to identify biomechanical deficits; 2) non-practical/-feasible injury screening tools for physical education class, sports teams, and physical activity; 3) movement competence assessment tools, which has not been designed considering both motor development and injury prevention strategies.

Bodyweight Squat

Some experts expressed their concerns about classifying the bodyweight squat as a fundamental movement skill. Bodyweight squat was categorized by the expert panel as a 'Balance/Stability' skill (66.7%) and 20% (n=3) of the expert panel considered this movement skill as strength and conditioning exercise.

Many authors have categorized and analyzed the squat pattern. Literature suggests that the squat can be used to assess an individual for neuromuscular control, stability, strength, and mobility within the kinetic chain.[30,166,35] Assessing and correcting the squat may help children become prepared for the rigorous demands of physical activity and sports participation.[30]

Myer et al. (2014) considered the squat as a fundamental movement pattern and proposed a strategy for its assessment.[30] Tompsett et al. (2015) categorized the squat as a basic human movement, which is the precursor of other fundamental and specialized movement skills.[173] Chek (2000) categorized the squat as a fundamental movement pattern which is related to activities of daily living, physical activity, and sports specific training.[162] Kritz et al. (2009) also identified the squat as a fundamental movement pattern and suggested that the bodyweight squat can be used to screen for the squat pattern.[172] Cook et al. (2010) use the deep squat in the Functional Movement Screen (FMS) to assess functional, symmetrical, and bilateral mobility of the hips, knees, and ankles.[38] Lubans et al. (2014) considered the bodyweight squat as a resistance training skill and included it in a resistance training skill battery for adolescents.[174]

The bodyweight squat can be used to identify biomechanical deficits that may result in deficient movement patterns.[31-32] Deficient movement patterns may influence lower- and upper-limb kinematics and kinetics and compromise performance and injury resilience during training and dynamic sports.[30-32,168] Deficits during the squat are categorized elsewhere as 1) Inefficient motor unit coordination or recruitment (i.e., neuromuscular); 2) muscle weakness; 3) strength asymmetry or joint instability; 4) joint immobility or muscle tightness.[175] The squat has direct biomechanical and neuromuscular implications in dynamic tasks related to sports and physical activities enjoyed by children, adolescents, and young adults (e.g., jumping, running).[31,90,45,165,166]

Bodyweight Squat: Evaluation Criteria

A combination of the proposed evaluation criteria presents a proper depth, where the femurs are parallel to the ground, hips are back, tibias are positioned vertical (in the frontal plane), and feet are flat on the floor.[30] Common technical elements and movement patterns should be identified to understand how the accepted evaluation criteria are related to the squat technique and possible biomechanical deficits.

The assessment of the squat can be divided into the upper- and lower-body domains[30] The upper body domain focus on the stability and posture of the head, neck, and torso.[30] The lower body domain focus on the joint positions of the hips, knees, and ankles during the squat.[169] The proposed and accepted evaluation criteria focused on the lower-body domain.

We did not propose any evaluation criterion related to the stance while performing the bodyweight squat; however, we stated that the feet should be shoulder-width apart in the description of the movement skill. A shoulder-width stance may help to avoid excessive load on the knee joint and standardize the assessment.[30] Escamilla et al. (2001) assessed the kinematics and kinetics of the squat at three different widths.[165] A wide stance may increase patellofemoral and tibiofemoral loads in the knee joint by up to 15% during the descent phase. An extremely narrow stance may increase forward knee translation and anterior shear forces.[166,175]

The evaluation criterion 'Push the hips back and bend the knees until the thighs are approximately parallel with the ground' does not include the ankle flexion, but it consists of the level in which the thighs should be at the end of the descent phase.[167,175] The expert panel achieved consensus on including this evaluation criterion in the first Delphi-round, and it was ranked first on the third Delphi-round. There is no evidence suggesting that squatting below the proposed parallel increases injury risk to the ligaments or menisci of the knee.[175] The most common deficit of depth during the squat is from the children squatting too shallow.[30] The child may lack isometric strength in the posterior chain to maintain bodyweight support at the apex of depth.[30] Tightness in the muscles of the posterior chain and hip adductors may further limit the ability of a child to achieve appropriate depth.[30]

