

Process-Based Assessment of Physical Literacy and the Connection to Injury Prevention Programs

Matthew B. Miller, MSc, CAT(C); John A. Jimenez-Garcia, BSc; Chang Ki Hong, MSc;
Richard G. DeMont, PhD, CAT(C)

ABSTRACT

Purpose: To review current physical literacy assessments and their links to injury prevention.

Methods: The authors reviewed physical literacy and injury prevention literature, with a focus on process-based assessments. This literature was examined for concepts of physical literacy and injury prevention.

Results: Assessments of physical literacy are primarily focused on evaluating children's performance on various fundamental movement skills. Skill assessments often focus on performance outcomes, whereas technique and position are process-based outcomes. Physical literacy assessments generally do not address risk of injury, but the prevention literature suggests technique and position are important in reducing injury risk.

Conclusions: The underlying constructs of physical literacy are linked to the framework of injury prevention programs; however, physical literacy assessments do not effectively address concerns related to injury risk. As such, more emphasis needs to be placed on evaluating the quality and process that children use to perform these fundamental movement skills, including aspects of injury prevention.

[*Athletic Training & Sports Health Care*. 2018;10(6):277-284.]

Regular physical activity has positive effects on the well-being of children and adolescents, including psychological, musculoskeletal, and physiological health.¹⁻⁵ Health concerns have been rising over the past decade. According to the World Health Organization, physical inactivity is the fourth leading cause of mortality in the world.⁶ The benefits of physical activity are clear, but there have been increasing levels of sedentary lifestyle habits among children and adolescents.^{6,7} The growing concern of decreased rates of physical activity in children is likely linked to the rising number of obese children, recently reported as 340 million worldwide.^{6,8} Responding to low levels of physical activity in children, governmental policies, intervention programs, and researchers have focused on promoting physical activity.^{6,9-13}

Physical literacy is an emerging concept to promote physical activity in children and throughout life. It is described as a way to enhance confidence, motivation, physical competence, and the knowledge and understanding to value engagement in physical activities for life. When individuals pursue physical activities, the exposure to physically challenging situations escalates and increases the risk of injury. There are several risk factors for injury in children (eg, hormonal changes, static postural alignment, and sex) that are not modifiable in prevention efforts.¹⁴ Modifiable risk factors, such as movement technique, are critical to study. If movements are performed poorly, they can result in high-risk positions that are often implicated in catastrophic injury.^{14,15} Injuries during childhood and adolescence have the potential for life-long effects, so mitigating injury risks from physical activity in children is necessary. The constructs of physical literacy should not only be used to promote physical activity but aim to prevent injury. Particularly, the relationship between the physical competence domain of physical literacy and injury preven-

From the Department of Health, Kinesiology, and Applied Physiology, Concordia University, Montreal, Quebec, Canada.

Submitted: May 1, 2018; Accepted: September 17, 2018

The authors have no financial or proprietary interest in the materials presented herein.

Correspondence: Richard G. DeMont, PhD, CAT(C), Department of Health, Kinesiology, and Applied Physiology, Concordia University, 7141 Sherbrooke St. West, Montreal, Quebec, H4B 1R6, Canada. E-mail: richard.demont@concordia.ca
doi:10.3928/19425864-20180924-01

tion should be a priority. A connection between physical literacy and injury risk is apparent; however, there is no evidence to support this relationship.

This review explores the relationship between physical literacy assessment tools and injury prevention programs. We compared current physical literacy assessment tools with existing injury prevention programs. Our goal was to determine whether physical literacy assessments include characteristics similar to injury prevention programs (ie, movement capacities and fundamental movement skills). Additionally, we wanted to determine the need for emphasis on injury prevention strategies within physical literacy assessment tools.

The physical literacy assessment tools, injury prevention programs, and other supporting literature were obtained through selected search criteria from common web-based academic search engines. Primary search criteria included “children,” “physical literacy assessment,” “injury prevention program,” “gross motor skill assessment,” “injury prevention,” and “reduce injury,” and searches were primarily conducted in PubMed and Web of Science. Other search criteria were selected based on literature, and secondary searches were performed using key words such as “fundamental movement skills,” “process-based assessments,” and “movement capacity.” References from the selected literature were also examined for further resources. Because there is a large body of literature related to injury prevention, we selected articles based on relevance to children, physical literacy, and movement assessment. We did not use any limits in our search criteria; however, we prioritized “injury prevention” and “movement assessment” as opposed to “rehabilitation” and “orthopedic assessment” in our search strategy. Although the difference between assessments of physical literacy and injury prevention interventions limit our ability to directly compare each tool, there are similarities between the movement skills found in each. Similarities between the movement skills highlight the importance of exploring how the concepts of physical literacy and injury prevention are connected, which is the focus of this review.

