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TOPIC HIGHLIGHT

New Concepts in the Assessment of Exercise Capacity Among Children with Congenital Heart Disease: Looking beyond Heart Function and Mortality

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ABSTRACT

Cardiopulmonary exercise testing is a valuable tool in the diagnosis and management of pediatric congenital heart disease. Parent and child reports of the child's physical activity relative to peers are also routinely used to monitor heart function. Unfortunately, objective measures of their physical activity indicate that most children with congenital heart disease lead sedentary lives, which increase their risk of secondary morbidities. Current recommendations emphasize the need to proactively counsel patients to engage in at least 60 minutes of physical activity daily. Information regarding the child's current capacity for physical activity can be obtained through a physical literacy assessment and enhanced use of cardiopulmonary exercise results. Physical literacy is the knowledge, motivation, behaviour and physical competence needed to adopt and maintain a physically active lifestyle. Protocols to assess these physical literacy domains are well established, with the Canadian Assessment of Physical Literacy offering the first comprehensive assessment of all domains. Cardiopulmonary exercise protocols that incorporate sub-maximal stages, and measures of the child's willingness to perform maximal intensity exercise provide important information about the child's capacity for physically active play with peers, which seldom requires a maximal effort. Measures of physical literacy and sub-maximal cardiorespiratory capacity thus provide important information when counselling children with congenital heart defects and their parents regarding the child's daily physical activity participation.

Key words: Physical activity; Sedentary lifestyle; health risks; counselling; physical literacy; health-related fitness

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INTRODUCTION

Exercise testing has been a staple in the care of children with congenital heart defects for more than 25 years[1]. The gold standard exercise test throughout this time has been maximal exercise capacity, typically measured with a bicycle or treadmill protocol. Results from the maximal exercise test are reported as the percentage of predicted maximal oxygen consumption (VO_2) achieved. The maximal exercise test provides important information about heart function, arrhythmias, and cardiac output during exercise[2]. Maximal exercise capacity is known to be associated with mortality and morbidity among children with corrected congenital heart defects[3].

Currently more than 95% of children with non-critical and 70% of children with critical congenital heart defects survive to adulthood[4]. As such, clinical and research attentions have turned toward secondary morbidity and quality of life. Children with congenital heart defects are known to lead sedentary lifestyles[5] that persist into adulthood[6]. These sedentary lifestyles increase the risk for secondary morbidities such as hypertension, obesity, diabetes, and acquired heart disease[7]. Given the long-term implications of sedentary lifestyles for children with congenital heart defects, the American

Heart Association has published a scientific statement (May 2013) on the promotion of physical activity to individuals with congenital heart defects[8]. The AHA statement suggests that clinicians should proactively promote physical activity to all individuals with congenital heart defects during every clinical encounter, and that physical activity, fitness and motor skill should also be assessed.

Research among healthy individuals has demonstrated that moderate amounts of daily physical activity have a substantial impact on health and quality of life[9]. In order to optimize the health benefits of physical activity, international recommendations state that children should perform at least 60 minutes of physical activity daily[10-14]. Research with children with congenital heart defects has demonstrated that daily physical activity may be reduced even when maximal exercise capacity is age-appropriate[6,15-19]. As a result, an assessment that only measures maximal exercise capacity may not provide the information needed to appropriately counsel patients about physical activity or assess the risk of morbidities associated with a sedentary lifestyle.

A NEW ASSESSMENT PARADIGM

In order to optimize the long-term health and quality of life of children with congenital heart defects, a new assessment paradigm that optimizes the use of exercise test results to promote physically active lifestyles is recommended. The new paradigm would incorporate a variety of exercise assessments within two broad categories: (1) physical literacy; and (2) expanded use of the data available from a maximal cardiopulmonary exercise test. Assessment results from these sources can provide important information about children's physical activity, and the barriers that limit their participation.

