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Review

Children With Congenital Heart Disease and the Canadian 24-Hour Movement Guidelines: A Scoping Review

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ABSTRACT

Factors such as physical activity (PA), sedentary time, screen time, and sleep affect the holistic health of children with congenital heart disease (CHD). Despite this, their proximity to reaching the Canadian 24-hour movement guidelines is unknown. This review sought to synthesize evidence for PA, sedentary time, screen time, and sleep behaviour of children with CHD and compare them with the Canadian 24-hour movement guidelines. Six online databases were searched for research published from January 2010 to May 2024. Eligible articles included research involving children aged 4-20 years with any type of CHD lesion as well as a measure of one of PA, sedentary time, screen time, or sleep, reported in a unit of time. The search resulted in 9199 articles, and after removing ineligible articles, 30 were identified for this review. Of the included articles, 30 measured moderate-to-vigorous PA (MVPA), 8 measured light PA, 14 measured sedentary

RÉSUMÉ

Certains facteurs tels que l'activité physique, le temps de sédentarité, le temps d'écran et le sommeil influencent l'état de santé général des enfants atteints d'une cardiopathie congénitale. On ignore cependant si ces enfants sont près d'atteindre les Directives canadiennes en matière de mouvement sur 24 heures. Cet article vise à synthétiser les données probantes relatives à l'activité physique, au temps de sédentarité, au temps d'écran et aux habitudes de sommeil chez les enfants atteints d'une cardiopathie congénitale, et à les comparer aux Directives canadiennes en matière de mouvement sur 24 heures. Nous avons consulté six bases de données en ligne à la recherche de travaux de recherche publiés entre janvier 2010 et mai 2024. Les articles devaient porter sur des travaux menés chez des jeunes âgés de 4 à 20 ans, peu importe le type de cardiopathie congénitale dont ils étaient atteints, et comprendre au moins un paramètre évaluant

Congenital heart disease (CHD) is a birth abnormality that affects 1 in 100 children,[1] and its prevalence has been increasing since 2009.[2] This increase is likely due to improved techniques for detecting mild CHD severities and greater use of echocardiography globally.[2] With better detection, children with CHD receive higher quality medical care sooner, which has improved their life expectancy.[3] In addition, this has caused a greater emphasis to be put on improving other health outcomes across the lifespan, aside from their heart lesion.

Now that children with CHD are living longer, comorbidities such as lower bone strength,[4] greater health anxiety,[5] and a greater risk of cardiovascular health complications[6-8] are being reported. Short- and long-term cardiovascular health complications in this population include greater rates of arterial stiffness,[6] an increased risk of premature cardiac damage, and vascular remodelling,[7] as well as higher central and systolic blood pressure.[7,8] The severity of these comorbidities can be reduced by participation in physical activity (PA). PA improves exercise capacity,[9-13] self-efficacy,[9,14] cardiac function,[6,12,15] and quality of life[10,16,17] in children with CHD. In addition, PA is especially important for their cardiovascular health as it improves arterial stiffness,[6,15] lipid profile,[18] and vascular function.[19]

Despite earlier hesitation from physicians and parents,[17,20-22] research has shown that children with CHD can safely participate in most forms of PA and exercise.[23-25] However, it can be challenging for children with CHD to engage in moderate-to-vigorous PA (MVPA) for as long as their peers due to their lower exercise capacity.[22,26] One reason why children with CHD have impaired exercise capacity is their lower peak oxygen uptake than healthy peers;[27] this difference is amplified

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time, 1 measured screen time, and 3 measured sleep time. Forty percent of studies reported that children with CHD met the MVPA guidelines. Within these, a subset of studies (n = 20) examined the percentage of the sample that reached the guideline and found that an average of 43% of children with CHD attained the MVPA guideline. No conclusions could be made for light PA or sedentary time because there is no clear quantification or numerical recommendation in the Canadian 24-hour movement guidelines. In addition, future research should include evaluations of the screen and sleep time of children with CHD due to very limited research in the area.

l'activité physique, le temps de sédentarité, le temps d'écran ou le sommeil mesuré en unité de temps. La recherche a fait remonter 9 199 articles, parmi lesquels nous en avons retenu 30 après élimination des articles non pertinents. Les 30 articles retenus faisaient état d'une activité physique modérée ou intense; huit, d'une activité physique légère; le temps de sédentarité a été mesuré dans 14 articles; le temps d'écran, dans un seul, et le temps de sommeil, dans trois articles. Dans 40 % des études, les enfants atteints d'une cardiopathie congénitale respectaient les degrés d'activité physique modérée ou intense préconisés dans les directives. Le pourcentage de l'échantillon qui respectait les directives a été examiné dans un sous-ensemble de ces études (n = 20) et en moyenne, 43 % des enfants atteints d'une cardiopathie congénitale atteignaient le degré d'activité physique modérée ou intense recommandé. Aucune conclusion n'a pu être tirée concernant l'activité physique légère ou le temps de sédentarité, faute de quantification ou de recommandation numérique dans les Directives canadiennes en matière de mouvement sur 24 heures. Les recherches menées à l'avenir devraient par ailleurs inclure les enfants atteints d'une cardiopathie congénitale chez qui le temps d'écran et le sommeil sont évalués, compte tenu du nombre très limité de travaux réalisés à ce jour dans ce domaine.

in children with more severe lesions.[27] Regardless of this difference, children with CHD should not limit the amount of exercise they do[27,28] but may have to alter the frequency, intensity, type, and time of PA bouts.[26,28]

Contrary to PA, sedentary time can have a negative influence on the comorbidities of CHD. Sedentary time and family history of obesity are related to higher central adiposity in children with CHD.[29] Furthermore, there are no differences in sedentary time between children with CHD of various severities.[30-32] However, PA and sedentary time are just a part of what impacts the holistic health of children with CHD. Screen time is an increasingly prevalent aspect of modern childhood; thus understanding and managing screen time levels in children with CHD is essential to their holistic health. Screen time has been found to have positive (homework), negative (television), and ambivalent (video games) impacts on academic achievement and health outcomes in the general population.[33] In addition, a systematic review found that high screen time can lead to a significant reduction in sleep.[34] Research evaluating sleep in children with CHD is very sparse. Despite this, sleep is important as it makes up most of a child's day,[35] and poor sleep habits can impact the health benefits received from MVPA.[36] In fact, for children with CHD, better sleep quality is positively associated with higher levels of PA.[37] Therefore, understanding 24-hour movement patterns of children with CHD could provide insight into their holistic health.