LITERATURE

Physical Literacy

Physical literacy is an emerging concept in the physical education and health promotion domains; however, researchers often differ in their theoretical approach and definition.¹⁶ A recent systematic review⁷ did a comprehensive

search of physical literacy assessment tools and found that 70% of research addressing physical literacy used the definition of physical literacy proposed by Whitehead.¹ This approach is defined as having the knowledge and understanding, daily behavior, physical competence, and motivation and confidence to participate in physical activity throughout life.¹³ We used the Whitehead definition of physical literacy in this review for three reasons: (1) it is the most widely used, (2) the Whitehead¹ perspective of physical literacy is a holistic and individualized approach to participation in physical activity, which we believe is key to the development of children's participation in physical activity, and (3) the individualized approach deemphasizes competition and promotes inclusion.

The concept of physical literacy as proposed by Whitehead is often thought of in four domains: knowledge and understanding, daily behavior, motivation and confidence, and physical competence.^{1,13} Knowledge and understanding is an abstract concept that suggests that knowing and understanding the importance of physical activity will motivate individuals to participate in physical activity and, as a result, enhance their physical literacy.¹ The domain of daily behavior encompasses the habits and lifestyle that an individual chooses to pursue each day. Motivation and confidence are concepts that develop when an individual participates in a physical activity. Finally, the physical competence domain aims to describe the movement capabilities of an individual. These four distinct domains form the basis of physical literacy and are inter-linked.¹

The physical competence domain of physical literacy is of particular interest for this literature review. Physical competence specifically relates to the movement capacities of an individual, which encompass balance, strength, agility, endurance, flexibility, and body control. These abilities are considered fundamental to human movement.¹ Movement capacities give individuals the ability to perform a wide range of movement skills, such as running, jumping, climbing, and balancing.¹ The movement capacities are often labeled fundamental movement skills, and are typically grouped in three areas: object manipulation (eg, handling a ball or tennis racket), locomotion (eg, running, skipping, and jumping), and stability and balance (eg, standing on one leg and awareness of body position) (**Figure 1**).¹¹⁻¹³ Developing children typically establish their fundamental movement skills in early childhood (between the ages of 3 and 7 years), and these skills provide the basis for later

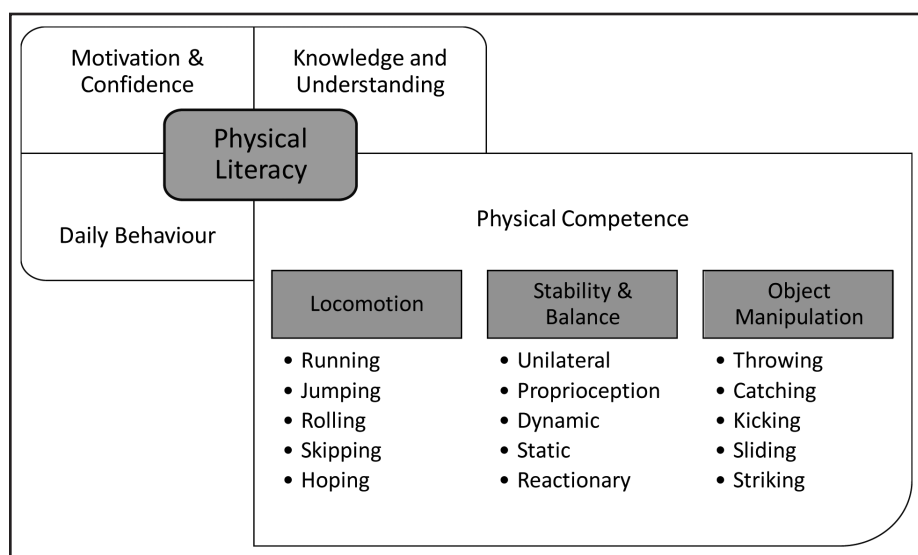


Figure 1. The fundamental movement skills in the physical competence domain of physical literacy. Created based on the concept of Whitehead.¹

specialized movements associated with sport-related skills.¹⁷ At approximately 7 years of age, children enter a “context-specific period” in which they apply their fundamental movement skills to learn specialized movements required for the participation in physical activity.¹⁷ To ensure the passage into this “context-specific period,” children require motivation, practice, and instruction in an environment that enhances learning, to break through a theoretical “proficiency barrier.”¹⁸ Failure to provide such opportunities will delay the application of fundamental movement skills to more specialized movements required for physical activity participation, which may potentially lead to injury.¹⁹ The fundamental movement skills acquired by children 8 years and older can either accelerate or restrict the development of these specialized skills that are essential to the child’s participation in physical activity.¹⁷ The assessment of fundamental movement skills through physical literacy assessments is critical to ensure the transition to specialized movement skills and continued participation in physical activity, which should help mitigate injury risk.