ASSESSMENT OF PHYSICAL LITERACY

Physical literacy is the attributes, skills, characteristics and behaviours that enable a physically active lifestyle[20]. Unlike traditional concepts of fitness or exercise capacity, physical literacy considers the impact of a much broader range of factors that may impact physical activity, such as motor skill, knowledge and understanding, motivation or daily behaviour. Taken together, physical literacy represents the child's capacity to achieve and maintain a physically active lifestyle. The Canadian Assessment of Physical Literacy is a valid and reliable measure of the physical literacy of children 8 to 12 years of age. It provides an overall measure of physical literacy, as well as sub-domain scores for motivation and confidence, knowledge and understanding, physical competence and daily behaviour[21]. The benefits and limitations of the Canadian Assessment of Physical Literacy are briefly summarized in figure 1. Detailed protocols are available at www.capl-ecsft.ca. Simple screening tasks, suitable for administration in healthcare settings, that can identify children who are struggling on their physical literacy journey are currently being evaluated (unpublished data). Comprehensive, valid and reliable protocols to assess a broad spectrum of physical literacy components among young children or adolescents have not yet been published, although individual protocols for specific aspects of physical literacy (e.g., accelerometry for daily behaviour, handgrip dynamometry for muscular strength) are available.

Assessment of Motivation and Knowledge

The concept of assessing a child's motivation for physical activity often seems counterintuitive because most adults believe that children are naturally active. Parents will say that their children never sit still or that keeping up with their children is exhausting, and yet objective measures of their activity indicate that they spend their discretionary time in primarily sedentary pursuits[22]. We know that motivation, confidence and self-efficacy for physical activity are critically important to the physical activity participation of healthy children[23,24]. Youth with congenital heart disease indicate that physical activity is not a valued pursuit and experiences of exclusion, low self efficacy, fatigue and covert fears combine to further decrease physical activity motivation[25]. Research suggests that the severity of the cardiac defect does not have a direct effect on physical activity participation. Rather individual beliefs about self-efficacy for physical activity, the recommendations provided by the cardiologist and parental attitudes are of primary importance[26].

A comprehensive assessment of the many facets of knowledge (activity opportunities, rules, skill development, recommended behaviours, etc.) and motivation (enjoyment, social support, adequacy, benefits, etc.) that influence childrens' physical activity participation would be difficult to administer. There are many published questionnaires that assess motivation for physical activity, but most are designed for adults (e.g., RM 4-FM (Deci & Richard); Processes of Change (Marcus & Forsyth; Exercise Motivations Inventory (Markland); Physical Activity Enjoyment Scale (Kendzierski & DeCarlo)). Questionnaires specifically for children (Children's Self-perceived Adequacy and Predilection for Physical Activity[27] often include assessment components specific to school physical education, rather than or in addition to the more general concept of physical activity. The questionnaire component of the Canadian Assessment of Physical Literacy (www.capl-ecsfp.ca) is designed to assess the physical activity knowledge and motivation of children 8 to 12 years of age. The questionnaire can be completed online, and automated scoring provides feedback regarding the child's physical literacy knowledge and motivation. Most healthy children have knowledge and motivation levels that are lower than what is considered adequate for physical literacy. Preliminary data among children who have congenital heart defects indicate that they obtain similar results (unpublished data).

It is important that clinicians counselling children with congenital heart defects regarding physical activity consider the knowledge and motivation of the child, as well as the knowledge and motivation of significant adults who care for the child. Support for the child's physical activity among immediate family members is very important, but the knowledge and motivation of other adults (e.g., teachers, day care providers, parents of other children) should also be considered. Developing sufficient motivation for physical activity and the acquisition of knowledge regarding appropriate physical activity opportunities are the foundation of the earliest stages of behaviour change[28]. Patients will begin to contemplate changing their physical activity behaviour only when they become aware of the need for change. In order to move from contemplation to the preparing for action stage, patients must develop sufficient motivation for physical activity and resolve any ambivalence towards a change in behaviour[28,29]. Clinicians should explore the child's physical activity interests as well as the physical activity resources available when counselling patients and families. It is also helpful to introduce the child/family to a broad range of appropriate physical activity opportunities to ensure that a lack of knowledge or uncertainty about activity does not inappropriately restrict the child's participation. Research indicates that over 40% (33/81) of parents of children with congenital heart defects have questions or concerns about their child's physical activity participation (unpublished data).