We do not include any evaluation criteria to assess the ascent phase of the squat. This is a limitation of this study, and future research is warranted. The ascent phase of the squat should follow the same path as the descent phase.[30,175] The upper-body of the child should remain stable, and the shoulders and hips should rise at the same pace. The vertical distance between the shoulders and hips should stay the same.[30,176] The hips commonly raise faster than the shoulders in the early stages of learning, which would increase trunk flexion.[30]

Bodyweight Squat: Frontal Plane

The goal position, in the frontal plane, is to have the tibia in vertical alignment perpendicular to the floor, allowing error to lateral knee positions.[30,169] From an observational standpoint, the medial knee motion (knee valgus) is a much more common deficit relative to lateral knee motion (knee varus).[30] Thus, we proposed the evaluation criterion 'knees do not come in'. This evaluation criterion was accepted in the first Delphi-round and ranked third in the third Delphi-round. Additionally, the evaluation criterion 'Knees and toes aligned' was proposed after the first Delphi-round, accepted in the second Delphi-round, and ranked second on the third Delphi-round.

Knee valgus can be product of poor neuromuscular control and lack of function or strength of the lower-body musculature, especially the posterior chain complex.[30] Active valgus (i.e., hip adduction and knee abduction resulting from muscular contraction) is often the cause for observed dynamic valgus during the squat.[169] Dynamic valgus is defined as "the position or motion, measured in 3 dimensions, of the distal femur toward and the distal tibia away from the midline of the body."[176]

Weakness in the ankle musculature is associated with faulty movement patterns while squatting. A lack of strength in the medial gastrocnemius, tibialis anterior and tibialis posterior decreases the children's ability to control knee valgus. Foot pronation motions may contribute to excessive medial knee displacement and dynamic valgus.[166]

Bodyweight Squat: Sagittal Plane

The expert panel achieved consensus on accepting the evaluation criterion 'Knees do not go too far in front of toes' in the second Delphi-round. This evaluation criterion ranked fourth in the third Delphi-round. Excessive anterior translation of the knees over the toes is suggested to increase shearing forces on the knee and higher extensor torque.[170] However, there is no known evidence of a defined point in which the injury risk exceeds the potential benefits during the squat.[30] A conscious effort to limit forward knee translation has been shown to increase forward trunk lean, resulting in higher forces at the hip and spine, increasing the risk of injury in those joints.[170,171] Pushing the hips back at the initiation of the squat movement may decrease the load to the knees and posterior chain, which is also a safer strategy for the lumbar spine.[31] We proposed the evaluation criterion 'Push the hips back and bend the knees until the thighs are approximately parallel with the ground' to find deficits on this specific movement pattern.

In the sagittal plane, the children should attempt to match the tibia angle in parallel with an upright trunk, while keeping the feet flat on the floor.[30] Often weak glutes influence the body to use a strategy to place a load on the knees, increasing tibia progression.[31] Excessive tibial progression angle can also be generated either by weakness in calf, soleus, and hamstrings or by quadriceps dominance.[30] Restricted hip and ankle mobility may also hinder proper tibial progression angle.[30]

Bodyweight Squat: Foot Position

We proposed the evaluation criterion 'Keep the heels down all the time' to ensure the individual feet are stable and planted on the ground.[30] The expert panel achieved consensus on accepting this evaluation criterion in the first Delphi-round and ranked it fifth in the third Delphi-round. Allowing the heels to rise off the ground is suggested to lead to compensatory torques in the ankles, knees, hips, and lumbar spine.[167] Additionally, with heels raised off of the ground, the athlete has a smaller surface area as a base of support, which may reduce the children's ability to perform a controlled and balanced squat.[30]

The expert panel did not achieve consensus on accepting the evaluation criterion 'Toes pointing slightly outward.' This evaluation criterion aims to promote normal patella tracking.[169,175] Extreme tibial rotation in a closed kinetic chain movement may lead to increased loads on the static knee structures and should be avoided for most squat variations.[30]

