



Higher screen time, lower muscular endurance, and decreased agility limit the physical literacy of children with epilepsy

Daniela Pohl^{a,b,c,*}, Anastasia Alpous^a, Sabrina Hamer^a, Patricia E. Longmuir^{a,b}

^a Children's Hospital of Eastern Ontario Research Institute, 401 Smyth Road, Ottawa, Ontario K1H 8L1, Canada

^b University of Ottawa, Faculty of Medicine, 401 Smyth Road, Ottawa, Ontario K1H 8L1, Canada

^c Children's Hospital of Eastern Ontario, 401 Smyth Road, Ottawa, Ontario K1H 8L1, Canada



ARTICLE INFO

Article history:

Received 19 April 2018

Revised 6 May 2018

Accepted 6 May 2018

Available online 19 October 2018

Keywords:

Exercise

Childhood

Physical activity

Fitness

Sedentary behavior

Seizures

ABSTRACT

Objective: The objective of this study was to determine the physical literacy (the motivation, confidence, physical competence, and knowledge contributing to the capacity for physical activity) of children with epilepsy, as compared with that of their healthy peers.

Methods: Patients age 8–12 years with epilepsy, without any disabilities interfering with their ability to answer questionnaires and perform vigorous physical activity, were recruited from the Neurology Clinic at the time of visits. They completed the Canadian Assessment of Physical Literacy (CAPL), a comprehensive battery of tests reflecting the primary domains of physical literacy (motivation/confidence, physical competence, knowledge/understanding, and daily behavior). Daily behavior was assessed by pedometer step counts, as well as self-reported moderate-to-vigorous physical activity and screen time. Physical competence included agility and movement skill measures as well as physical fitness. Children with epilepsy were matched with healthy peers from a large research database of over 6000 Canadian children.

Results: We tested 35 children with epilepsy, divided into those with presumed self-limiting forms of epilepsy (49%) and those with chronic disease (51%). Only a small proportion of participants (23%) were taking more than one antiepileptic medication, and only one patient was taking three anticonvulsants. Children with epilepsy including those with self-limiting forms had significantly lower total physical literacy scores, lower agility and movement skills, and lower muscular endurance, and reported more screen time than their healthy peers. Only 11% of the children with epilepsy achieved the recommended level of physical literacy. However, the children with epilepsy were knowledgeable about and highly motivated to participate in a physically active lifestyle.

Conclusions: Children with epilepsy demonstrate poor physical literacy levels, with potential immediate and long-lasting negative impacts on general health and psychosocial well-being. Programs promoting physical literacy in children with epilepsy should be encouraged, specifically interventions decreasing screen time and enhancing muscular endurance and motor skills, thereby facilitating healthier lifestyles.

© 2018 Elsevier Inc. All rights reserved.

1. Introduction

There is growing evidence regarding the positive effects of exercise in individuals with epilepsy, including broader health and psychosocial benefits, as well as favorable effects on seizure frequency and severity [1–4]. Participation in physical activity has been demonstrated to improve general health, neurocognitive and psychological domains, social integration as well as quality of life in children with epilepsy [3,5,6]. Physical exercise has been shown to decrease epileptiform discharges in children during a video-telemetry study [7]. Beyond exercise training,

physical activity is important for the physical, mental, and social well-being of all children. For optimal health, children should participate in at least 60 min of moderate-to-vigorous physical activity and several hours of light activity daily [8].

A recent International League against Epilepsy (ILAE) consensus paper concludes that people with epilepsy, including children and adolescents, should not be restrained from and instead encouraged to take part in sport activities [9]. However, studies have shown that adults with epilepsy have lower rates of physical fitness, physical health in general, and increased body mass indices (BMIs) [10–13]. Adults with a history of childhood-onset epilepsy have lower levels of physical activity and an increased likelihood of obesity and depression compared to their peers, placing them at higher risk of developing early secondary health conditions [14]. Children with epilepsy participate in fewer group and total sports activities compared with their healthy siblings, have higher BMIs, and are at risk for poor bone health [15,16]. Poor

Abbreviations: AED, Antiepileptic drug; BMI, Body mass index; CAMSA, Canadian Agility and Movement Skill Assessment; CAPL, Canadian Assessment of Physical Literacy; ILAE, International League Against Epilepsy.