In recent years, Canada has shifted focus from the MVPA guidelines to 24-hour movement guidelines as it acknowledges the holistic impact PA, sedentary time, screen time, and sleep have on the health and development of children.[35,38] The Canadian 24-hour movement guidelines have 5 recommendations: (1) engage in on average 60 minutes of MVPA per day, (2) participate in several hours of light PA, (3) have no more than 2 hours of recreational screen time, (4) limit sitting for extend periods, and (5) sleep uninterrupted for 9-11 hours (children aged 5-13 years) or 8-10 hours (children aged 14-17 years).[38] There are specific PA recommendations for children with CHD,[22,26,28] and these share the same general recommendations as the MVPA guidelines in the Canadian 24-hour movement guidelines; with the acknowledgement that alterations to the intensity, type, and time of PA may need to be considered for each child's personal abilities.[26,28] Although MVPA is still the most effective factor for improving health, substituting sedentary time for time spent in light PA or sleep can provide further health benefits.[39-41] Therefore, focusing on the holistic effect of PA, sedentary time, screen time, and sleep can increase long-term well-being rather than exclusively focusing on MVPA.

Independent research exists for PA, sedentary time, screen time, and sleep in children with CHD. The purpose of this review was to synthesize current literature on the PA, sedentary time, screen time, and sleep patterns of children with CHD aged 4-20 years and then compare the findings with the Canadian 24-hour movement guidelines.[38]

Methods

Protocol and registration

To aid in the creation of this scoping review, the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) checklist of reporting items was used.[42,43] In addition, this review is registered with the Open Science Framework (https://osf.io/wngde). A search strategy was created in collaboration with a librarian to identify published research that evaluated the PA, sedentary time, screen time, and sleep patterns of children with CHD. We modified the PICO (Population, Intervention, Comparison, Outcomes) to PIO to formulate our search strategy around children with CHD (Population), PA, sedentary time, screen time, or sleep (Intervention), and one intervention variable reported in a unit of time (Outcome). An outline of the search terms used in our search strategy is shown in Supplemental Table S1, and the full search strategy is available through the Open Science Framework link.

Eligibility criteria

To be included in the current review, studies needed to include participants aged 4-20 years with any type of CHD lesion; report PA, sedentary time, screen time, or sleep in units of time (ie, seconds or minutes); have full-text accessible; be published between January 2010 and May 2024; and be written in English. Non−peer-reviewed publications (ie, dissertations or conference proceedings) were excluded. Although the 24-hour movement guidelines are for children up to 17 years of age and we initially had that as our age criteria, we choose to go to 20 years of age to include more studies where the majority of their participants were within the guidelines and general paediatric age range. Furthermore, only 4 included studies recruited participants older than 18 years.[32,37,44,45]

Information sources

The literature search was conducted in June 2024 using the following 6 databases: American Psychological Association (APA) PsycInfo, Cumulative Index to Nursing and Allied Health Literature (CINAHL), EMBASE: Excerpta Medica & EMBASE Classic, MEDLINE: Ovid MEDLINE, Public Health Database, and SPORTDiscus. Four independent scoping reviews were performed for PA, sedentary time, screen time, and sleep; then the results were combined. After completing the searches, titles and abstracts were exported into Microsoft Excel (Microsoft Corp, Redmond, WA).

Selection of sources of evidence

Screening was completed by 2 authors independently (M.S.C. and M.T.). The first round of screening involved reading the title and abstract, and then removing any articles that did not fit the eligibility criteria. The second round of screening involved a full-text review to evaluate whether the studies fit within the eligibility criteria. After completing the first 2 rounds of screening, the 2 authors (M.S.C. and M.T.) met and compared eligible articles; if there was any disagreement, a third author resolved the differences (M.C.E.).

Data extraction

Similarly, data extraction was completed independently by 2 authors (M.S.C. and M.T.). Extracted data included author, location, study design, number of participants, diagnosis of participants, relevant methodology, and results. The authors extracted data from all eligible studies and then compared the extracted data. If there was any disagreement, a third author resolved the differences (M.C.E.). The search strategy and review methodology are further described in our review registration.

Quality assessment

The National Heart, Lung, and Blood Institute Study Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies was used to assess the quality of articles included in this review.[46] Although a quality assessment is not required for scoping reviews, we completed one to provide more context to the reader about the research included in this review (Supplemental Table S2). This tool focuses on 14 concepts that are key to a study's internal validity. Then, an overall grade is given based on the general quality of the article. Quality assessment was completed independently by 2 authors (M.S.C. and M.T.). Once completed, the authors met to discuss their outcomes. Any disagreements were resolved by a third author (M.C.E.).

Results

After applying the search strategy, 9199 articles were identified for initial screening, which included 4164 PA, 665 sedentary time, 2933 screen time, and 1437 sleep articles. After removing 3294 duplicates, 5905 articles remained for title and abstract screening. After title and abstract screening, 5728 articles were removed. Finally, a full-text review was performed on 177 articles to determine whether they met the previously mentioned inclusion criteria. In total, 149 articles were excluded after full-text review because of them being conference proceedings (n = 53), the tool used not measuring time (ie, questionnaire, pedometer; n = 40), reviews or editorials (n = 22), the age range of the population (n = 18), results not reported in time (n = 9), population not having a congenital heart defect (n = 5), not written in English (n = 1), or dissertation literature (n = 1). The authors also undertook a reference check and found 1 additional article. Lastly, 1 more article was added because it was known to an author (M.S.C.). This resulted in the final 30 articles included in this review (Fig. 1). Of these, 10 articles were from Canada, 5 from Germany, 4 from the United States, 3 from Sweden, 2 from each of Belgium, Northern Ireland, and the United Kingdom, and 1 from each of Denmark and the Netherlands.

Study descriptives

Table 1 shows the study descriptives (design, sample size, age, and CHD diagnosis); how the outcome of PA, sedentary time, screen time, or sleep was measured; results; and the reported percentage of the sample that reached the MVPA guidelines (if applicable). Of the included studies, 30 of 30 (100%) measured MVPA, 8 of 30 (27%) measured light PA, 14 of 30 (46%) measured sedentary time, 1 of 30 (3%) measured screen time, and 3 of 30 (10%) measured sleep. Figure 2 shows the average hours per day spent in the different guideline categories with the range of values as error bars. Average daily time spent for each outcome was calculated and found to be 0.9 hours for MVPA (range: 0.18-4.17 hours), 3.9 hours for light PA (range: 1.67-9.86 hours), 2-3 hours for screen time, and 9.1 hours for sleep (range: 7.34-10.20 hours).

Supplemental Table S2 summarizes the procedure for each study's assessment of PA and sedentary time. Differences were seen in the version of accelerometer, epoch, placement, and valid wear day; these characteristics are important to consider when assessing whether guidelines have been met and is included as a supplement for those interested in examining those variables.