Physical literacy is a concept adopted by governmental and physical education domains in several countries (United Kingdom, Germany, United States, Canada, New Zealand, and Australia) and, as a result, there is increasing research interest to further explore physical literacy.⁸ As a product of these research initiatives, tools to assess physical literacy have been developed and are currently being used. There are qualitative tools such as interview techniques, reflective diaries, focus groups, and participant observation, and quantitative tools such as accelerometers, ques-

tionnaires, and physical assessments.¹⁶ Due to the large number of assessment tools and the goals of our review, we evaluated tools that primarily seek to assess the level of physical competence that an individual possesses by evaluating a series of movement-based skills that contribute to a child’s physical literacy. Three tools have been developed to assess all four constructs of physical literacy: the Canadian Assessment of Physical Literacy (CAPL), the Physical Literacy Assessment for Youth (PLAY) tools, and the Passport for Life (P4L). The Assessment of Basic Motor Competencies (MOBAK), Test of Gross Motor Development 2 (TGMD-2), McCarron Assessment of Neuromuscular Development (MAND), POLYGON-FMS, and Basic Human Movements (BHM) only assess the physical competence domain of physical literacy. Most of the physical literacy assessment tools are used to evaluate movement skills within the physical competency domain of physical literacy.^{13,20-27}

The CAPL, PLAY, P4L, POLYGON-FMS, and MOBAK are similar in design; they include a series of movement skills in the three areas of physical competence (object manipulation, locomotion, and balance).^{13,20,25,26} The CAPL also includes anthropometric measures (body mass index and waist circumference) and standardized strength and flexibility measures (grip strength and sit and reach).¹³ The TGMD-2 includes gross motor movements (locomotion skills) and the MAND includes gross and fine motor movements of the hands and fingers.^{23,24} The BHM provides a unique perspective on the movement skills, suggesting there are seven basic human movements that must be mastered

before learning balance, locomotion, or object manipulation skills.²¹ The BHM framework is also unique in using a process-based assessment that evaluates movement process, as opposed to movement performance. Movement process is discussed in detail later in this article.

Stringent psychometric testing will help researchers, physical educators, personal trainers, parents, and others to select the most appropriate assessment for their population of interest. The PLAY, CAPL, P4L, POLYGON-FMS, MOBAK, and TGMD have achieved content and face validity, and can be used to assess physical literacy skills in children at various ages (CAPL and MOBAK in children ages 8 to 12 years, P4L in children ages 7 to 14 years, POLYGON-FMS in 8 year olds, and the TGMD-2 in children with the mean age of 12 years. The PLAY, CAPL, and MOBAK have also achieved construct validity.^{13,20,24,25,28} The MAND and BHM have yet to be assessed for validity. The CAPL, POLYGON-FMS, P4L, and TGMD have reported reliability estimates, with the P4L, POLYGON-FMS, and TGMD tools reaching reliability coefficients for interclass and intraclass correlations of greater than 0.80, and the CAPL reporting reliability coefficients between 0.46 and 0.99. The P4L also reported internal consistency values of 0.62 to 0.86 on various aspects of the assessment. The remaining physical literacy assessments have yet to yield any reliability data.^{13,24,25,28}

There are many available assessments of physical literacy, some of which are validated, but the majority do not include any link to injury prevention programs. This review is not a comprehensive analysis of all physical literacy assessments, but we have examined several popular and readily available assessment tools. The link between physical literacy and injury prevention is missing in that the physical literacy assessments that we reviewed do not consider injury risk or injury prevention strategies. This oversight may inhibit a child's transition into more specialized movements by neglecting to adequately prepare them for more challenging physical activities, which could leave children vulnerable to injury and life-long consequences.

Injury Prevention Programs

Injury is an unfortunate but integral part of sport participation, and lower extremity injuries consist of 66% of all sport-related injuries.²⁹ A non-contact anterior cruci-

ate ligament (ACL) injury requiring surgical reconstruction can cost between \$5,000 and \$17,000 (U.S. dollars) per patient, and long-term costs on society are estimated to be as much as \$38,000 (U.S. dollars).^{29,30} Between 2001 and 2008, an estimated 2.6 million children were treated in emergency rooms for sport-related injuries in the United States with peak injury frequency occurring at age 14 years, which highlights the importance of teaching injury prevention strategies in childhood.³¹ The yearly costs to society of treating sport-related injuries experienced by children is approximately \$1.8 billion (U.S. dollars).³² The high costs associated with childhood injury as a result of sport participation have likely increased since these numbers have been published, highlighting the importance of reducing injury risk and investigating injury prevention program effectiveness.