* Corresponding author at: Division of Neurology, Children's Hospital of Eastern Ontario, University of Ottawa, 401 Smyth Road, Ottawa, Ontario K1H 8L1, Canada.

E-mail address: dpohl@cheo.on.ca (D. Pohl).

physical fitness and obesity place children at risk for decreased bone mass accrual, and, later in life, for diabetes, arthritis, heart disease, and stroke. Children with epilepsy also have higher rates of emotional, behavioral, social, and academic difficulties than healthy children and those with other chronic health conditions, and are at risk for social isolation [17]. Emerging research indicates the important contribution of childhood physical activity to supporting mental health, decreasing behavioral and social problems, and enhancing academic performance [18].

Several population-based surveys assessing physical activity and exercise in adolescents and adults with epilepsy have revealed conflicting results, including decreased versus similar physical activity levels as compared to the general population [2,19–23]. Interestingly, a recent study has demonstrated similar levels of physical activity among adults with and without epilepsy when assessed by questionnaire, while objective measures of cardiopulmonary effort demonstrated lower exercise capacity among adults with epilepsy as compared to that in controls [24]. However, there is a paucity of studies using objective measurements of physical activity and fitness in individuals with epilepsy, especially in children and adolescents. In order to develop effective, targeted interventions to support healthy active lifestyles among children with epilepsy, we need to understand their strengths and weaknesses relative to all aspects of physical activity.

Physical literacy is defined as the motivation, confidence, physical competence, and knowledge as well as understanding to value and take responsibility for engagement in physical activities for life [25]. Physical literacy represents the constellation of factors that support the safe and enjoyable participation in physical activity. To the best of our knowledge, there are so far no data on physical literacy in children with epilepsy.

We assessed the physical literacy of children with active epilepsy using the Canadian Assessment of Physical Literacy (CAPL), and compared their results with those of healthy peers in the community. We characterized in detail all domains of physical literacy in children with epilepsy, hoping to identify modifiable deficits. Our long-term goal is to develop physical activity educational programs for children with epilepsy and their families, in order to improve their short and long-term general health and quality of life.

2. Material and methods

2.1. Participants and study design

A cross-sectional study design was used to compare the physical literacy of children with epilepsy with that of a reference population of Canadian children without known health conditions. Informed consent was obtained from the parents of all of the participants. This study was approved by the Children's Hospital of Eastern Ontario Research Ethics Board.

2.1.1. Study participants

Children with epilepsy were recruited between November 1, 2012 and February 4, 2014 via the outpatient Neurology clinic of the Children's Hospital of Eastern Ontario, Ottawa, Ontario, Canada. All patients potentially meeting study eligibility criteria were identified from medical records. Children were eligible for the study if they were 8 to 12 years of age, and had been diagnosed with epilepsy, with at least one seizure in the 12 months prior to recruitment. Patients were excluded if they had a syndrome or disability that prevented completion of the study protocol (requiring academic functioning of at least grade 3 level), or if their current medical status limited vigorous physical activity. During the recruitment period, 298 potentially eligible children were identified via chart review. Of those patients, 102 were excluded because their neurodevelopmental delays or disabilities would have interfered with the completion of the study protocol, and 84 were excluded because they had been seizure-free for 12 months or longer. Of the remaining 112 children, permissions to contact the family were received from the treating neurologists for 103 patients. Of those, 16 families were not approached because they could not be reached. Of the 87 families

contacted by our research coordinator, 44 consented to the study (51%), and 35 children (22 girls and 13 boys) completed the entire study protocol (40%), whereas nine children were unavailable for assessment dates, and three families withdrew from the study prior to the assessment date. The participating children with epilepsy were then matched with healthy peers from a large research database of Canadian Assessment of Physical Literacy results for over 6000 Canadian children, 8 to 12 years of age. Children were matched based on age (within 1 month), gender, and month of assessment (within 1 month), the latter to adjust for known differences in physical activity by season of the year.