Quality of studies

After applying the National Heart, Lung, and Blood Institute evaluation, 10 studies were rated good,"[32,44,45,49,52,56,62,71,72,74] 12 were "fair,"[9,30,37,47,54,58,60,61,63,64,69,73] and 8 were "poor."[15,16,19,55,57,65–67] It should be noted that one of the studies included used the subset of an original sample.[37,44] Supplemental Table S3 depicts the quality evaluation.

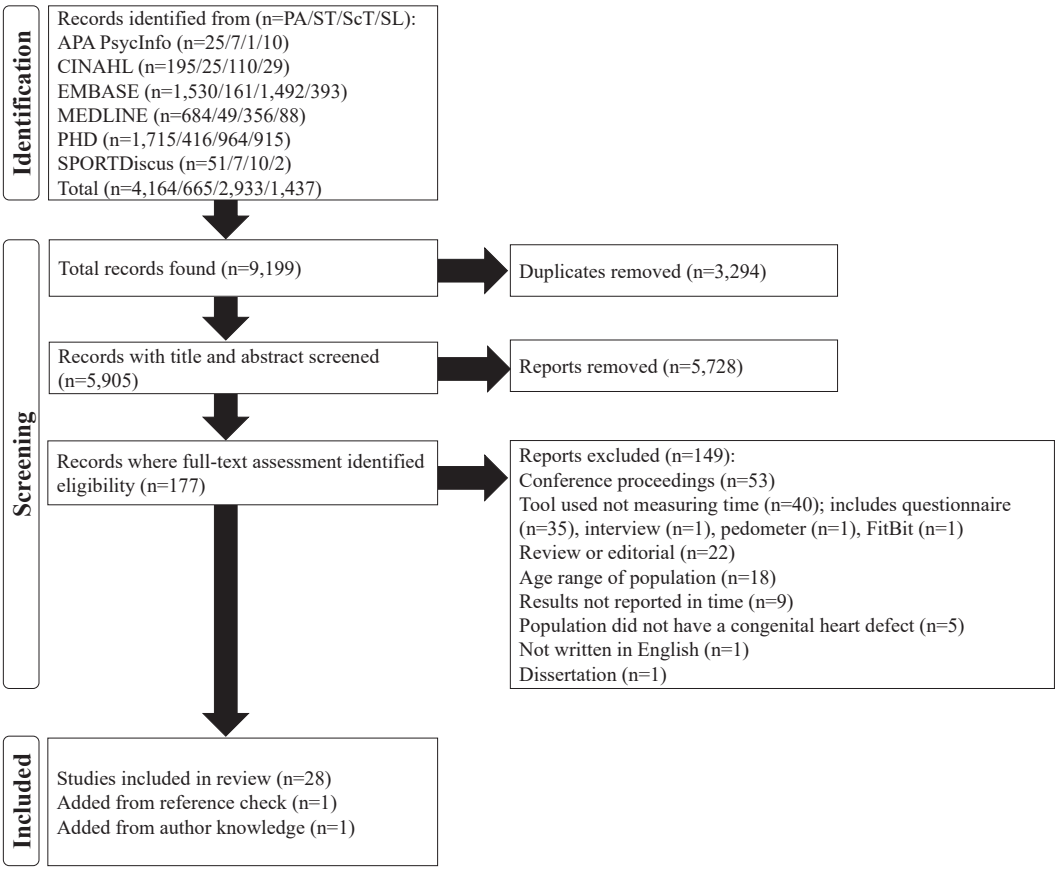

Figure 1. Flowchart of search results and review process, adapted from Page et al.[42] APA, American Psychological Association; CINAHL, Cumulative Index to Nursing and Allied Health Literature; EMBASE, EMBASE: Excerpta Medica & EMBASE Classic; MEDLINE, Ovid MEDLINE (MEDLINE); MET, metabolic equivalent; PA, physical activity; PHD, Public Health Database; ScT, screen time; ST, sedentary time; SL, sleep.

Discussion

The purpose of this review was to explore the current knowledge of attainment of the Canadian 24-hour movement guidelines by children with CHD. We focused on synthesizing studies that evaluated PA, sedentary time, screen time, and sleep. The major finding was that over one-third of children with CHD in studies reviewed attained the MVPA guideline. There is limited research regarding screen time and sleep, making conclusions on these guidelines difficult. Currently, there are no quantitative guidelines for light PA and sedentary time; however, these are an essential part of a child's 24-hour movement pattern, and this need to be addressed within the Canadian 24-hour movement recommendations.

Comparison with Canadian 24-hour movement guidelines

The Canadian 24-hour movement guidelines have 5 recommendations: (1) engage in on average 60 minutes of MVPA per day, (2) participate in several hours of light PA, (3) have no more than 2 hours of recreational screen time, (4) limit sitting for extend periods, and (5) sleep uninterrupted for 9-11 hours (children aged 5-13 years) or 8-10 hours (children aged 14-17 years).[38] Twelve of the 30 studies (40%) reported average MVPA values that would attain the 24-hour movement guidelines.[9,15,16,30,37,44,57,64,66,69,73,74] Studies stated that 2%,[72] 8%,[32] 10%,[45] 12%,[73] 14%,[56] 19%,[30] 25%,[19,56] 26%,[60] 30%,[54] 32%,[52] 33%,[30,65,66] 76%,[57] 77%,[74] 80%,[15,16] 82%,[74] 90%,[37,44] and 93%[64] of their respective populations attained the MVPA recommendations for an average of 43%. In addition, the average daily time spent engaged in MVPA was 0.9 hours (range: 0.18-4.17 hours). There is no specific time recommendation for light PA within the 24-hour movement guidelines because there is currently insufficient evidence to suggest a duration.[38] Based on a previous study, it has been suggested that "several hours" are equal to or greater than 2 hours of light PA.[76] If the definition of greater than or to equal 2 hours is used, 6 of the 9 studies (67%) that evaluated light PA would have shown that their participants met the guideline for light PA.[44,52,61,63,71,72] Finally, the average time spent in light PA based on the included studies was 3.9 hours (range: 1.67-9.86 hours).