Walking Lunge

We proposed the walking lunge to observe the process of the forward lunge pattern in consecutive steps. The forward lunge can be described as an extended forward step, flexing the lead hip and knee and dorsiflexing the lead ankle while lowering the body toward the floor.[177,187] The lunge as an extended forward step is related to any bipodal locomotor skill (e.g., running, leaping). 86.7% (n=13) of the expert panel categorized the walking lunge as both 'Locomotor' and 'Balance/Stability' skill. A movement skill under the "Both" category may assess dynamic stability, which is essential for integrative neuromuscular training and injury prevention programs.[35]

The lunge pattern is considered as a fundamental movement pattern due to its occurrence in activities of daily living, physical activity, and sports.[162,163] Using the lunge to identify and correct faulty movement patterns before increasing training loads and performing other movement skills may enhance children's movement competence, injury resilience, and long-term development.[163]

Kritz et al. (2009) considered the lunge as a fundamental movement pattern and proposed the forward lunge to screen the lunge pattern.[163] Crill et al. (2004) studied the reliability, gender differences, and the relationship between lunge distance and height.[187] Cook et al. (2010) included the inline lunge and the hurdle step in the Functional Movement Screen to assess the bilateral functional mobility and stability of the torso, shoulder, hips, knees, and ankles.[38] Lubans et al. (2014) considered the lunge as a resistance training skill and included it in a resistance training skill battery for adolescents.[174]

The variables that may affect the ability of the children to perform the lunge pattern are related to either anthropometric variables, laterality, previous injury, or lack of coordination, range of motion, and stability.[38,163]

Walking Lunge: Evaluation criteria

The proposed evaluation criteria aimed to assess body alignment in extended forward steps. The walking lunge assesses bilateral performance to identify asymmetries and imbalances that may lead to injury.[38,163] Common technical elements and movement patterns should be identified to understand how the accepted evaluation criteria are related to the lunge technique and possible biomechanical deficits.

Literature suggests that the torso should remain stable and vertical with the lumbar spine in a neutral position.[38,177] We proposed evaluation criteria related to the upper-body. The expert panel achieved consensus on accepting the evaluation criteria 'Upper-body straight and eyes focused in the direction travelled' and 'No twisting nor bending back'; these evaluation criteria were ranked second and fifth respectively. The evaluation criteria 'Shoulder to back-knee in-line', and 'Arms move in opposition to legs' were proposed, but the expert panel did not achieve consensus on accepting them.

Regarding the performance of the walking lunge, we proposed the evaluation criteria 'High foot lift when stepping', but the expert panel did not achieve consensus on accepting it. The evaluation criterion 'Back-knee does not touch the ground' was accepted and ranked eighth.

Walking Lunge: Foot Position

The inability to control foot position and the lack of ankle mobility are related to movement strategies that are identified as injury mechanisms.[38,183] Kovacs et al. (1999) and Flanagan et al. (2003) found that various positions of the ankle and foot during activities of daily living and sports (e.g., squatting and lunging) resulted in increased forces at the knee and hip.[178,179]

During the performance of a lunge pattern, faulty movement strategies may be present when the toes extremely point either inward or outward, and the lead heel lifts off the ground.[163,179] Regarding foot position, we proposed the evaluation criteria 'Toes pointing forward', 'Front-heel down,' and 'Weight in the middle of the front-foot.' The expert panel achieves consensus on accepting 'Toes pointing forward' and 'Front-heel down,' and they were ranked sixth and seventh respectively. 'Weight in the middle of the front foot' was not accepted.

