# Assessment of Physical Activity in Children and Adolescents with Congenital Heart Defects

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**Abstract:** Disorder of the cardiovascular system is the most common cause of death worldwide and sufficient physical activity plays an import role in preventing these deaths. Children and adolescents with congenital heart defect are at risk of living a sedentary life as a result of overprotection and uncertainty regarding physical activity recommendations. Assessment of physical activity level should therefore be part of regular follow-up in this population. A whole range of subjective and objective measure instruments of physical activity are available. However, not all are suitable in children and adolescents. Questionnaires have the advantage of being inexpensive and simple, but reduced recall capability of children and adolescents and low-to-moderate correlation with objective measures of physical activity are of concern. At present a single unobtrusive motion sensor allowing valid and long-term monitoring of physical activity may be the best choice.

**Keywords:** Congenital heart defect, children, physical activity, assessment.

## INTRODUCTION

Cardiovascular disease is the leading cause of death worldwide and disorders of the cardiovascular system represent the foremost cause of preventable death globally [1]. Increased physical activity as part of an improved lifestyle, will contribute to cardiovascular disease prevention. In adults there is a strong link between reduced physical activity and all-cause mortality [2]. It is generally accepted that physical activity is important also for child health, well-being and quality of life [3]. This benefit of physical activity on cardiovascular health is maintained into the elderly [4]. In the last years we have seen a trend towards a less active lifestyle among teenagers, partly due to increases in electronic media use [5,6]. Information about the importance of physical activity and the physical activity level of children and adolescents with congenital heart defects (CHD) is scarce [7,8]. Lunt *et al.* reported that West Australian male adolescents aged 12-18 years with CHD were less active than healthy peers and only a minority received physical activity advice at regular follow-up [8]. Other studies of young adult patients with CHD suggest that moderate physical activity is correlated to improved exercise capacity and perceived physical functioning [9-11], which in turn is related to a reduced risk of hospitalisation and death [12]. Furthermore, studies have shown that patients with CHD or their parents tend to overestimate the patients physical activity level and that there is poor correlation between physical activity level and cardiovascular status [8,13-15]. Objective measures of physical activity in the population of children and adolescents with CHD could help us identify correlates of sedentary behaviour and guide us in future interventions to reduce sedentary behaviour [16,17]. However, assessment of physical activity is challenging in children due to the typically short and sporadic nature of their physical activity and the range of developmental maturity across ages [18-20].

The purpose of this review is to give the practitioners and researchers a practical guide for monitoring of habitual physical activity in children and adolescence with congenital heart defects. A short presentation of the most common methods for assessing physical activity under free-living conditions is presented in this article.

## PHYSICAL ACTIVITY

Physical activity is defined as any bodily movements produced by skeletal muscles that result in energy expenditure [21]. It is described by the four dimensions; 1) frequency, 2) duration, 3) intensity and 4) type of activity [21]. Any assessment of physical activity should ideally measure all of these dimensions and account for day-to-day variations. To be complete it must also capture the domains in which physical activity occurs, that is occupational, domestic, transportation, and leisure time. Physical activity and basal metabolic rates (BMR) are the main contributors to total energy expenditure (TEE) [22]. The World Health Organisation (WHO) has defined the physical

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activity level (PAL) as the ratio of TEE to BMR. A minimum PAL of 1,44 – 1,84 is recommended for children and adolescents aged 3 – 18 [23]. The metabolic equivalent of task (MET) expresses the energy cost of physical activity and is defined as the ratio of metabolic rate during a specific physical activity to a reference metabolic rate. One MET is commonly defined as 3,5 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$. METs can be converted to kilocalories (1 MET = 1 $kcal \cdot kg^{-1}$ $h^{-1}$). During different types of physical activities metabolic rate may vary approximately 9-fold, ranging from 2 MET (slow walking) to 18 MET (competitive running). Tables to convert different types of physical activity into METs and PAL are available [24]. The WHO gives recommendation on physical activity level (PAL) in children [23]. They suggest that children should perform a minimum of 60 minutes per day of moderate-intensity physical activity, which may be carried out in cumulative boots of ten or more minutes [25].