Although there is no explicit recommendation for hours spent in sedentary time for comparison, children with CHD spent around 7 hours sedentary per day.[30,32,44,52,54,58,61,63,64,67,69,71,72,77] The only study that reported screen time found that on average children with CHD engaged in around 2-3 hours of screen time.[65] This is similar to what has been reported in children 3-5 years of age with CHD.[78] For sleep, 2 of the 3 studies (67%) reported children with CHD engaged in 9-10 hours of sleep.[64,67] Furthermore, sleep quality and quantity are more likely to be impacted after cardiac

Table 1. Study descriptive and outcomes

Author and location	Study design	CHD, n (female)	Age (y), mean ± SD or median (IQR)	CHD diagnosis (n)	Outcome—how outcome is measured	Results, mean ± SD or median (IQR)	Percentage of sample that reached MVPA guidelines (%)
Longmuir et al. (2011),[47] Canada	CSS	64 (25)	9.1 (7.7, 10.5)	Fontan (64)	MVPA—Puyau et al. (2004),[48] ≥1600 counts/min	MVPA (min/wk) 341 (271, 422)	NR
Ewalt et al. (2012),[30] United States	CSS	21 (16)	10.7 ± 3.2	CoA (5), HLHS (4), VSD (3), mitral valve prolapse (2), ASD (1), Bicuspid aortic valve and stenosis (1), D-TGA (1), DILV (1), pulmonary stenosis (1), ToF (1), tricuspid atresia (1)	MPA—MET value of 4.0-6.9 VPA—MET value greater then 7.0 ST—≤50 steps per 30 s period	MPA (min/d) 57.5 ± 37.9 Weekday 53.1 ± 36.5 Weekend 60.6 ± 48.2 VPA (min/d) 13.1 ± 12.4 Weekday 13.3 ± 11.6 Weekend 14.1 ± 18.5 ST (min/d) 398.7 ± 106.5 Weekday 423.9 ± 120.8 Weekend 348.0 ± 100.2	33
Longmuir et al. (2013),[49] Canada	RCT	EG: 31 (12) AG: 30 (13)	EG*: 9.3 ± 1.3 AG*: 8.6 ± 2.0	EG: HLHS (8), tricuspid atresia (6), double-inlet left ventricle (6), pulmonary atresia (2), double-outlet right ventricle (9) AG: HLHS (12), tricuspid atresia (4), DILV (8), Pulmonary atresia (2), double-outlet right ventricle (4)	MVPA—Puyau et al. (2004),[48] ≥1600 counts/min	MVPA (min/wk) EG*: 349 ± 127 AG*: 343 ± 123	NR
Morrison et al. (2013),[45] Northen Ireland	RCT	IG: 72 (24) CG: 71 (33)	IG*: 15.24 CG*: 15.89	IG: minor CHD (19), acyanotic corrected (27), cyanotic corrected (15), cyanotic palliated (11) CG: minor CHD (20), acyanotic corrected (34), cyanotic corrected (15), cyanotic palliated (2)	MVPA—Trost et al. (2011),[50] MET value >3 (approximately >2200 counts/min)	MVPA (min/d) IG*: 28.4 ± 20.1 CG*: 32.7 ± 28.7	10
Hedlund et al. (2016),[44] Sweden	CSS	30 (14)	14.2 ± 3.2 (range 8.9-20.4)	Hypoplastic right ventricle (20), hypoplastic left ventricle (9), unbalanced AVSD (1)	LPA—Evenson et al. (2008),[51] >100 but <2296 counts/min MVPA—Evenson et al. (2008),[51] ≥2296 counts/min ST—Evenson et al. (2008),[51] ≤100 counts/min	LPA‡ (%/d) 41.1 ± 3.3 MVPA‡ (%/d) 10.3 ± 4.2 ST‡ (%/d) 48.6 ± 4.4	90
Klausen et al. (2016),[52] Denmark	RCT	158 (66)	IG*: 14.6 ± 1.3 CG*: 14.6 ± 1.2	CoA (52), TGA (35), Steno-Fallot tetralogy (21), atrioventricular septal defect (9), DORV (7), TCPC (6), truncus arteriosus (4), other (24)	LPA—not specified MVPA—Andersen et al. (2006),[53] >2000 counts/min ST—not specified	IG*: LPA (h/d) 3.1 ± 0.7 MVPA (min/d) 45.8 ± 24.1 ST weekday (h/d) 3.2 ± 1.6 ST weekend (h/d) 4.4 ± 1.9 CG*: LPA (h/d) 2.9 ± 0.2 MVPA (min/d) 49.8 ± 26.6 ST weekday (h/d) 3.2 ± 1.7 ST weekend (h/d) 4.9 ± 1.9	32

Banks et al. (2017),[9] Canada	CSS	137 (59)	TOF 7.9 ± 2.0 SV 6.6 ± 1.7 TGA 7.7 ± 2.3 ASD 8.5 ± 2.1	ToF (37), SV (35), TGA (34), ASD (31)	MVPA—Puyau et al. (2004),[48] ≥1600 counts/min	MVPA (min/wk) ToF 389 ± 211 SV 405 ± 256 TGA 423 ± 196 ASD 454 ± 246	NR
Voss, Duncombe et al. (2017),[32] Canada	CSS	90 (41)	13.6 ± 2.7	Bicuspid aortic valve (6), VSD (5), mild aortic stenosis (4), ASD (4), mixed aortic valve disease (3), mild pulmonary stenosis (2), mitral valve disease (1), small patent ductus arteriosus (1), ToF (11), CoA (7), moderate/ severe aortic stenosis (2), total anomalous pulmonary venous return (1), ostium primum atrial septal defect (1), sinus venosus atrial septal defect (1), Ebstein's anomaly (1), Shone syndrome (1), Pentalogy of Cantrell (1), Fontan (17), TGA (8), double-outlet ventricle (2), valved conduit (2), cardiac transplant (9)	MVPA—Evenson et al. (2008),[51] ≥2296 counts/min ST—percentage relative to valid accelerometer wear time, where percentage of sedentary time equals daily sedentary minutes (<100 counts/min) divided by accelerometer wear time (min)	MVPA 42.6 (28.9-56.9), ST† (%/d) 70.0 (61.2-75.9)	8
Voss, Gardner et al. (2017),[54] Canada	CSS	30 (16)	13.0 ± 2.2	CHD, categorized as mild, moderate, or severe (24), Innocent murmurs (4), cardiac transplant (1), electrophysiological disorders (1)	MVPA—Evenson et al. (2008),[51] >2296 counts/min ST—Evenson et al. (2008),[51] <100 counts/min	MVPA (min/d) 40.3 (27.1-57.1) ST† (%/d) 68.1 (61.4-76.4)	30
Zaqout et al. (2017),[55] Belgium	CSS	66 (41)	10.5 ± 1.9	TGA (22), VSD (19), ToF (15), CoA (10)	MVPA—Evenson et al. (2008),[51] ≥2296 counts/min	MVPA (min/d) 46.4 ± 25.0	NR
McKillop et al. (2018),[56] Canada	RCT	IG*: 18 (7) CG*: 18 (11)	IG*: 15.28 ± 1.53 CG*: 14.48 ± 1.56	IG: VSD (7), TGA (3), ASD (2), CoA (2), aortic stenosis (1), Fontan (1), pulmonary arteriosus (1), HLHS (1) CG: VSD (6), ToF (3), ASD (2), CoA (2), Fontan (2), TGA (1), truncus arteriosus (1)	LPA—Evenson et al. (2008),[51] >100 but <2296 counts/min MVPA—Evenson et al. (2008),[51] ≥2296 counts/min ST—Evenson et al. (2008),[51] <100 counts/min	IG*: LPA (min/d) 178.92 ± 39.48 MVPA (min/d) 50.34 ± 16.24 ST (min/d) 593.27 ± 68.28 CG*: LPA (min/d) 163.11 ± 33.17 MVPA (min/d) 44.19 ± 16.56 ST (min/d) 590.59 ± 49.36	IG: 27 CG: 18
Hedlund et al. (2019),[37] Sweden	CSS	30 (14)	13.4 (range: 8.9-20.4)	Fontan circulation (30)	MVPA—Evenson et al. (2008),[51] ≥2296 counts/min SL—Sadah et al. (1994)	MVPA (min/wk) 946.5 (range: 306.0-1847.0) SL (min/night) 440.3 (range: 260.7-517.0)	90