Walking Lunge: Frontal Plane

Since the knee is not designed to adapt excessive mediolateral or anteroposterior movement,[180,181] we proposed the evaluation criteria 'Toes and knees in line with the hips' and 'Knees do not come in' which were accepted by the expert panel. The cause of the mediolateral movement of the lead knee during a forward lunge may be related to poor strength or activation of the rectus femoris, hamstrings, and hip abductor and adductor muscles.[38,182] During a forward lunge, the knees of the lead and trail legs should be aligned with the hips and ankles during flexion and extension in the ascent and descent phases.[38,163,177]

Walking Lunge: Sagittal Plane

In the sagittal plane, the lead knee should be over the lead foot, and the lead heel should remain in contact with the ground as the child's center of mass moves toward the ground.[163] If the center of mass moves forward, the lead tibia translates anteriorly, and the lead heel raises from the ground, an increase in patellofemoral shear force may be present.[170,171] Considering the anterior tibial translation, we proposed the evaluation criteria 'Front-heel down' and 'Front-knee does not go too far in front of the toes,' and the expert panel achieved consensus on accepting them.

Locomotor Skills

The expert panel accepted the locomotor skills 'running,' 'horizontal jump,' 'vertical jump,' 'leaping,' and 'single-leg hop.' These movement skills are considered as fundamental movement skills (Locomotor skills) in motor development[23] and physical literacy literature.[21,22] A high percentage of the expert panel (73.3%) classified running as a 'Locomotor' skill while leaping (60.0%) and single-leg hop (46.7%) were categorized as both 'Locomotor' and "Balance/Stability' skills.

The accepted movement skills have been used in other process-based movement competence assessment tools such as TGMD-2, Get Skilled Get Active. Recently, Hulteen et al. (2018) proposed evaluation criteria to assess running with injury strategies in mind for adolescents.[188] Running and single-leg hop have been analyzed in biomechanical studies, and technical elements and deficits have been identified.[35,189]

Locomotor Skills: Running

Running at any speed is characterized by a flight phase were either one leg or no leg striking the ground throughout the gait cycle.[190] Running shows increased step length and cadence compared to walking.[191] We analyzed the biomechanical elements of running to propose the evaluation criteria.

Stride length is the distance from initial contact of one foot until the same foot makes contact with the ground again. Step length is the distance between initial contact of one foot and the initial contact of the opposite foot. Cadence is the number of steps taken in a certain amount of time.[190] As running cadence, stride, and step length increase, velocity and ground reaction forces increase. These forces increase the stress in joints of the lower limbs and the risk for musculoskeletal injuries.[190,191]

Running should be evaluated because it is involved in many physical activities and sports. This locomotor skill requires a greater range of motion of all lower limb joints than walking.[190] Running also presents a higher amount of eccentric muscle contraction than walking because of the higher impact forces.[96] The biggest issue with running remains the high injury rate. Approximately 50% of runners experience an injury yearly, and 25% are injured at any given time.[193]

Locomotor Skills: Single-Leg Hop and Leaping

Previous reviews suggest single-leg jumps and hops are valid and reliable field-based neuromuscular control assessment tools.[35] We proposed the single-leg hop and leaping, which involve taking off from one leg and landing in either the same or the opposite leg. These movement skills have been suggested to identify differences in the execution of lower limb muscular imbalances and observable biomechanical deficits (e.g., knee valgus, stiffer landing mechanics, poor trunk stabilization).[196,199]

Single-leg jumps and holds, as unilateral tasks, may be preferred to bilateral variations due to their higher sensitivity for determining asymmetrical deficits in neuromuscular control.[202] Research suggests that the ability to decrease force during single limb landing and subsequently regenerate and direct motion may be a key factor for reducing the risk of injury.[201] Although children have a preferred plant leg and preferred kick or drive leg,[184] neuromuscular tests should attempt to identify lower limb asymmetries and muscle imbalances. Asymmetry in force and torque profiles have a higher risk of injury.[35]

Locomotor Skills: Horizontal Jump and Vertical Jump

The expert panel achieved consensus on accepting horizontal jump and vertical jump. These movement skills were classified as both 'Locomotor' and 'Balance/Stability' skills. Assessing the jump-landing maneuver with both horizontal and vertical displacement is essential for physical literacy[21,22] and motor development programs;[23,159] similarly, landing mechanics are crucial to injury risk screening.[111]