Although this is not an exhaustive review of prevention programs, there have been several injury prevention programs created to mitigate modifiable injury risks (ie, FIFA 11+, Harmoknee, Prevent Injury and Enhance Performance [PEP] program, FootyFirst, and the Gaelic Athletic Association 15 training program).³³⁻³⁶ The most widely used is the FIFA 11+, which was originally created for female soccer players aged 13 to 17 years as a pre-game and pre-practice warm-up.^{34,37} This program uses a variety of exercises, movements, and stretches designed to reduce injury. The original research on the FIFA 11+ program concluded that although there was not a significant reduction in lower extremity injury, the overall risk of injury was reduced.^{34,37} As a result, this program has been adopted by many female soccer teams worldwide.^{34,37}

Other researchers have evaluated the FIFA 11+ program because of the program's success and suggested that, beyond reducing the risk of injury, the FIFA 11+ positively impacts performance measures (eg, speed, jump height, and jump symmetry) and improves dynamic postural control and concentric knee strength.^{33,38-40} Of particular interest are the movement skills in the FIFA 11+ related to locomotion (eg, running, hopping, jumping, cutting, landing, and deceleration) and balance (eg, one leg balance and hopping on one foot), which overlap with the fundamental movement skills in the physical literacy construct.^{1,13,34} Children participating in sports that require locomotion skills involving cutting, landing, and deceleration have been identified as having an increased risk of injury.²⁹

Balance skills are considered an integral part of both physical literacy assessments and injury prevention pro-

grams. Physical literacy researchers identify balance as one of the three categories of fundamental movement skills,^{1,13} and injury prevention researchers suggest balance as a necessary component when designing a prevention program.²⁹ Recent research indicates that balance can be evaluated using nine components: functional stability limit, underlying motor systems, static stability, verticality, reactive postural control, anticipatory postural control, dynamic stability, sensory integration, and cognitive influences.⁴¹ In a recent review of 21 tools used to assess balance in children, it was discovered that no assessments include all nine components, which suggests that some balance assessments are missing important components.⁴² For example, reactive postural control is an important component of balance and a primary factor in fall prevention for children, but was not included in any balance assessment.^{42,43} Balance is also an important component of injury prevention programs and has been integrated into many existing protocols.^{5,34} The FIFA 11+ incorporates three components of balance: static stability, dynamic stability, and reactive postural control,³⁴ which are assessed and enhanced through single-leg balance, lateral jumps, and partner perturbations.³⁴ Much like the physical literacy balance assessment protocols, the majority of published injury prevention programs do not include all nine components of balance.

The FIFA 11+ and other injury prevention programs have succeeded by reducing injury rates, but recent reviews cite variations between prevention programs as a limitation when comparing programs.⁴⁴⁻⁴⁷ Herman et al.⁴⁴ noted difficulty in comparing injury prevention interventions due to inconsistency in program design, referring to variations in length and frequency of training sessions and program duration. There was also a lack of consistency in the exercise selection to achieve similar goals. The use of eccentric hamstring curls was used in one study⁴⁸ in contrast to a combination of core strengthening and isometric hip strengthening in another⁴⁹ to achieve the same goal of reducing hamstring injury. The between-program variation has limited researchers' ability to compare injury prevention programs and determine the most effective means of preventing injury. However, from a clinical standpoint, having many effective means of reducing injury risk allows clinicians, athletic trainers, and other users to design individualized injury prevention programs tailored to the needs of their participants. The individualized approach may also be of benefit in physical literacy assessments as it relates to Whitehead's definition of physical literacy.

Despite the between-program variation found in injury prevention programs, the National Athletic Trainers' Association (NATA) has published a position statement regarding the best practices for injury prevention programs.²⁹ The NATA suggests that injury prevention programs should be performed during the pre-season and in-season, at least two to three times per week, and focus on balance, strength, agility, movement technique, plyometrics, and flexibility.²⁹ These suggestions aid in the development of the relationship between injury prevention and physical literacy, especially by highlighting the importance of injury prevention in children.²⁹ Further, the NATA position statement suggests that continued participation in injury prevention programs (throughout the year and over extended periods of time) will maintain the benefits of reduced injury rates, indicating the need for long-term participation in injury prevention methods.^{29,37} These recommendations align with participation in physical activity starting early and continued throughout life. The concept of physical literacy mirrors the assertion of beginning physical activity at a young age and continuing throughout life. Assessments of physical literacy can evaluate movement competency to enhance physical activity participation in a way that is robust to injury, but reevaluation of the outcomes of such assessments is necessary to establish a link between physical literacy and injury prevention programs.