Continued

Table 1. Continued.

Author and location	Study design	CHD, n (female)	Age (y), mean ± SD or median (IQR)	CHD diagnosis (n)	Outcome—how outcome is measured	Results, mean ± SD or median (IQR)	Percentage of sample that reached MVPA guidelines (%)
Brudy et al. (2020),[57] Germany	CSS	162 (60)	LHO 10.4 ± 3.4 RHO 12.0 ± 2.6 IS 13.0 ± 3.5 TGA after switch 12.1 ± 3.2 TCPC 12.4 ± 3.4 Other 10.5 ± 3.8 Total 11.8 ± 3.2	RHO (53), LHO (28), TCPC (25), IS (20), TGA (19), other (17)	MVPA—Measured by Garmin Vivofit Jr	MVPA (min/d) RHO 73.5 ± 23.2 LHO 88.7 ± 28.6 TCPC 69.9 ± 22.9 IS 78.2 ± 27.9 TGA 89.4 ± 25.6 Other 82.4 ± 25.1 Total 84.1 ± 24.2	76
Härtel et al. (2020),[58] Germany	CSS	21 (9)[§]	18 (14, 31)[§]	HLHS (7), DILV (4), DORV (2), SILV (1), TGA (4)[§]	LPA—Freedson et al. (1998),[59] >100 but <1952 counts/min MVPA—Freedson et al. (1998),[59] >1952 counts/min ST—Freedson et al. (1998),[59] >0 but <100 counts/min	LPA[‡,§] (%/d) 20.1 (12.1, 30.3) MVPA[‡,§] (%/d) 6.3 (2.7, 11.3) MVPA[§] (min/d) 42 (16, 97) ST[‡,§] (%/d) 73.6 (60.6, 85.1)	27
Kuan et al. (2020),[60] Canada	CSS	142 (58)	12.7 ± 2.4	CoA (42), Fontan (40), ToF (33), TGA (27)	MVPA—Evenson et al. (2008),[51] ≥2296 counts/min	MVPA (min/d) 45.5 ± 20.6	26
Lopez et al. (2020),[19] Canada	CSS	104 (41)	12.2 (2.4)	CoA (32), Fontan (28), ToF (24), TGA (20)	MVPA—Evenson et al. (2008),[51] ≥2296 counts/min	MVPA (min/d) 46.7 ± 20.2	25
White et al. (2020),[61] United States	CSS	34 (13)	12.4 (4.8)	Fontan (24), heart failure (6), pulmonary hypertension (4)	LPA—Evenson et al. (2008),[51] >100 but <2296 counts/min MVPA—Evenson et al. (2008),[51] ≥2296 counts/min ST—Evenson et al. (2008),[51] <100 counts/min	LPA[‡] (% wear time) 33.9 (15) MVPA[‡] (% wear time) 1.7 (2.5) ST[‡] (% wear time) 64.3 (17)	NR
Brudy et al. (2021),[16] Germany	CSS	343 (135)	LHO 12.2 ± 3.3 RHO 11.9 ± 3.1 IS 12.3 ± 3.5 TGA 11.9 ± 3.1 TCPC 13.2 ± 3.4 Other 11.4 ± 3.6 Total 12.1 ± 3.3	RHO (86), LHO (66), TCPC (55), IS (54), TGA (37), miscellaneous (45)	MVPA—Measured by Garmin Vivofit Jr	MVPA (min/wk) RHO 76.4 ± 29.6 LHO 90.1 ± 29.8 TCPC 82.0 ± 27.0 IS 84.1 ± 26.1 TGA 99.0 ± 29.8 Other 76.8 ± 23.5 Total 83.6 ± 28.7	80
Callaghan et al. (2021),[62] Northen Ireland	RCT	IG: 82 (32) CG: 81 (31)	IG*: 8.5 CG*: 8.32	IG*: acyanotic no intervention (17), acyanotic corrected (30), cyanotic corrected (20), cyanotic palliated (15) CG*: acyanotic no intervention (13), acyanotic corrected (31), cyanotic corrected (35), cyanotic palliated (12)	MVPA—Evenson et al. (2008),[51] ≥2296 counts/min	IG*: MVPA (min/d) 42.5 ± 22.75 CG*: MVPA (min/d) 45.22 ± 27.56	NR