Jump-landing actions with rapid decelerations and stops frequently occur in many sports.[85] These jump-landing actions have been associated with injuries such as stress fractures,[199] patellar tendinopathy (PT),[203] patellar femoral pain syndrome (PFPS),[189] ACL injury,[111,184-186,196,197] and ankle sprain.[178] The jump-landing sequence requires good coordination, muscle control, dynamic stability, and flexibility.[176] Deficient jump-landing mechanics may increase valgus strain on the knee during take-off and landing, and decrease the absorption of ground reaction forces.[184] This mechanism generates more stress on the knee joint, which then increases the risk of injury occurrence.[176]

Since many researchers suggested a relationship between jump-landing and musculoskeletal injuries,[111,176,185,203] identifying neuromuscular and biomechanical risk factors and malalignments in jump-landing tasks may help to determine which children are at risk of lower extremity injuries.[175] These variables are easily determined in a laboratory setting, but using them to screen individuals in the field is complicated, time-consuming, and expensive.[175]

Evaluation Criteria: Locomotor Skills

We proposed evaluation criteria to identify risk factors for musculoskeletal injuries. The accepted evaluation criteria are consistent in all the accepted movement skills. Each movement skill has at least one accepted evaluation criterion that differentiates it from the others and assesses its expected execution. The evaluation criteria are based on neuromuscular risk factors for lower limb injuries which can be categorized into leg dominance, quadriceps dominance, ligament dominance, trunk dominance, and reduced dynamic stability.[35,184] Hewett et al. (2010) suggested that lower limb kinematics should be screened and identified[184] to help clinicians, practitioners, and academics to propose and implement effective injury prevention strategies.

The evaluation criteria were also proposed to complement each other because an evaluation criterion may mean nothing without associating it with other evaluation criteria.[38] For example, a consistent knee valgus in all the movement skills may identify a child with increased risk for lower limb injury; moreover, if a knee valgus and reduced hip flexion are combined, the risk of injury may increase.[111] The evaluation criteria follow the rationale of process-based assessment and screening tools and focus on specific movement patterns to asses movement competence and identify any possible risk of injury.

Locomotor Skills: Frontal Plane

Regarding lower limb alignment in the frontal plane, we focused on the position of the knee and proposed the evaluation criteria 'Knees do not come in' and 'Hip, knee, and toes aligned.' 'Knees do not come in' was accepted for horizontal jump and vertical jump. 'Hip, knee, and toes aligned' was accepted for leaping and single-leg hop.

Boden et al. (2009) suggest that repeated performance of faulty movement patterns with insufficient hip control of motion leads to the valgus collapse and a possible ACL rupture. [198] Hewett et al. (2005) observed that hip adduction, knee abduction, and ankle eversion contribute to the position of dynamic valgus.[164]

Ligament dominance is a neuromuscular imbalance that refers to the primary use of anatomic (bony configuration and articular cartilage) and static stabilizers (ligaments) rather than the muscular prime movers to absorb the ground reaction forces.[184,185] The knee joint and ligaments absorb the high amounts of force in a short time period, which may result in ligament rupture.[184] The muscles of the posterior kinetic chain (e.g., gluteal muscles, hamstrings, gastrocnemius, and soleus) are essential for lower limb muscular control and avoidance of ligament dominance. These muscles must be adequately recruited to absorb reaction forces.[185] Forces experienced during landing, cutting, running, and jumping tasks performed during sports and physical activities may be higher than two or three times the individual's body mass.[184]

Locomotor Skills: Sagittal Plane

Padua et al. (2009) stated that the knee flexion angle influences ACL loading. Quadriceps contractions at low knee flexion angles (0°-30°) can generate anterior shear forces the lead to increased knee loading.[111] Video analysis showed that most non-contact ACL injuries occur during a sharp deceleration or landing action with the knee close to extension at initial ground contact.[196] Thus, quadriceps dominance is a muscular imbalance that refers to the primary use of the quadriceps to stiffen and stabilize the knee joint.[35,184] The quadriceps tendon pulls the tibia anteriorly relative to the femur, and the ACL helps to avoid excessive anterior tibial translation.[184,111]