FINDINGS

Linking Physical Literacy and Injury Prevention

Fundamental textbooks in motor learning areas suggest that assessments using product measures (ie, speed, strength, and repetitions) are much more abundant than those using process measures, which is consistent with the physical literacy research.¹¹ The physical literacy assessments discussed above evaluate the physical performance of a child in a variety of fundamental movement skills, by evaluating performance based on speed, number of repetitions, and frequencies.¹¹ There are a limited number of physical literacy-specific assessments developed to evaluate the process a child uses to perform these skills (ie, technique, form, and body position). Process-oriented assessments are designed to evaluate how a movement is performed, with the goal of describing the qualitative movement patterns being exhibited.⁵⁰ Some common examples of process-based assessments are the TGMD-2²⁴ and the Landing Error Scoring System.⁵¹ These assessments use evaluation criteria such

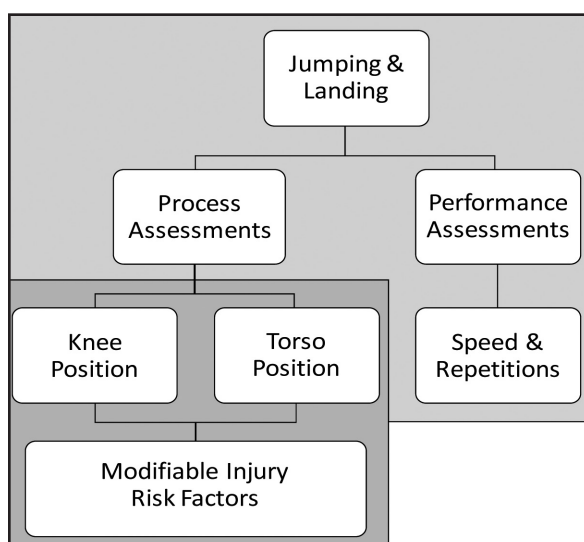


Figure 2. The relationship between process-based outcomes and injury risk factors.

as “take off and land on both feet simultaneously” and “decreased knee and hip flexion angle.” Process-oriented assessments involve outcomes that result in the optimal body position required to perform a movement, as opposed to a performance-oriented assessment that result in a time to completion or number of repetitions for a specific movement.⁵⁰

We also believe that a process-based assessment of physical literacy focuses on the individual as highlighted in Whitehead’s¹ definition of physical literacy and deemphasizes competition. A focus on the individual while deemphasizing competition allows children to grow, develop, and learn important movement skills without the perceived consequences of losing or failure. There are some disadvantages to a process-based outcome as-

essment, particularly the complexity of performing the assessment, the number of skills, and the time it takes to accurately assess the movement.⁵⁰ Despite these shortcomings, an important difference between process-based and performance-based outcomes is the ability of process-based outcomes to evaluate the technique of a movement skill. This distinction is more than evaluating how an individual moves his or her body, and it may have implications in screening for injury-risk factors. **Figure 2** demonstrates the relationship between process and performance assessments and the connection process-based assessments has with modifiable injury risk factors.

The recent NATA position statement on the prevention of ACL injury suggests a series of components necessary to incorporate in an injury prevention program, including feedback on movement technique.²⁹ This feedback highlights the importance of form and body position in reducing the risk of injury. The position statement specifically encourages teaching movement patterns that focus on body control and movement quality when implementing injury prevention training programs in children.²⁹ These recommendations highlight the importance of focusing on movement process as opposed to movement performance in children. Physical literacy assessments have generally focused on performance-based measures, yet the NATA position statement recommends focusing on movement technique when developing injury prevention programs with children.²⁹ This contrast establishes an important gap between physical literacy assessments and injury-prevention programs. Physical literacy assessments have neglected any discussion about how they relate to injury prevention and reducing injury risk factors in children.