Chapelski et al. (2021),[63] Canada	CSS	14 (5)	12.8 ± 2.0	ToF (4), TGA (4), pulmonary valve stenosis (2), VSD (2), DILV (1), coarctation (1)	LPA—Evenson et al. (2008),[51] >100 but <2296 counts/min MVPA—Evenson et al. (2008),[51] ≥2296 counts/min ST—Evenson et al. (2008),[51] <100 counts/min	LPA* (min/d) 206.1 ± 66.3 MVPA* (min/d) 41.7 ± 26.1 ST*,† (%/d) 85 ± 7	NR
Skovdahl, Olofsson, Sunnegårdh, et al. (2021),[64] Sweden	CSS	36 (9)	Children: 9.8 ± 2.6 Adolescence: 15.9 ± 2.1	Valvular aortic stenosis (36)	Defined by VO2net cut-points Children: LPA—<8 mg MVPA—≥8 and <37 mg ST—≥37 mg SL—reported in diary Adolescence: LPA—<12 mg MVPA—≥12 and <59 mg ST—≥59 mg SL—reported in diary	Children‖: LPA (min/d) 100.2 MVPA (min/d) 249.9 ST (min/d) 501.2 SL (min/d) 588.7 Adolescents‖: LPA (min/d) 117.7 MVPA (min/d) 152.0 ST (min/d) 634.6 SL (min/d) 535.7	93
Willinger et al. (2021),[15] Germany	CSS	387 (162)	12.2 ± 3.3	RHO (89), miscellaneous (78), LHO (69), isolated shunts (57), TCPC (57), TGA (37)	MVPA—Measured by Garmin Vivofit Jr	MVPA (min/d) 83.3 ± 28.1	80
Zaqout et al. (2021),[65] Belgium	CSS	66 (32)	VSD 10.9 ± 1.8 COA 10.2 ± 2.1 TGA 10.4 ± 1.9 ToF 10.5 ± 1.9	TGA (22), VSD (19), CoA (10), ToF (15)	MVPA—Evenson et al. (2008),[51] ≥2296 counts/min ScT—self-reported	MVPA (min/d) TGA 55.3 ± 22.5 VSD 39.9 ± 23.5 CoA 53.6 ± 30.7 ToF 38.9 ± 22.8 ScT (h/wk) TGA 16.6 ± 9.0 VSD 16.6 ± 9.2 CoA 13.4 ± 6.7 ToF 23.4 ± 11.4	33
Blanchard et al. (2022),[66] Canada	CSS	236 (101)	SV 8.2 ± 2.1 ToF 8.1 ± 2.0 TGA 8.0 ± 2.2 ASD 8.7 ± 2.1	SV (104), ToF (48), TGA (47), ASD (37)	MVPA—Puyau et al. (2004),[48] ≥1600 counts/min	MVPA (min) SV weekly 341± 138 Weekday 53 ± 21 Weekend 50 ± 22 ToF weekly 327 ± 141 Weekday 51 ± 21 Weekend 37 ± 22 TGA weekly 416 ± 164 Weekday 63 ± 24 Weekend 50 ± 31 ASD weekly 424 ± 271 Weekday 62 ± 38 Weekend 54 ± 45	33
Elmesmari et al. (2022),[67] United Kingdom	CSS	20 (10)	6.0 ± 2.2	ASD (6), ToF (4), AVSD (2), HLHS (2), VSD (2), TGA (1), TAPVR (1), PDA (1), mitral atresia (1)	MVPA & ST—ActivPAL uses algorithms to record time-spent in different movement states SL—Alghaeed et al. (2013),[68] sleep duration for each day was determined by manual inspection of the event file	MVPA (h/d) 1.9 ± 0.9 ST (h/d) 8.1 ± 1.7 SL (h/d) 10.2 ± 0.9	NR

Continued

Table 1. Continued.

Author and location	Study design	CHD, n (female)	Age (y), mean ± SD or median (IQR)	CHD diagnosis (n)	Outcome—how outcome is measured	Results, mean ± SD or median (IQR)	Percentage of sample that reached MVPA guidelines (%)
Leo et al. (2022),[69] United Kingdom	CSS	7 (3)	8.8 ± 3.7	HLHS (7)	LPA—Freedson et al. (2005),[70] >150 counts/min but <500 counts MVPA—Freedson et al. (2005),[70] >500 counts/min ST—Freedson et al. (2005),[70] <150 counts/min	LPA[‡] (%/d) Weekday 12.8 Weekend 12 MVPA (min/d) 153 ± 36 Weekday (%/d) 26.3 Weekend (%/d) 28.3 ST[‡] (%/d) Weekday 60.9 Weekend 59.7	NR
Jackson, Fox, Rausch, et al. (2022),[71] United States	RCT	60 (28)	16.3 ± 1	Moderate CHD lesion (46), complex CHD lesion (14)	LPA—Evenson et al. (2008),[51] >100 but <2296 counts/min MVPA—Evenson et al. (2008),[51] ≥2296 counts/min ST—Evenson et al. (2008),[51] ≤100 counts/min	LPA (min/d) 255.7 ± 70.4 MVPA (min/d) 19.8 ± 12.4 ST (min/d) 568.7 ± 105.3	NR
Jackson, Fox, Swenski, et al. (2022), [72] United States	RCT	86 (34)	16.2 ± 1.0	Moderate CHD lesion (61), complex CHD lesion (25)	LPA—Evenson et al. (2008),[51] >100 but <2296 counts/min MVPA—Evenson et al. (2008),[51] ≥2296 counts/min ST—Evenson et al. (2008),[51] ≤100 counts/min	LPA (min/d) 247.1 ± 68.8 MVPA (min/d) 22.3 ± 15.3 ST (min/d) 565.8 ± 102.5	2
Sprong et al. (2023),[73] the Netherlands	CSS	62 (19)	7.8 (7.5, 7.9)	TGA (32), ToF (15), SVP (11), AAA (4)	MVPA—Evenson et al. (2008),[51] ≥2296 counts/min	MVPA (min/d) 64.1 ± 18.3	12
Willinger et al. (2023),[74] Germany	RCT	97 (49)	15.1 ± 2.0	RHO (29), LHO (22), Fontan (18), IS (14), TGA (7), other (7)	MVPA—measured by Garmin Vivofit Jr 2	MVPA* (min/d) IG: 79.3 (64.4, 93.1) CG: 72.6 (53.4, 86.2)	IG*: 77 CG*: 82

AAA, aortic arch anomaly; AG, activity group; ASD, atrial septal defect; AVSD, atrial ventricular septal defect; CG, control group; CHD, congenital heart disease; CoA, coarctation of the aorta; CSS, cross-sectional study; DILV, double inlet left ventricle; DORV, double outlet right ventricle; D-TGA, dextro-transposition of great arteries; EG, education group; HLHS, hypoplastic left heart syndrome; IG, intervention group; IQR, interquartile range; IS, isolated shunts; LHO, left heart obstruction; LPA, light physical activity; MET, metabolic equivalent; MPA, moderate physical activity; MVPA, moderate-to-vigorous physical activity; NR, not reported; RCT, randomized controlled trial; RHO, right heart obstruction; ScT, screen time; SD, standard deviation; SILV, single inlet left ventircle; SL, sleep; ST, sedentary time; SV, single ventricle; TAPVR, total anomalous pulmonary venous return; TCPC, total cavopulmonary connection surgery; TGA, transposition of the great arteries; ToF, tetralogy of Fallot; VPA, vigorous physical activity; VSD, ventricular septal defect.