The evaluation criterion 'Knee(s) and hip(s) bend to land softly in a controlled fashion' was accepted for the movement skills single-leg hop, leaping, horizontal jump, and vertical jump. We proposed this evaluation criterion to identify deficits in landing mechanics and the child's capacity to absorb ground reaction forces. A sustained extended position of the hip during jump-landing tasks may indicate a restricted hip flexion active motion.[176] Restricted hip motion and restricted knee flexion motion increase the strain on the patellar tendon and may increase the risk of lower limb injuries such as patellofemoral syndrome.[176,203]

Individuals should use the muscles of the posterior chain, which possess multiple tendon insertions, to control the lower limb during functional tasks (e.g., running, landing).[184] For instance, hamstrings tendons can work in the opposite direction of the quadriceps tendon in specific knee flexion angles.[184,196,199] The hamstrings are a synergist with the ACL and can pull the tibia posteriorly to decrease the stress on the ACL.[184] When the knee joint is extended, the hamstrings act in parallel to the ACL, so the hamstrings' potential to neutralize anterior tibial stress to the ACL is affected.[199]

A stiffer jump-landing technique is a risk factor for the development of both overuse and acute injuries.[176] Limited active hip flexion range of motion and reduced knee active range of motion prevent the knee from following normal flexion mechanics and lead to decreased absorption of ground reaction forces.[198] This deficient landing mechanics increases the stress on passive structures (e.g., ligaments and tendons).[176,198]

Landing mechanics are also crucial for running since the lower limb absorbs up to three times body weight when the foot strikes the ground.[192] Knee and hip bend slightly to land softly' was accepted and aims to assess landing mechanics in the sagittal plane.

Locomotor Skills: Upper-Body

Trunk dominance is the inability to control the trunk in three-dimensional space precisely.[184] Individuals who do not adequately sense the position of their trunk have a higher risk of knee, ligament, and ACL injury.[186,197,199,200] In children, trunk dominance may be related to growth and maturation factors.[184] 'Upper-body straight and eyes focused in the direction travelled' was accepted and aims to assess upper limb movement in running. If the trunk moves, the ground reaction force follows the movement of the trunk. When the trunk moves laterally, the center of mass moves with it, and the knee joint may be forced to adopt a valgus position.[184,196,199,200] If the trunk moves forward, there is an increased risk of falling.

'Swing bent arms in opposition to legs' was also accepted for running and aims to identify deficits in upper limbs motion. The arms help the children to maintain postural control during the running gait cycle.[190] Arm movement counterbalances the opposite leg and stabilizes the body.[191] This strategy helps the legs work with efficiency and the least energy expenditure.[192]

The expert panel accepted the evaluation criterion 'Swing arms to assist the movement' for the movement skills, horizontal jump, vertical jump, and single-leg hop. This evaluation criterion aims to identify if the children use their arms to stabilize the upper body. Upper limb motion can help in maintaining postural control during jump-landing tasks. Using the arms during jump-landing tasks allows individuals to balance and control their body orientation, which protects them from injuries to the lower extremity.[176]

Non-Accepted Movement Skills with four or more accepted evaluation criteria

Although the expert panel did not reach consensus on accepting forward roll and tuck jump, these movement skills have at least four evaluation criteria accepted. Forward roll has been used in integrative neuromuscular training and injury prevention programs.[101] Tuck jump has been suggested as a screening tool, and its validity and reliability have been tested.[35,184] Table 8 shows the accepted evaluation criteria for forward roll and tuck jump. We infer the final ranking by using the percentage of agreement.

Table 8. Non-accepted movement skills with four accepted evaluation criteria.