Table 1 Examples of Health-Related Fitness Protocols (reprinted from Longmuir et al, 2013[8]).

Health-Related Fitness Dimension	Examples of Assessment Protocols
Cardiorespiratory fitness	20-metre shuttle run, 15-metre shuttle run, modified Canadian Aerobic Fitness Test.
Flexibility	Sit and reach, Back-saver sit and reach.
Muscular strength	Handgrip strength, Standing broad jump, Vertical jump, Bosco jump protocol.
Muscular endurance	Plank static hold, Partial curl-up, Curl-up, Bent-arm hang, Push-up.
Body composition	Waist circumference, Body mass index, Waist-to-hip ratio, Sum of skinfolds.

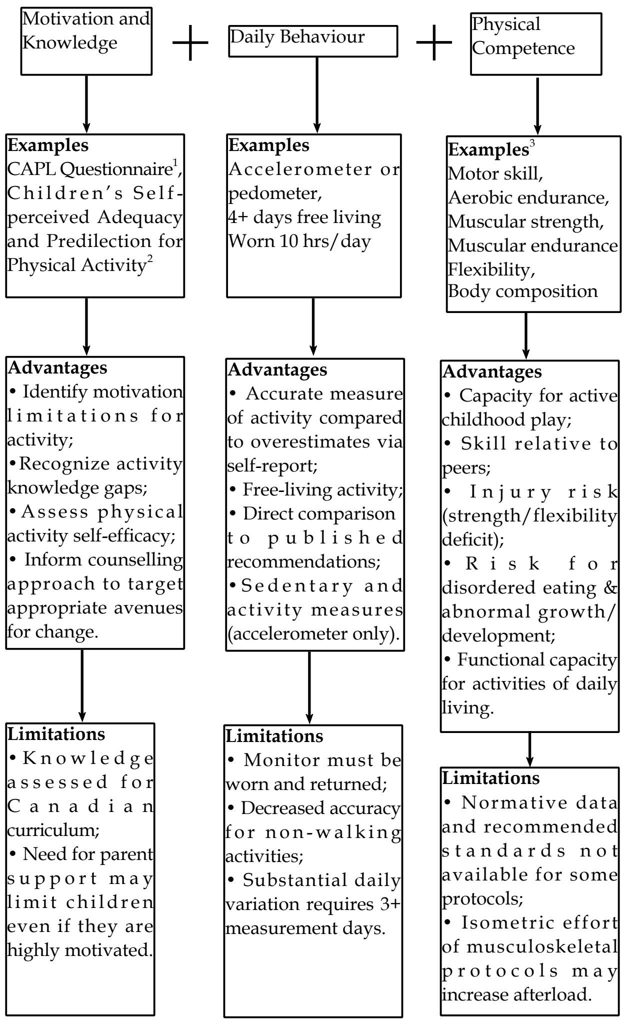

Figure 1 Physical Literacy Assessment Paradigm.

[1] CAPL questionnaire: motivation and knowledge components of the Canadian Assessment of Physical Literacy are available online (www.capl-ecsfp.ca);

[2] Hay JA. Adequacy in and predilection for physical activity in children. Clin J Sport Med 1992;2:192-201.

[3] CAPL assessment protocols are: obstacle course (motor skill), PACER shuttle run (aerobic endurance), hand grip dynamometry (muscular strength), plank isometric hold (muscular endurance), sit and reach flexometer (flexibility), body mass index (body composition).