* Longmuir et al.,[49] Morrison et al.,[45] Klausen et al.,[52] McKillop et al.,[56] Callaghan et al.,[62] Chapelski et al.,[63] and Willinger et al.[74] reported pre- and post-results from an intervention, but only the baseline data are reported in this scoping review.

† Percentage of day was calculated using a formula from Gabel et al.,[75] which is "sedentary time (min/d)/average wear time (min/d)."

‡ Hedlund et al.,[44] White et al.,[61] Leo et al.,[69] and Härtel et al.[58] did not specify how they calculated percentage of wear time.

§ Härtel et al.[58] reported demographics on a full sample of participants aged 14-31 years. This review only reported results from participants younger than 18 years.

‖ Skovdahl et al.[64] did not report standard deviation.

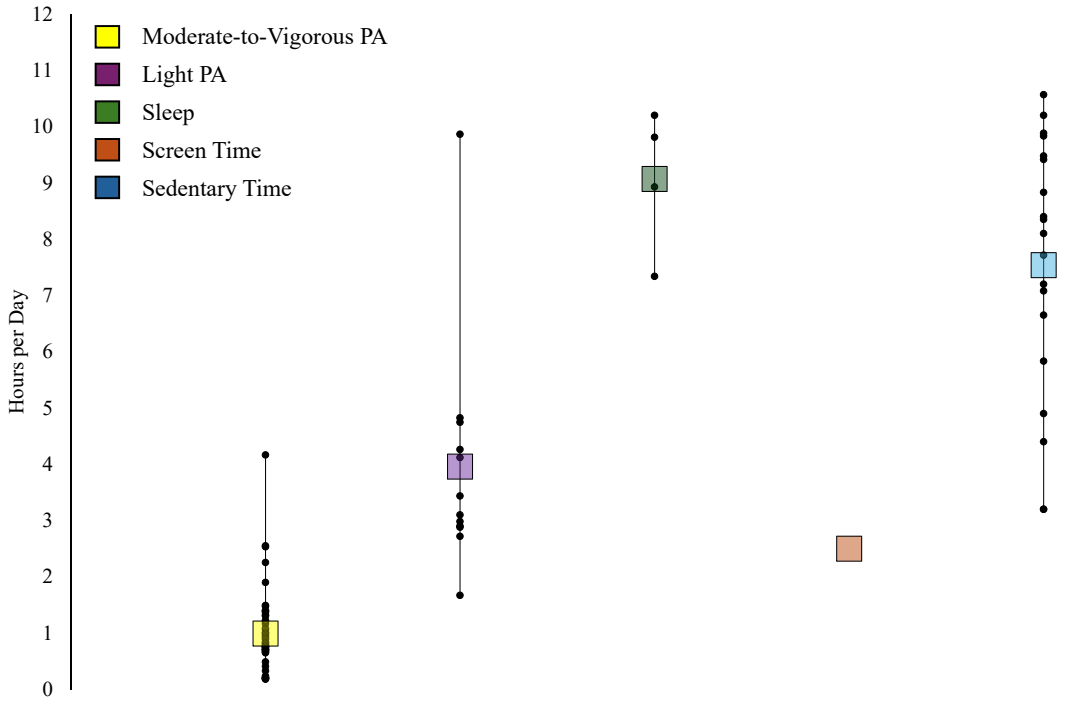

Figure 2. Scatter plot displaying the average hours per day reported for moderate-to-vigorous physical activity, light physical activity, sleep, screen time, and sedentary time. The error bars show the range of scores for each variable. Note that there are no error bars for screen time because only 1 study reported it. Each dot represents the average hours per day reported by an individual study. PA, physical activity.

surgeries,[79] but the guidelines only speak to quantity. The average reported time spent sleeping was 9.1 hours (range: 7.34-10.20 hours).

Differences in physical activity intensity attainment

Based on the suggestion of 2 hours,[76] the majority of studies report that children with CHD attained the light PA guideline but not the MVPA guideline. One study found that children with CHD engaged in more light PA than their typically developing peers.[61] This may suggest that activity patterns in children with CHD are influenced by their diminished peak oxygen uptake,[27] exercise capacity,[22,26] ability to physically keep up to peers,[80,81] or parental misunderstanding of appropriate PA intensity, leading children with CHD to potentially participate in more light PA and less MVPA.[17,20,22,81]

Other health factors such as a history of arrhythmia[47] and cases of cardiac incidents while being physically active[21] may lend to hesitancy in engaging in higher intensity PA for children with CHD. However, there is a greater risk of cardiac incidents in adolescents and young adults who are the least habitually active.[82,83] In addition, PA has continuously been shown to be safe for children with CHD.[22,23,26] Finally, children with CHD may engage in enough light PA to receive health benefits,[40,84] but engagement in MVPA is more important for their overall health.[39] Therefore, children with CHD should be encouraged not to only engage in PA in general but to participate at an intensity that would allow them to the meet the MVPA guideline.

Although health, social, and physical factors may hinder the ability of children with CHD to be active at high PA intensity levels, support from their family and practitioners[80,85–87] is essential for improving MVPA participation. Adults with CHD who received support and encouragement as a child to be physically active were more likely to be active adults.[88] In addition, there is a lack of information on CHD lesions and safe PA levels for children with CHD;[89,90] thus, parents need to be provided education about safe PA intensities for their child. Those interested in safe PA levels for children with CHD should consult with medical practitioners and CHD specific PA recommendations.[22,26,28]

Comparison with general population

It is important to note that when compared with typically developing peers, children with CHD engage in similar rates of MVPA and attain similar sleep hours. Recently, it was reported that 39% and 65% of Canadian children aged 7-17 years attain the MVPA and sleep guidelines, respectively.[91] This is similar to our review, which found that 40% of children with CHD attained the MVPA guideline, whereas 67% attained the sleep guideline. In addition, 27% of Canadian children attain the screen time recommendations; however, a comparison with children with CHD is inconclusive, as we found only 1 study that measured screen time. Again, no comparison can be made for light PA and sedentary time because of no quantitative recommendations. Our findings should be seen as positive, as they imply that children with CHD are engaging in similar amounts of MVPA and sleep. Furthermore, it may suggest that deficits in PA may have less to do with their heart lesion and are more impacted by individual or external factors (ie, confidence or restrictive parents). In fact, children with CHD may engage in more light PA than their peers,[61] highlighting their desire to be active.

Impact of study protocols

A challenge with synthesizing the data is the variety of methods used for its measurement. Pedometers, questionnaires, accelerometers, and commercial trackers have all been used to assess PA in children with CHD.[92] Although this review focused on tools that objectively measure time, Supplemental Table S3 shows the variety of characteristics used for the analysis of PA. These differences can lead to inaccuracy in the children's reported outcomes.