Tuck Jump	
	Knees and hips bend to land softly in a controlled fashion
	Arms swing forward and upward to assist the movement
	Land on both feet at the same time
	Knees do not go too far in front of the toes when landing
Forward Roll	
	Start in a squat position with knees between arms
	Hands placed on the ground, shoulder-width apart
	Chin and knees tucked into the chest
	Roll forward onto the back of shoulders and length of the back

Study Limitations

This study has certain limitations. We used 5-point Likert scales which have possible sources of bias due to different response styles. First, the ‘net acquiescence’ response style in which the respondents have a strong tendency to agree with items scored. Second, the ‘extreme’ response style in which the respondents have an exaggerated tendency to use the extreme categories of the scale.[157] Since the panel (sample) size was neither representative of any population nor statistically calculated, and recruiting of the experts was a subjective process, our results should not be interpreted as representing the views of all the experts of the studied fields. Additionally, iterative processes, such as the Delphi method, may lead to different kinds of bias due to the combination of too much feedback from too many experts over too many Delphi-rounds.[127] Finally, limitations related to data collection that may have impacted the results can be summarized in 1) not all the experts completed all rounds; 2) completing the study took longer than expected; 3) some participants opted out because they considered the surveys very long; however, most participants needed between 30 and 45 minutes to complete.

Conclusions

This study has provided preliminary validity evidence for four movement skills, each with four evaluation criteria to develop a tool to assess movement competence and identify musculoskeletal injury risk factors. Future research should evaluate other psychometric properties of the movement skills assessment tool, determine if there are long term implications of the results/score, and assess injury outcomes of an intervention. The intention of the movement skills assessment tool is to be used to assess movement-oriented interventions and injury prevention programs by establishing a baseline to individualize the intervention and track children’s progress. Intended users are physical education teachers, coaches, healthcare professionals, and practitioners with minimal equipment.

Establishing a process-oriented movement skill assessment tool that can both objectively assess movement competence and identify modifiable risk factors for musculoskeletal injury may lead to physical literate individuals, lower injury rates in children, and increased sports performance. The movement skills assessment tool may improve the adoption of, and compliance with, injury prevention programs by assessing noticeable changes in movement patterns. Information gained from the movement skills assessment tool can help inform effectively these changes to stakeholders.[39]

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Appendix

Table 9. Proposed movement skills and evaluation criteria.

Running	Evaluation Criteria
Description: Running is faster than walking, but it is not sprinting. It will present the pattern of heel strike-midfoot-forefoot and a flight phase. The movement should be smooth. Running will be evaluated over 20 meters marked by cones where the child will run and come back.	Upper-body straight and eyes focused in the direction travelled
	Swing bent arms in opposition to legs
	Knee drives upward and forward to lift the foot off the ground
	Knees do not come in
	Toes pointing forward
	Land on the heels
Leaping	**Evaluation Criteria**
Description: Leaping is the action of propelling the body forward and is performed by taking off on one foot and landing on the other foot. The movement should be smooth, and performed equally on both sides. Leaping will be evaluated on a 10-meter space marked by cones, and the child will have two trials.	Upper-body straight and eyes focused in the direction travelled
	Take off from one foot, land on the opposite foot
	Knee and hip bend to land softly in a controlled fashion
	Toes pointing forward
	Knees do not come in
	Knees do not go too far in front of the toes
Single-Leg Hop	**Evaluation Criteria**
Description: Single-Leg Hop is performed by small forward jumps taking off from one foot and landing on the same foot. The movement should be smooth, and performed equally on both sides. Single-Leg Hop will be evaluated on a 10-meter space marked by cones, and the child will have two trials on each side.	Upper-body straight and eyes focused in the direction travelled
	Take off from one foot, land on the same foot
	Swing arms to assist the movement
	Knee and hip bend to land softly in a controlled fashion
	Toes pointing forward
	Knees do not come in
Vertical Jump	**Evaluation Criteria**
Description: Vertical jump is the action of propelling the body up into the air from the ground using both legs and landing with both feet. The child will have three trials.	Upper-body straight and eyes focused forward
	Swing arms to assist the movement
	Knees and hips bend to land softly in a controlled fashion
	Knees do not come in
	Land in both feet at the same time
	Toes pointing forward
	Knees do not go too far in front of the toes when landing
Horizontal Jump	**Evaluation Criteria**
Description: Horizontal jump is the action of propelling the body forward using both legs and landing with both feet. The child will have three trials.	Toes pointing forward
	Upper-body straight and eyes focused forward
	Swing arms to assist the movement
	Knees and hips bend to land softly in a controlled fashion
	Land on both feet at the same time
	Knees do not come in
	Knees do not go too far in front of the toes when landing

Table 9. Proposed movement skills and evaluation criteria. Continued.