Assessment of Daily Behaviour

Asking patients about their physical activity participation is a well-established practice in paediatric cardiology. Physicians inquire about the types of activity the child performs, whether the child can do as much physical activity as peers, and whether any symptoms occur with exertion. In relation to supporting children with congenital heart defects to achieve the physically active lifestyle associated with optimal health, this traditional approach has several limitations. First, it relies on child self- or parent proxy-reports of the child's physical activity. Research has clearly demonstrated that subjective reports of physical activity participation are very inaccurate. There is low to fair agreement between parent and child reports of the child's physical activity[30] and the reported physical activity levels differ significantly from objective measures[31]. Children considered inactive based on accelerometer measures of daily activity were reported to be active by 80% of parents and 40% of the inactive children themselves[31]. Among patients with congenital heart disease, the inaccuracy of subjective estimates of exercise capacity has also been demonstrated[32,33] even among those who reported being asymptomatic[32]. An additional limitation is the use of peers as a reference for the child's activity level. Studies provide conflicting evidence as to whether children typically achieve the recommended level of physical activity[22,34]. For North American children[22,35] at least, most healthy peers lead sedentary lifestyles such that "being able to keep up with peers" does not represent a physically active lifestyle.

Pedometers and accelerometers are devices that measure walking steps or body acceleration, respectively. Pedometers provide a measure of the child's physical activity, while accelerometers can measure both sedentary and active behaviours. Population-based data for typical values among children as well as recommended levels for optimal health are available for both types of measures. Children should accumulate at least 12,000 steps per day[36] or at least 60 minutes per day of activity that is of moderate or higher intensity[10-14]. Accelerometers are considered more accurate, particularly for non-walking activities, but they are also more expensive ($200-$400 versus $10-$15 or less). More recently, pedometers that also estimate time spent in moderate-to-vigorous activity have been developed[37]. All of these devices are very small, making them suitable for even young children[38,39]. Most are water-resistant and are worn on the waist or wrist. Due to the high day-to-day and within-day variability of children's physical activity, 7 days of pedometer or accelerometer measurements with the device worn for at least 10 hours per day are recommended[40], although physical activity can be estimated from a minimum of 4 days (including 1 weekend day).

Objective measures of daily behaviour are valuable when counselling patients regarding physical activity because the data can dispel misconceptions about the child's level of activity. Measures of sedentary time are typically very high, on average 7 to 8 leisure hours per day for adolescents[22]. Data on the high amount of discretionary time spent in sedentary pursuits can counteract the most commonly cited barrier to increasing physical activity – a lack of time. Even when very few children achieve the daily physical activity recommendation, most children will achieve the recommended activity level on at least 1 day per week[36]. These data can be helpful in counselling children and parents that achieving the recommended activity level is possible for children with a congenital heart defect. They also demonstrate the feasibility of the recommended behaviour change. Although children with congenital heart defects are often sedentary[6,41], evidence that a physically active lifestyle is feasible for these patients can be seen in children with the most complex congenital heart defects who are able to achieve the recommended 60 minutes of daily activity[19] even in the presence of significant limitations to maximal exercise.

Assessment of Physical Competence

The physical competence domain within physical literacy refers to the motor skill, body composition and health-related physical fitness required to successfully participate in physical activity. Standardized protocols for assessing children's health-related fitness (aerobic endurance, muscular endurance, muscular strength, flexibility) and body composition are well established (examples in table 1 and Bar-Or and Rowland, 2004[42]). Traditional assessments of motor skill are more limited because many established protocols are designed to identify children with motor skill deficits or to focus primarily on younger children[43-46], which may limit their usefulness in describing the motor skill of typically developing children[47]. The Canadian Assessment of Physical Literacy combines an obstacle course assessment of motor skill with health-related fitness assessments (PACER shuttle run[48] for aerobic endurance, plank isometric hold for muscular endurance[49], handgrip for muscular strength[50], sit and reach for flexibility[50], and height, weight and waist circumference for body composition[50]) to indicate the child's physical competence for a physically active lifestyle.