The use of different epochs, wear time, and cut-points can impact the reported outcomes of PA and sedentary time.[93,94] This can lead to inaccuracy when comparing results that follow different methodologies and analyses.[95] In addition, different procedures can overestimate or underestimate the number of children who attain the guidelines for PA.[94] For the procedural differences in this review, 14 different accelerometers, 12 different cut-points, 7 different epochs, and 4 different wear times were used. In addition, it should be noted that a few studies did not report the epoch or wear days of their assessment procedure. Finally, the placement of the accelerometer was similar for accelerometers (near waist), whereas some devices (Garmin Vivofit jr.) are designed to be placed on the wrist.

Evaluation of 24-hour movement guidelines in children with CHD

Recently, studies have been published that have considerations[96] and new cut-points[97] for measuring PA and sedentary time in children with CHD. For epoch, researchers should strongly consider employing the same epoch their cut-points were validated in.[96] Finally, new vector counts for sedentary time (<10), light PA (>10-349), moderate PA (>349-785), and vigorous PA (>785) have been suggested for children with CHD.[97] They have shown good prediction accuracy but require further validation.[97] Consideration should also be given to the epoch because 60-second epochs have misclassified light PA as sedentary time and vigorous PA as light PA.[93] Furthermore, accelerometers do not provide information on how time sedentary was spent. To understand context for sedentary time, such as screen time, the best practice would likely have children self-report. Finally, sleep can be measured successfully using accelerometers.[37] Overall, accelerometers are effective for evaluating each aspect for the 24-hour movement guidelines and would only need self-reported data to better understand time spent sedentary. Other devices (ie, activPAL mirco monitor) may measure all 24-hours, but more research is needed to validate these devices.

Research gaps

One glaring finding of this review is that over 50% of the included articles did not report light PA, sedentary, screen time, or sleep. On the other hand, every study measured MVPA. This is likely because previous research has generally focused on the proven link between MVPA and health.[35] However, because MVPA makes up a small percentage of a child's day, there has been a shift to focus on other factors.[35] It is our opinion that the lack of non-MVPA research is related to the vast knowledge of MVPA's impact on health. We believe that the recent importance placed on a child's 24-hour movement behaviours[35,38,98,99] will engage research on light PA, sedentary time, screen time, and sleep.

As mentioned previously, sedentary time does not have specific quantitative recommendations included in the Canadian 24-hour movement guidelines. Guidelines for sedentary time should be nuanced to understand the complexities of sedentary time. For instance, sedentary time could include sitting, reading a book, and eating. In addition, the duration of sedentary periods can be important. Thus, the development of sedentary guidelines should be aware of its intricacies. Getting a better understanding of how children with CHD spend their sedentary time (ie, homework or television) can provide awareness of barriers to PA and areas important for targeted intervention.

Sleep research is also lacking in children with CHD with only 3 of 30 studies (11%) measuring sleep. Although other research has either no difference[67,100,101] or greater latency to sleep[37] when compared with peers, more research is needed to better understand this behaviour and determination of sleep quality as it may be especially important in this population.

Suggestions

There are few recommendations for future research in the area of 24-hour movement behaviours of children with CHD. Based on the review's findings, only 8 of 30 (27%) articles reported light PA, and of the 8 articles, 6 (67%) reported levels of light PA high enough to sufficiently reach the literature recommendation of greater than 2 hours.[76] Future research should include a report of engagement of children with CHD in light PA because it has been suggested that they may engage in more light PA than their peers.[61] Therefore, children with CHD may be motivated to be active but perhaps have other barriers restricting their engagement in MVPA (ie, fear or physical limitations). Thus, it could be suggested that for children with CHD, focusing on increasing engagement in light PA (or reducing sedentary time) may be a more accomplishable goal for improving their health.[39-41]

When evaluating PA and sedentary time in children with CHD, it would be beneficial to include measurements of screen time and sleep. Because there may be a relationship between MVPA and sleep in children with CHD,[37] this may be a confounding factor that is not currently being considered. Furthermore, having a measurement of screen time when assessing sedentary time can give specific evidence as to how children with CHD may be engaged in that behaviour. Our current understanding is limited as only 1 study evaluated screen time. Overall, all 24 hours of a child's day are important and impact health outcomes,[35] so only assessing MVPA or sedentary time is not evaluating holistic health of children with CHD.

Finally, it would be worth evaluating if the 24-hour movement guidelines are effective in altering the behaviours of children with CHD. It has been suggested that focusing on enjoyment or well-being rather than measurable outcomes (ie, fitness or time)[102] may be more beneficial to alter behaviours. Perhaps enjoyment could be the reason why children with CHD engage in higher levels of light PA than MVPA. However, perception of movement intensity of children with CHD is unknown.

Limitations

One limitation of the comparison with the Canadian 24-hour movement guidelines is that they are made for children aged 5-17 years, but the eligible age range for this review was up to 20 years. The age range was expanded to 20 years to include more studies that had the majority of their participants aged 5-17 years but extended their scope to emerging adulthood.

Finally, a measurement of PA missing from this review is step count. Studies measuring step count were excluded because there are no current step count recommendations within the 24-hour movement guidelines. However, studies have suggested that 10,000-15,000 steps per day[103,104] may be sufficient for attaining the MVPA recommendations. Extensive research has been performed on the step count of children with CHD and has reported daily values ranging from 7338 to 11,772,[6,15,16,32,54,57,60,62,67,105,106] with the average around 8835 daily steps.

Conclusions

It is unlikely that children with CHD attain all 5 of the Canadian 24-hour movement guideline recommendations. The majority of studies that report sleep have values that attained the guideline; however, there were only 3 such studies. Forty percent of studies reported that children with CHD met the MVPA guideline. In addition, of those studies that reported the percentage of the population meeting the MVPA guideline (n = 20), an average of 43% of children with CHD attained the 60 minutes of MVPA per day. Currently, the Canadian 24-hour movement guidelines lack clear recommendations for light PA and sedentary time, thus making conclusions on attainment not possible. To better assess the attainment of these recommendations, quantification or numerical values need to be assigned to the guidelines. Lastly, research on screen time and sleep is lacking in this population. This review summarized the movement behaviours of children with CHD and provided recommendations for future research in the hopes to fill the current gaps in this area.

Ethics Statement

The research reported has adhered to the relevant ethical guidelines.

Patient Consent

The authors confirm that patient consent is not applicable to this article because this is a review article synthesizing existing literature.

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Supplementary Material

To access the supplementary material accompanying this article, visit *CJC Pediatric and Congenital Heart Disease* at https://www.cjcpc.ca// and at https://doi.org/10.1016/j.cjcpc.2024.10.008