## ASSESSMENT OF PHYSICAL ACTIVITY

Several instruments, both subjective and objective, are available for reliable assessment of habitual physical activity in children. No instrument is ideal for all clinical or research questions (see Table **1**). The correlations between subjective (self- or proxy-reported questionnaire, diaries or logs) and objective (doubly labeled water, motion sensors, heart rate monitoring or direct observation) methods are reported to be low-to-moderate, with a tendency of overestimation by subjective methods [26]. None of the available methods have been properly validated in children and adolescents with congenital heart defect.

Before one decide which instrument to use it is mandatory to define the primary outcome variable of interest, together with an evaluation of the reliability and validity of the method. In this setting you also have to consider the feasibility of the assessment method, such as costs, age of participants and post processing work. Strath *et al.* [27], have presented an excellent decision matrix guide to selecting a physical activity instrument. Although primarily meant for adult participants, the same principles also apply for children.

### Subjective Assessment Instruments

#### *Diaries/Logs*

Self-report instruments are the most widely used tool to assess physical activity due to its simplicity and cost-benefit perspective. Physical activity diaries or logs are self-administered or proxy-reported and give information about the type of activity, the time spent in a specific activity and the rate of intensity. It is a continuously record throughout the day on an activity-by activity or time-by-time base. They are typically

**Table 1: Pros and Cons of Measures of Habitual Physical Activity in Children and Adolescents**

| Tool | Pro | Con |
|---|---|---|
| *Self-report/subjective assessment* | | |
| Diary/Log | Inexpensive, simple, in combination with motion sensor | Proxy-related bias, nv-DLW, post-processing, participant burden |
| Questionnaire | | |
| Global | Inexpensive, participant burden, simple, fast, post-processing | nv-DLW, validity, reliability, small children (<10y) |
| Short recall or historical | Inexpensive, participant burden | nv-DLW, validity, reliability, small children (<10y), post-processing |
| *Objective assessment* | | |
| DLW | “Gold standard” | Expensive, post-processing, patient burden |
| Motion sensors | | |
| Pedometer | Inexpensive, Preschoolers/unobtrusive, v-DLW, immediate feedback to patient (motivational purpose) | Only activity duration |
| Accelerometer | Acceptable costs, unobtrusive, v-DLW, activity duration and intensity, accurate | Post-processing |
| Multi-sensing | Greater research potential | nv-DLW, obtrusive, post-processing, risk of technical failure, heart rate related issues |

nv-DLW; not validated against doubly labeled water, DWL; doubly labeled water, v-DWL; validated against doubly labeled water.

paper-and-pen-based and the participant burden is high. An example of such an instrument is The Bouchard Physical Activity Record, which also has been validated in children [28]. Cell phone-based physical activity diaries have been developed to overcome some of the burden and measurement error related to the paper diary [29]. It has been suggested that the combination of objective measurements and time activity diaries increase data validity and give better insight into age and gender related differences [30]. Physical activity diaries may have acceptable reliability and validity in the adult populations, but is more challenging in children and adolescent because of their highly variable physical activity pattern and limited ability to recall details of recent activities and due to proxy-related bias by social desirability [31].

### *Questionnaires*

The wide range of available structural physical activity questionnaires in school-children and adolescents makes it difficult for clinicians and researchers to decide which physical activity questionnaires is the most suitable for a specific variable of interest. In children they are self-reported, proxy-reported or interviewer administered and can be paper-and-pen based (most) or web-based [32]. The questionnaire may be *global*, containing only a few (2-4) items, like the Teen Health Survey [33], providing a quick overview of a person´s physical activity level or *historical*, providing detailed surveys over a longer period (months or years). In between there are *short recall* physical activity questionnaires, typically with 7-12 items, aiming at determining the total volume of physical activity during a specific or typical day or week. Examples of short recall physical activity questionnaires are the Physical activity Questionnaire for older children (PAQ-C) or adolescents (PAQ-A) [34,35] or the web-based Synchronised Nutrition and Activity Program (SNAP) [32]. The use of electronic questionnaires has several advantages with written surveys. A standardized computer survey is cost and time saving allowing many individuals to report data at the same time. It offers the possibility of transient data management and interpretation of the results. Since no written records exist, the confidentiality of sensitive data is better handled. This may give responders a greater feeling of anonymity giving rise to a more honest reporting [36].