Physical competence assessment results contribute valuable information when counselling children with congenital heart defects regarding a physically active lifestyle. The intermittent activity that characterizes the play of younger children[51] depends much more heavily on skill, strength, flexibility, and balance than aerobic endurance. Older youth also identify a perceived lack of skill as being a primary barrier to participation[25]. As such, the physical activity participation of children with congenital heart defects is typically not disadvantaged because of cardiac function or maximal exercise limitations, and even those with cardiac limitations can successfully participate[52]. In fact, some studies have suggested that children with complex heart defects may perform sub-maximal aerobic exercise as or more efficiently (i.e., with similar or lower levels of energy expenditure) compared to healthy peers[53,54]. Unfortunately, sedentary lifestyles, which are adopted by many children with congenital heart defects, are associated with decreased health-related fitness[55] and motor skill[56]. Thus, the decreased physical competence often observed among children with congenital heart defects is hypothesized to result primarily from their "hypoactive" lifestyles[6]. Fortunately, exercise training[57,58] and increased physical activity[59] can improve the fitness and motor skill of children with simple and complex congenital heart defects.

ENHANCED USE OF CARDIOPULMONARY EXERCISE TEST RESULTS

As summarized by Rhodes and colleagues[2], maximal cardiopulmonary exercise tests provide important information regarding the cardiopulmonary function of patients with congenital heart defects. Most directly, these maximal effort tests indicate the child's capacity for high intensity physical activity. However, the physiological changes that occur in response to an exercise stimulus can also provide important information regarding cardiovascular status, such as the response to changing vascular pressures, heart rate limitations due to sinus node dysfunction, or the impact of ventricular dysfunction, residual shunts or valvular disorders[2]. When interpreting test results, it is important to determine whether the highest values attained represent a truly maximal effort (and therefore represent the individual's maximum cardiorespiratory capacity) or simply the peak voluntary effort that was generated during the assessment. Maximal exercise capacity is primarily (40% to 70%) influenced by genetics[60]. Established criteria for a maximal effort in children include a plateau in oxygen consumption despite increased workload (which only occurs in about 50% of children), a heart rate of at least 195 beats/minute, a blood lactate concentration of 9 mmol/litre or a respiratory gas exchange ratio that exceeds 1.0[42].

While information on the function of the cardiovascular system during maximal exercise is beneficial for disease management, the health benefits of daily physical activity accrue with moderate intensity activity[11,13]. Thus, cardiopulmonary exercise protocols that incorporate sub-maximal exercises stages of at least 3 minutes duration (e.g., Bruce treadmill protocol) can provide important information to enhance physical activity counselling even in the absence of a maximal effort. Normative data for the heart rate response of children at each stage of the Bruce protocol[61] provide important information regarding the child's capacity for daily physical activity and active play with peers. Sub-maximal exercise response is also an effective way to monitor the effects of training over time, as the energy and effort required for a given workload will decrease as physical fitness improves even in the absence of changes to maximal exercise capacity. The target activity intensity to increase cardiorespiratory fitness in children is an intensity of 60% to 80% of maximal exercise capacity[42]. Children as young as 7 years of age can be taught to monitor and maintain their target exercise intensity based on perceived exertion[62]. When counselling children with congenital heart defects and their families, it is important to educate families on the differences between maximal and typical exercise, as well as how the child's capacity is suited for the typical energy demands of childhood physical activity[42,63].

CONCLUSION

Physically active lifestyles are important for the physical and mental health of children with congenital heart defects. Exercise assessments should include measures of physical literacy, as well as sub-maximal cardiorespiratory capacity. These results provide a more accurate and comprehensive picture of the child's capacity for a physically active lifestyle, and are the foundation for providing effective physical activity counselling to the child and family.

CONFLICT OF INTERESTS

There are no conflicts of interest with regard to the present study.

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