Skipping	Evaluation Criteria
Description: Skipping is a rhythmical combination of a long step-hop on one leg and the transference of weight to the other leg to repeat the pattern. Skipping has uneven rhythm.	Upper-body straight and eyes focused in the direction travelled
	Alternated step-hop pattern
	High knee lift
	Swing bent arms in opposition to legs
	Toes pointing forward
	Knees do not come in
Dodging	**Evaluation Criteria**
Description: Dodging involves quick changes in direction to evade, chase, or flee from something or someone. When dodging, the knees and hips bend to slightly lower the center of gravity, and the body shifts rapidly in a sideways direction after planting and pushing off from the external foot. The movement should be smooth, and performed equally on both sides.	Eyes focused in the direction travelled
	Upper-body straight
	Plant one foot and bend the knee to stop
	Push off from the external foot to quickly change direction
	Swing bent arms in opposition to legs
	Knees and hips bend to lower the body during the change of direction
	Knees do not come in or out
Sliding (Lateral Shuffle)	**Evaluation Criteria**
Description: Lateral shuffle is a sideways movement where the lead foot takes one step to the side, and the trailing foot chases the lead foot. The feet do not cross. The movement should be smooth, and performed equally on both sides.	Upper-body straight
	Knees are slightly bent
	Weight on balls of the feet
	Lead-foot steps in the direction of travel, free foot follows quickly behind
	Toes pointing perpendicular to the direction travelled
	Knees do not come in or out
Tuck Jump	**Evaluation Criteria**
Description: Tuck jump is an action that involves propelling the body vertically into the air from the ground using both legs, bringing the knees up towards to the chest, and landing with both feet. The movement should be smooth.	Knees do not go too far in front of the toes when landing
	Knees and hips bend to land softly in a controlled fashion
	Immediately jump after landing
	Land on both feet at the same time
	Knees lifted during the flight phase
	Knees do not come in
	Toes pointing forward
Bodyweight Squat	**Evaluation Criteria**
Description: Squatting involves flexing the knees and hips allowing the hips to move back while lowering the center of gravity. The feet are in a comfortable distance apart and the hands are placed either crossed on the chest or extended out in front of the body. The movement should be smooth, and the child will have three trials.	Upper-body straight and eyes focused forward
	Keep the heels down all the time
	Push the hips back and bend the knees until the thighs are approximately parallel with the ground
	Knees do not come in
	Knees do not go too far in front of the toes
	Toes pointing slightly outward

Table 9. Proposed movement skills and evaluation criteria. Continued.

Walking Lunge	Evaluation Criteria
Description: The lunge is a movement where the child takes an extended step forward and bends both the front and back legs to approximately 90 degrees. The front foot should be flat on the floor and the child should continue this movement over the 10-meter space, alternating legs with each step. The movement should be smooth, performed equally on both sides.	Upper-body straight and eyes focused in the direction travelled
	Toes and knees in line with the hips
	Knees do not come in
	Front-heel down
	Front-knee does not go too far in front of the toes
	Toes pointing forward
Forward Roll	**Evaluation Criteria**
Description: The forward roll is a movement in which one's body is rolled around the frontal axis onto the back of the shoulders and the length of the back by swinging the legs over the head.	Start in a squat position with knees between arms
	Chin and knees tucked onto the chest
	Hands placed on the ground, shoulder width apart
	Legs extend simultaneously to push off the ground
	Roll forward onto the back of shoulders and length of the back
	Landing on both feet by maintaining a flexed position
	Roll in a straight line