Physical activity questionnaires may be particular troublesome in youth due to their cognitive immaturity with reduced ability of abstract thinking and to perform detailed recall [37]. It has been suggested that recall instruments should only be used in children who are ≥ 10 years old and the time from physical activity to report should be kept as short as possible to enhance validity [38]. Furthermore, their activity pattern, characterised by short bouts of high intensity activity, is more difficult to recall and to capture in a questionnaire. It is therefore recommended to use short (24 h) and structured recall periods in a segmented format (before school, lunch, after school, evening meal, etc.) [39,40]. Due to its ability to capture at least three dimensions of physical activity (frequency, duration and intensity), at low costs and low patient burden, together with immediate availability of the results and little personnel and data processing needed, global questionnaires are probably the only instrument suitable in an out-patient setting. However, in a review including 61 versions of physical activity questionnaires for youth, Chinapaw *et al.* [41] concluded that no questionnaires were available with both acceptable reliability and validity. In another review by Biddle and Co-worker [42], only the Physical Activity Questionnaire for Children/ Adolescents (PAQ-C/PAQ-A) [34,35], the Youth Risk Behaviour Surveillance Survey (YRBS) [43], and the Teen Health Survey [33] were considered suitable for selected population surveillance and received support from the majority of the expert panel.

## Objective Assessment Instruments

### *The Doubly Labeled Water Method*

The doubly labeled water (DLW) method is by many experts considered the gold standard to measure total energy expenditure in free-living individuals over a period of 1-3 weeks [44]. It is the method of choice to validate other instruments in their ability to assess physical activity under free-living conditions [45]. The theoretical considerations and assumptions that underpin the method are complex and outside the scope of this review [46]. It is non-invasive and can be applied in all ages and populations [47]. Due to high costs, a significant participant level of burden and detailed and time intensive data processing, it is only suitable for small-sample scientific studies.

### *Motion Sensors*

Motion sensors are small, lightweight (< 50 grams) instruments capable of detecting the amplitude and frequency of acceleration in vertical or multiple axes. They should be unobtrusive and easy to wear and placed close to the centre of mass of the body. An increasing number of smart phones have built in motion sensors with the potential as activity monitor [48]. Due to substantial variation in activity pattern, children and adolescents need to be monitored for at least 4 days to get a true picture of their habitual physical activity level [49]. It is therefore important that the device has sufficient battery and storage capacity. Motion sensors do not capture all body movements and this is a limitation of the method. Therefore it has been suggested that the combination with a diary, explaining the type of physical activity performed, would increase the validity of the data collected by the motion sensor [30].

*Pedometers* are simple and inexpensive motion sensors originally designed to measure walking behaviour. The volume of physical activity is outputted as the number of steps taken and typically displayed on a digital screen [50]. Most pedometers have a spring-suspended lever arm moving up and down with vertical acceleration of the device. The Yamax SW-200 has been validated in children against other pedometers and direct observation [51-53]. Today most manufacturers also offer piezoelectric pedometers. This device consists of a horizontal suspended beam and a piezoelectric crystal that directly measures vertical acceleration [50]. Some studies have indicated that piezoelectric pedometers are more sensitive to slow walking speed compared to spring-suspended lever arm models [51]. The New Lifestyle NL-2000 [51] and the Omron Walking Style Pro [54] have been validated in children against other pedometers. The pedometer has some obvious advantages in children toward other physical activity assessment instruments. Foremost, it is light and unobtrusive, a very important factor especially in the smallest children. They are easy to use and the outcome – a step count - is easily understood even by children [55]. Furthermore it is inexpensive and can be used in large-scale studies. Newer models can measure steps per time unit. Especially those with the possibility to measure minute-by-minute physical activity may be suitable in pre-school children where the duration of physical activity should be captured, irrespective of intensity [56]. In general it is not possible to estimate the time spent in a specified activity intensity threshold range using a pedometer. A digital screen offer the possibility to motivate behaviour change, an advantage of pedometers that can be of use in adolescents and adults.

