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Physical activity in children with CHDs through the microscope of the methodologist

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Childhood is a time period of large physical and physiological development. An important factor promoting this development is physical activity. The broader definition of childhood, but also of children, includes individuals up to 18 years old. However, due to the distinct developments when puberty starts and the change in physical activity pattern, a narrower definition of childhood and children includes individuals up to 12 years old to distinguish them from adolescence and adolescents 13–18 years old. The physical activity in children is characterised by short, spontaneous bursts of high intensity activities interspersed with periods of low and moderate intensity. [1,2] Further, participation in a diversity of activities with varying intensity in younger ages is associated with more physical activity later in childhood and adolescence.[3] It is therefore plausible to assume that any factor that interferes with performing spontaneous and joyful physical activity in childhood may reduce participation later in life.

Every year approximately 8 out of 1000 children are born with congenital heart defects (CHDs).[4] Advances in clinical care and surgical procedures have improved survival rate. In Sweden, for example, over 97% of these children are expected to reach adulthood.[5] Depending on the severity of the CHDs and the complexity of restoring a functional circulation, there will be a variation in physical capacity (or physical constraint) and complications later in life. The aerobic capacity (as an indicator measure of the physical capacity) may be 30 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$ or lower in individuals with more severe CHDs (e.g. univentricular) which is a reduction compared to their healthy peers, and range to 40 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$ or higher in those with only mild defects (e.g. septum defects) which is similar to individuals with no CHDs.[6] In addition to the physical capacity, psychological factors such as the own experience of the CHDs, influenced by the attitude and knowledge of the parents, caregivers, peers, teachers, etc., would determine the physical activity pattern.[7–9] Importantly, these individuals live among us, and they do not always tell us about their CHDs. If we do not know about it, we probably do not understand their experience and behaviour and unlikely provide the proper support.

Several studies have been performed to compare physical activity among children with CHDs of varying severity and with healthy controls, using self-report instruments or activity monitors like accelerometers. These studies have been evaluated in recent reviews.[6,10,11] Interestingly, in contrast to what would be expected from differences in physical capacity, there is no clear evidence of difference in physical activity among children with varying severity of CHDs or compared to their healthy controls. Our research group has worked with development of physical activity measurement, including all steps from data collection and processing to statistical modelling.[12] This has been summarised together with other methodological research in a review directed to clinical investigators.[13] The results have delineated several explanations to the unexpected findings presented above, which are presented in a recent review.[6] The major ones related to objective measurement are presented below.

The most common activity monitor is the accelerometer worn in an elastic belt around the waist. The raw acceleration is processed in several steps to get a useful measure of physical activity. One of these steps involves frequency filtering to remove unwanted noise from the useful part of the acceleration signal.[14] Unfortunately, in those accelerometers commonly used in studies of children with CHDs, the filter has been set too narrow, attenuating a substantial part of the acceleration signal. This attenuation increases with increasing movement frequency, that is, the faster you move the body not only due to higher activity intensity but also due to smaller body size (as in children), the more the acceleration signal is removed (Fig 1A). The basic acceleration signal recorded by the accelerometers is the step frequency. The signal frequency ranges from 1 Hz during slow walking to 3 Hz or higher during running.[14] The narrow frequency filter has already attenuated half of the acceleration signal at 2 Hz, corresponding to the step frequency during fast walking.[15] Unfortunately, this error is disguised when calibrating the accelerometer measure for different intensity categories (e.g. moderate, vigorous) against a reference method such as indirect calorimetry, instead leading to difficulties to discriminate physical activity intensity and an overestimation of time spent physically active.[16] In previous methodological studies, this measurement error was evident[17] and contributed to that a clear difference in physical activity was not observed when comparing children with CHDs of various severities to their healthy controls.[18]