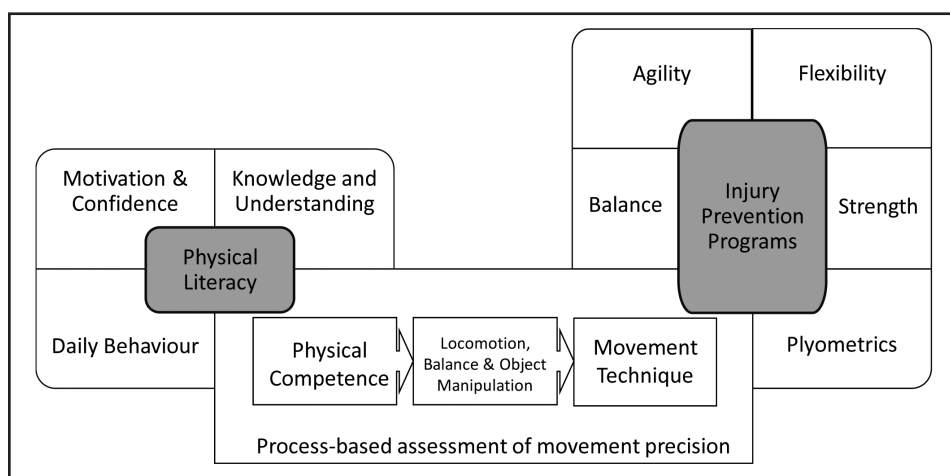


Figure 3. The connection between physical literacy, process-based assessments, and injury prevention programs.

On closer examination, injury prevention and physical literacy are closely associated. The physical competence domain of physical literacy encompasses the fundamental movement skills of locomotion, balance, and object manipulation.^{1,13} The ability to perform the fundamental movement skills at a competent level to mitigate injury risk is established through the child's body stability and balance, and movement technique, that together contribute to avoidance of compromising positions.⁴⁰ By assessing fundamental movement skills with a process-based assessment, children will be evaluated on their body position and movement quality, and movement quality has been identified as a biomechanical risk factor that can predict noncontact or indirect-contact ACL injuries.⁵¹ Process-based assessment criteria that evaluate body positions identified as vulnerable to injury have the potential to screen children for modifiable injury risk factors and the child's level of physical competence. This link highlights the potential of physical literacy assessments to screen for precision of movement indicated for injury prevention (demonstrated in **Figure 3**). By using a process-based assessment, the gap between physical literacy tools and injury prevention programs narrows. This comparison further highlights the importance of an assessment with process-based outcomes, as opposed to a performance-based assessment.

CONCLUSIONS

Physical literacy is an important concept that encourages the participation in physical activity from a young age.¹ Currently, these assessments are primarily targeted toward children and evaluate their performance in a variety of fundamental movement skills. The underlying constructs of physical literacy are linked to the framework of injury prevention programs; however, physical literacy assessments do not effectively address concerns related to injury risk. As such, more emphasis needs to be placed on evaluating the quality and process that children use to perform these fundamental movement skills, including aspects of injury prevention.

FURTHER RESEARCH

Future research efforts should focus on establishing scientifically robust assessment tools that use process-based outcomes to evaluate children's movement capabilities. Developing physical literacy assessments that include the evaluation of body position, form, and

technique of fundamental movement skills will not only encourage participation in physical activity, but the continued practice of these movements may result in children being more resistant to injury when they pursue further physical activity throughout their life.

REFERENCES

1. Whitehead M. The concept of physical literacy. *European Journal of Physical Education*. 2001;6:127-138.
2. Girardi A, Babul S, Rajabali F, Pike J; BC Injury Research and Prevention Unit for the Provincial Health Services Authority. The injury consequences of promoting physical activity: an evidence review. <http://www.injuryresearch.bc.ca/wp-content/uploads/2013/05/Injury-and-Physical-Activity-FINAL-Report-May24131.pdf>. Published April 2013.
3. Loprinzi PD, Cardinal BJ, Loprinzi KL, Lee H. Benefits and environmental determinants of physical activity in children and adolescents. *Obes Facts*. 2012;5:597-610.
4. Reiner M, Niermann C, Jekauc D, Woll A. Long-term health benefits of physical activity: a systematic review of longitudinal studies. *BMC Public Health*. 2013;13:813.
5. Kiani A, Hellquist E, Ahlqvist K, Gedeberg R, Michaëlsson K, Byberg L. Prevention of soccer-related knee injuries in teenaged girls. *Arch Intern Med*. 2010;170:43-49.
6. World Health Organization. *Global Recommendations on Physical Activity for Health*. Geneva, Switzerland: Author; 2010.
7. Edwards LC, Bryant AS, Keegan RJ, Morgan K, Jones AM. Definitions, foundations and associations of physical literacy: a systematic review. *Sports Med*. 2017;47:113-126.
8. Keegan RJ, Keegan SL, Daley S, Ordway C, Edwards A. *Getting Australia Moving: Establishing a Physically Literate and Active Nation (Game Plan)*. Canberra, Australia: University of Canberra; 2013.
9. Comeau ME, Bouchard DR, Levesque C, et al. Association between functional movements skills and health indicators in children aged between 9 and 12 years old. *Int J Environ Res Public Health*. 2017;14:1010.
10. Lai SK, Costigan SA, Morgan PJ, et al. Do school-based interventions focusing on physical activity, fitness, or fundamental movement skill competency produce a sustained impact in these outcomes in children and adolescents? A systematic review of follow-up studies. *Sports Med*. 2014;44:67-79.
11. Gallaupe DL, Ozmun JC, Goodway J. *Understanding Motor Development: Infants, Children, Adolescents, Adults*, 7th ed. New York: McGraw-Hill; 2012.
12. Bayli I, Way R, Higgs C, Norris S, Cardinal C; Sport for Life Society. Canadian Sport for Life: Long Term Athlete Development Resource Paper 2.1. http://sportforlife.ca/wp-content/uploads/2017/04/LTAD-2.1-EN_web.pdf?x96000. Published 2016.
13. Longmuir PE, Boyer C, Lloyd M, et al. The Canadian Assessment of Physical Literacy: methods for children in grades 4 to 6 (8 to 12 years). *BMC Public Health*. 2015;15:767.
14. Padua DA, DiStefano LJ, Beutler AI, de la Motte SJ, DiStefano MJ, Marshall SW. The Landing Error Scoring System as a screening tool for an anterior cruciate ligament injury-prevention program in elite-youth soccer athletes. *J Athl Train*. 2015;50:589-595.
15. Boden BP, Torg JS, Knowles SB, Hewett TE. Video analysis of anterior cruciate ligament injury: abnormalities in hip and ankle kinematics. *Am J Sport Med*. 2009;37:252-259.