An *accelerometer* is perhaps the most promising tool to objectively assess habitual physical activity from a researchers point of view. Because sedentary behaviour is a risk factor for disease, independent of the physical activity level, modern accelerometers should be able to measure posture and not only movement [57]. As a result of this, manufacturer have developed instruments with sensors consisting of a piezo-electric, piezo-resistive and/or capacitive element, within an enclosed casing, capable of measuring the gravitational field, combined with low weight and long battery life. Plasqui *et al.* [58,59] and Westerterp *et al.* [45] recently presented a review of the most common accelerometers, giving details about technical specifications and validation using DLW as the reference.

Compared to a pedometer an accelerometer measure both intensity and duration of physical activity, which is of interest within surveillance research due to their relationship to current physical activity public health guidelines [23]. The sampling time or epoch typically ranges from 1 s up to 1 min. To capture the sporadic and short-lasting activity pattern of preschool children the possibility to choose a short epoch length (15-30 s) must be available [60,61]. The issue of epoch length interact to influence accelerometer-derived moderate-to-vigorous physical activity also in adults [62]. Raw data outputs (i.e., counts or counts/min) can be transformed to derive the time of physical activity spent in certain intensity categories based on count cut-points. For each instrument it is important to determine if available count cut-points have been validated in the population you want to study [63]. If not, alternative data processing using the raw acceleration signal is recommended [64].

Accelerometers have been used in a number of studies assessing physical activity level and the post-interventional change in such, in children and adolescents with congenital heart defect [14,65,66].

### *Physiological Measures and Multi-Sensing Methods*

Other physiological variables, such as heart rate monitoring, skin temperature or galvanic skin response, can be measured separately or included in multi-sensing instruments. By nature multiple sensor systems increase the risk of technical failure. Especially in children the use of larger multi-sensing instruments or multiple accelerometers decrease wear ability. Heart rate monitoring may have several limitations in children with certain congenital heart defects due to impaired chronotropic response to exercise and the use of beta-blockers. Furthermore, it is influenced by sympathetic reactivity at low-intensity levels of activity [67]. Its accuracy may be improved by calibrating the patients´ heart rate and energy expenditure response to different levels of activity using indirect calorimetry or doubly labeled water [68]. Whether the addition of extra sensors or the use of multiple accelerometers significantly improves the accuracy of estimating energy expenditure in children and adolescents is yet to be confirmed [69].

## FUTURE RESEARCH

Patients with chronic diseases may have a different physical activity pattern than the healthy population. The use of methodologies established for children without chronic disease when predicting physical activity level in children with chronic disease has been questioned [70]. Information about validated physical assessment instruments in chronic disease populations is lacking [71,72]. This is also the case for children and adolescents with congenital heart defects. Proper validation studies of all available physical activity assessment tools against DLW would be appreciated.

## CONCLUSION

Physical activity level should be assessed regularly in children and adolescents with congenital heart defects. There is no single physical activity assessment instrument that is appropriate for all situations, populations and primary outcome of interest. The best option seems to be single unobtrusive pedometers or accelerometers allowing valid and long-term assessment of habitual physical activity.

## DISCLOSURE/CONFLICT OF INTEREST STATEMENT

The information contained within this review does not constitute an endorsement or recommendation on the behalf of the authors, of any product, manufacturer, or distributor discussed herein. Authors have no financial or other interest in the products or distributors of the products reviewed. This work was not supported by any form of external financial support.

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