2.1.2. The Canadian Assessment of Physical Literacy (CAPL)

Children who participated in the study completed the Canadian Assessment of Physical Literacy (CAPL), which has published validity and reliability for children 8 to 12 years of age [26]. The CAPL is a comprehensive battery of assessments that reflect the primary domains within the Canadian consensus definition of physical literacy (Motivation and Confidence; Physical Competence; Knowledge and Understanding; and Daily Behavior) [25]. Daily Behavior was assessed by daily pedometer step counts (average over 7 days), as well as self-reported moderate-to-vigorous physical activity and screen time. Physical Competence assessed agility and movement skills as well as physical fitness. The Canadian Agility and Movement Skill Assessment (CAMSA) measures simple, complex, and combined movement skills [27]. Physical fitness measures were the Progressive Aerobic Cardiovascular Endurance Run (PACER) shuttle run protocol [28] (aerobic endurance), handgrip dynamometry [29] (muscular strength), sit and reach [29] (flexibility), isometric plank hold [30] (muscular endurance), and body composition [29] (height, weight, and waist circumference). The CAPL questionnaire assessed Knowledge and Understanding (relative to Canadian physical education curricula) as well as Motivation and Confidence, including physical activity adequacy and predilection [31] and benefits-barriers [32]. Overall physical literacy score and domain-specific scores, and the stages used to interpret raw scores were calculated, relative to self-reported age and gender, using the scoring system developed by an international Delphi panel [33]. The CAPL stages used to interpret raw scores are defined as follows: Beginning (less than the 17th percentile), Progressing (17th to 65th percentile), Achieving (above the 65th percentile to the 85th percentile), and Excelling (above the 85th percentile).

2.2. Data analysis

Statistical analyses were performed using SPSS (version 24.0). Descriptive statistics (mean \pm SD, median, and frequencies) characterized the clinical status of children with epilepsy and the age, gender, and BMI z-scores for all study participants. Dependent variables were overall physical literacy score and the subdomain scores for daily behavior, physical competence, knowledge and understanding, and motivation and confidence. Independent sample *t*-tests compared children with epilepsy to the matched population for continuous variables, while chi-square statistics were used to compare categorical variables. Statistical significance was set at $p < 0.05$ for regression analyses and all analyses of CAPL total score. Based on a Bonferroni correction for multiple primary outcomes, domain and individual protocol scores were considered significant at $p < 0.0125$ (0.05/4) to accommodate for four primary subscores (i.e., four domain scores). Univariate correlations and multivariable linear regression models, using backward variable selection, examined the differences between study groups accounting for sex, age, and BMI and the impact of clinical status on the physical literacy outcomes among children with epilepsy.

3. Results

3.1. Participants

The demographic information for study participants with epilepsy and the reference population are provided in Table 1. No difference

Table 1
Characteristics of study participants with epilepsy and matched peers without a known health condition.

Demographic characteristic		Children with epilepsy n (%)	Matched healthy children n (%)	Total n (%)
Sex	Both	35 (100)	228 (100)	263 (100)
	Boys	13 (37)	83 (36)	96 (37)
	Girls	22 (63)	145 (64)	167 (63)
Age	Mean age \pm 1SD	10.2 \pm 1.5	10.3 \pm 1.4	10.3 \pm 1.4
Type of epilepsy ^a	Self-limiting	17 (49)	–	–
	Chronic	18 (51)	–	–
Seizure type in previous year	No tonic–clonic	17 (49)	–	–
	1 or more tonic–clonic	18 (51)	–	–
Seizure frequency in previous year	\leq 3 seizures/year	19 (54)	–	–
	$>$ 3 seizures/year	16 (46)	–	–
AED number at testing date ^b	\leq 1 AED	27 (77)	–	–
	$>$ 1 AED	8 (23)	–	–

^a Type of epilepsy was grouped by expected long-term outcome into: **Self-limiting** = childhood absence epilepsy, childhood epilepsy with centrottemporal spikes, childhood occipital epilepsy (Gastaut); or **Chronic** = juvenile myoclonic epilepsy, juvenile absence epilepsy, epilepsy with generalized tonic–clonic seizures alone, nocturnal frontal lobe epilepsy, Dravet syndrome, focal epilepsy; febrile infection related epilepsy syndrome (FIRES), steroid-responsive encephalopathy with thyroid disease, epilepsy secondary to tuberous sclerosis, focal epilepsy: symptomatic (stroke, hemorrhage) or focal impaired awareness seizures or temporal lobe or nocturnal focal to bilateral tonic–clonic seizure or following acute disseminated encephalomyelitis (ADEM) and brain biopsy.