16. Edwards LC, Bryant AS, Keegan RJ, Morgan K, Cooper SM, Jones AM. 'Measuring' physical literacy and related constructs: a systematic review of empirical findings. *Sports Med*. 2018;48:659-682.
17. Clark JE, Metcalfe JS. The mountain of motor development: a metaphor. In: Clark JE, Humphrey JH, eds. *Motor Development: Research and Reviews*, vol 2. Reston, VA: National Association for Sport and Physical Education; 2002:163-190.
18. Seefeldt V. Developmental motor patterns: implications for elementary school physical education. In: Nadeau C, Holliwell W, Newell K, Roberts G, eds. *Psychology of Motor Behavior and Sport*. Champaign, IL: Human Kinetics; 1980:314-323.
19. Stodden DF, Goodway JD, Langendorfer SJ, et al. A developmental perspective on the role of motor skill competence in physical activity: an emergent relationship. *Quest*. 2008;60:290-306.
20. Herrmann C, Seelig H. Structure and profiles of basic motor competencies in the third grade-validation of the test instrument MOBAK-3. *Percept Mot Skills*. 2017;124:5-20.
21. Tompsett C, Sanders R, Taylor C, Cobley S. Pedagogical approaches to and effects of fundamental movement skill interventions on health outcomes: a systematic review. *Sports Med*. 2017;47:1795-1819.
22. Issartel J, McGrane B, Fletcher R, O'Brien W, Powell D, Belton S. A cross-validation study of the TGMD-2: the case of an adolescent population. *J Sci Med Sport*. 2017;20:475-479.
23. McCarron LT. *MAND: McCarron Assessment of Neuromuscular Development: Fine and Gross Motor Abilities*, rev. ed. Dallas, TX: Common Market Press; 1997.
24. Ulrich DA. *Test of Gross Motor Development*, 2nd ed. Austin, TX: PRO-ED; 2000.
25. Lodewyk KR, Mandigo JL. Early validation evidence of a Canadian practitioner-based assessment of physical literacy in physical education: passport for life. *The Physical Educator*. 2017;74:441-475.
26. Kriellaars D, Robillard B; Canadian Sport Institute. Physical literacy assessment for youth. http://sportforlife.ca/wp-content/uploads/2016/12/PLAYself_Workbook.pdf. Published August 2013.
27. Zuvela F, Bozanic A, Miletic D. POLYGON: a new fundamental movement skills test for 8 year old children: construction and validation. *J Sport Sci Med*. 2011;10:157-163.
28. Cairney J, Veldhuizen S, Graham JD, et al. A construct validation study of PLAYfun. *Med Sci Sports Exerc*. 2018;50:855-862.
29. Padua DA, DiStefano LJ, Hewett TE, et al. National Athletic Trainers' Association Position Statement: prevention of anterior cruciate ligament injury. *J Athl Train*. 2018;53:5-19.
30. Mather RC 3rd, Koenig L, Kocher MS, et al. Societal and economic impact of anterior cruciate ligament tears. *J Bone Joint Surg Am*. 2013;95:1751-1759.
31. Schwebel DC, Brezaussek CM. Child development and pediatric sport and recreational injuries by age. *J Athl Train*. 2014;49:780-785.
32. Aaron DJ, Laporte RE. Physical activity, adolescence, and health: an epidemiological perspective. *Exerc Sport Sci Rev*. 1997;25:391-405.
33. Daneshjoo A, Mokhtar A, Rahnama N, Yusof A. The effects of injury prevention warm-up programmes on knee strength in male soccer players. *Biol Sport*. 2013;30:281-288.
34. Soligard T, Myklebust G, Steffen K, et al. Comprehensive warm-up programme to prevent injuries in young female footballers: cluster randomised controlled trial. *BMJ*. 2008;337:a2469.
35. O'Malley E, Murphy JC, McCarthy Persson U, Gissane C, Blake C. The effects of the Gaelic Athletic Association 15 training program on neuromuscular outcomes in Gaelic football and hurling players: a randomized cluster trial. *J Strength Cond Res*. 2017;31:2119-2130.