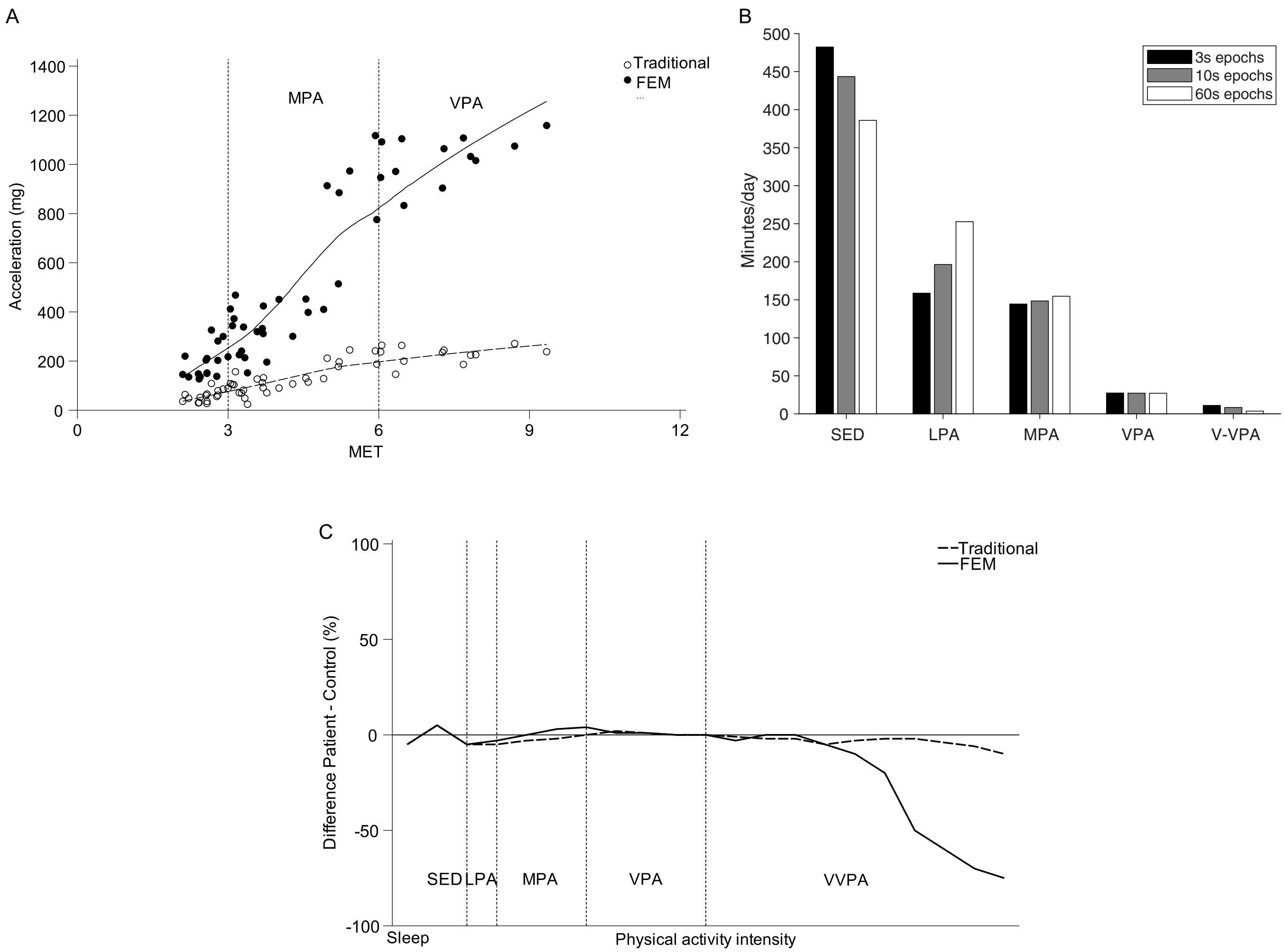

Figure 1. **(A)** Relationship between physical activity intensity (MET) and accelerometer measure (mg) in children; the attenuation of the acceleration signal with the traditional narrow frequency filter interferes with discrimination of intensity levels from the regression model (e.g. moderate physical activity (MPA) from vigorous physical activity (VPA)) compared to the frequency extended filter (FEM) (figure adapted from Fridolfsson et al 2018). (**B**) Time spent in different physical activity intensity levels in children using 3, 10, or 60-second epoch; longer epochs attenuate the intensity variation and assign more time to light physical activity (LPA) and moderate physical activity (MPA) and less to high intensity short bursts (V-VPA) (figure created from data in Skovdahl et al 2021). Please observe that hours are spent in sedentary and light physical activity, while only minutes to seconds in vigorous to very vigorous physical activity. Consequently, having all intensity levels on the same scale (minutes) will not visualise the differences. (**C**) Difference in physical activity pattern between children with valvular aortic stenosis compared to their controls using a high-resolution spectrum (crude intensity categories are indicated) with traditional narrow frequency filter or frequency extended filter (FEM); with the FEM, the difference in the short bursts of high intensity physical activity is revealed (figure adapted from Skovdahl et al 2021).

Another explanation may be the measure used to distinguish individuals being sufficiently physically active. Often time spent in moderate-and-vigorous physical activity is compared, as this measure is the foundation for our physical activity guidelines. However, one consequence of using this measure is that it mixes up physical activities of a wide intensity range, stressing the physical capacity to various degree. Another consequence of this measure when applied to accelerometer data is that it includes physical activities at an intensity corresponding to as low as slow walking,[15] which would not stress the physical capacity, not even for individuals with more complex CHDs. There is an overestimation of the importance of measuring moderate-and-vigorous physical activity and an underestimation of the importance of measuring the physical activity pattern that may distinguish children with CHDs from their healthy peers. This is probably one reason to why we do not detect a difference in physical activity. As it seems that short bursts of high intensity physical activity have the strongest association with cardiometabolic health in children, not continuous time spent in the lower part of moderate physical activity,[12] it is crucial that the activity monitors used capture this intermittent physical activity pattern.

A third explanation is the resolution used to analyse collected data. Children's bursts of high intensity activities have a duration of less than 10 seconds.[1,2,19] In previous research in children with CHDs using accelerometers, the resolution of analysing data (epoch length) has been set to 10 seconds or larger time periods. Consequently, the low resolution would also contribute to that the activities stressing the physical capacity would be less likely captured (e.g. the short bursts of high intensity physical activity) (Fig 1B), reducing the detected difference among children with CHDs and compared to their healthy controls.

In a recent study of physical activity in children treated for congenital valvular aortic stenosis and controls matched for age, sex, address, and time of measurement (as part of a larger project), the frequency filter was extended to include all relevant acceleration signals, the resolution of analysing data was set to 3 seconds, and instead of crude intensity categories the accelerometer data were divided into a spectrum of smaller intensity intervals.[20] Now the expected difference in physical activity pattern was detected: short and spontaneous bursts of high intensity activities (Fig 1C).

In conclusion, this paper highlights methodological aspects that are important to consider when using accelerometers to evaluate the physical activity in children with CHDs of various severity. Methodological advances need to be employed in clinical research to achieve accurate as well as relevant measures of physical activity.[6,13] This is important in order to draw correct conclusions about the physical activity in these patients.

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Ethical standards. The author asserts that all procedures contributing to this work comply with the ethical standards of the relevant national guidelines on human experiments (Swedish Ethical Review Authority) and with the Helsinki Declaration of 1975, as revised in 2008, and has been approved by the institutional committees (The Regional Ethics Committee in Gothenburg, No. 1026-17, No. 582-18). Concerns data presented in Figure 1.

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