36. Mandelbaum BR, Silvers HJ, Watanabe DS, et al. Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes: 2-year follow-up. *Am J Sports Med*. 2005;33:1003-1010.
37. Soligard T, Nilstad A, Steffen K, et al. Compliance with a comprehensive warm-up programme to prevent injuries in youth football. *Br J Sports Med*. 2010;44:787-793.
38. Daneshjoo A, Mokhtar AH, Rahnama N, Yusof A. Effects of the 11+ and Harmoknee warm-up programs on physical performance measures in professional soccer players. *J Sports Sci Med*. 2013;12:489-496.
39. Daneshjoo A, Rahnama N, Mokhtar AH, Yusof A. Bilateral and unilateral asymmetries of isokinetic strength and flexibility in male young professional soccer players. *J Hum Kinet*. 2013;36:45-53.
40. Daneshjoo A, Rahnama N, Mokhtar AH, Yusof A. Effectiveness of injury prevention programs on developing quadriceps and hamstrings strength of young male professional soccer players. *J Hum Kinet*. 2013;39:115-125.
41. Sibley KM, Beauchamp MK, Van Ooteghem K, Straus SE, Jaglal SB. Using the systems framework for postural control to analyze the components of balance evaluated in standardized balance measures: a scoping review. *Arch Phys Med Rehabil*. 2015;96:122-132.
42. Sibley KM, Beauchamp MK, Van Ooteghem K, Paterson M, Witmeier KD. Components of standing postural control evaluated in pediatric balance measures: a scoping review. *Arch Phys Med Rehabil*. 2017;98:2066-2078.
43. Maki BE, McLroy WE. Postural control in the older adult. *Clin Geriatr Med*. 1996;12:635-658.
44. Herman K, Barton C, Malliaras P, Morrissey D. The effectiveness of neuromuscular warm-up strategies, that require no additional equipment, for preventing lower limb injuries during sports participation: a systematic review. *BMC Med*. 2012;10:75.
45. Porter T, Rushton A. The efficacy of exercise in preventing injury in adult male football: a systematic review of randomized controlled trials. *Sports Med Open*. 2015;1:4.
46. Lopes TJA, Simic M, Myer GD, Ford KR, Hewett TE, Pappas E. The effects of injury prevention programs on the biomechanics of landing tasks: a systematic review with meta-analysis. *Am J Sports Med*. 2018;46:1492-1499.
47. Petushek EJ, Sugimoto D, Stoolmiller M, Smith G, Myer GD. Evidence-based best-practice guidelines for preventing anterior cruciate ligament injuries in young female athletes: a systematic review and meta-analysis. *Am J Sports Med*. 2018;36036354651878246.
48. Petersen J, Thorborg K, Nielsen MB, Budtz-Jørgensen E, Hölmich P. Preventive effect of eccentric training on acute hamstring injuries in men's soccer: a cluster-randomized controlled trial. *Am J Sports Med*. 2011;39:2296-2303.
49. Steffen K, Myklebust G, Olsen OE, Holme I, Bahr R. Preventing injuries in female youth football: a cluster-randomized controlled trial. *Scand J Med Sci Sports*. 2008;18:605-614.
50. Logan SW, Barnett LM, Goodway JD, Stodden DF. Comparison of performance on process- and product-oriented assessments of fundamental motor skills across childhood. *J Sports Sci*. 2017;35:634-641.
51. Padua DA, DiStefano LJ, Beutler AI, de la Motte SJ, DiStefano MJ, Marshall SW. The Landing Error Scoring System as a screening tool for an anterior cruciate ligament injury-prevention program in elite-youth soccer athletes. *J Athl Train*. 2015;50:589-595.

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