^b AED = antiepileptic drug.

between study groups was observed for self-reported age and gender as these variables were matched between groups. Children with epilepsy were divided into those with presumed self-limiting forms of epilepsy (childhood absence epilepsy, childhood epilepsy with centrottemporal spikes, childhood occipital epilepsy) and those with chronic disease (49% versus 51%). Only a small proportion of participants (23%) were taking more than one antiepileptic medication, and only one patient was taking three anticonvulsants at the time of testing. The mean duration of epilepsy prior to testing was 41 months (standard deviation 38 months, range 3 to 149 months), with a median of 29 months.

3.2. Overall CAPL score

Total physical literacy scores were significantly different between groups (99% confidence interval [CI]: 0.04, 8.2; $p = 0.009$), as the participants with epilepsy had a lower total physical literacy score than the reference group (Table 2). Only 11% (4/35) of the children with epilepsy achieved the recommended level of physical literacy (achieving or excelling category of CAPL score), significantly fewer than the 30% (68/227) of matched controls ($\chi^2 = 5.2$; $df = 1$, $p = 0.02$).

Table 2
Physical literacy scores of children with epilepsy compared with those of matched population of Canadian children without a known health condition.

Canadian Assessment of Physical Literacy (CAPL) score	Children with epilepsy mean \pm SD ^a	Matched healthy children mean \pm SD ^a	99% CI of difference ^b	p -Value ^c
Total physical literacy score	56.7 \pm 9.2	61.3 \pm 10.8	0.04, 9.2	0.009
Overall daily behavior score	12.9 \pm 6.6	17.8 \pm 7.0	1.6, 8.1	<0.001
Pedometer step score	9.1 \pm 5.1	9.5 \pm 4.7	–2.1, 2.9	0.69
Self-reported screen time score	3.4 \pm 2.6	5.2 \pm 2.8	0.5, 3.0	<0.001
<i>Physical competence score</i>	<i>18.0 \pm 3.4</i>	<i>19.4 \pm 4.2</i>	<i>–0.4, 3.2</i>	<i>0.04</i>
Motor skill score	27.3 \pm 6.6	31.0 \pm 5.7	0.4, 6.8	0.004
Endurance (PACER) score	17.4 \pm 7.5	19.2 \pm 9.1	–1.9, 5.6	0.20
Grip strength score	9.4 \pm 5.0	9.1 \pm 4.3	–2.7, 2.1	0.71
Flexibility (sit and reach) score	5.2 \pm 2.4	5.1 \pm 2.4	–1.3, 1.1	0.78
Body mass index z-score	0.9 \pm 1.4	0.5 \pm 1.3	–1.1, 0.3	0.17
Waist circumference score	12.8 \pm 4.4	11.7 \pm 4.7	–3.3, 1.1	0.18
Muscular endurance (plank) score	4.8 \pm 3.0	7.0 \pm 4.1	0.7, 3.8	<0.001
Motivation and confidence score	13.6 \pm 2.6	12.2 \pm 2.6	–0.1, –2.7	0.005
Knowledge and understanding score	12.3 \pm 2.4	11.9 \pm 2.6	–1.6, 0.8	0.40

Significant differences shown in bold.

Trends shown in italics.

^a For all measures a higher score represents a healthier behavior (e.g., higher sedentary score = less sedentary time).

^b CI = confidence interval.

^c Independent samples t -test. Significance set at $p < 0.05$ for CAPL total score. To account for multiple subscores, a Bonferroni correction was applied ($p = 0.0125$ (0.05/4) primary subscores (i.e., 4 domain scores)).

3.3. Daily behavior domain

Daily pedometer step counts were not significantly different (99% CI: –408, 2569, $p = 0.06$) but tended to be lower among children with epilepsy (9692 \pm 2932 steps per day) compared with matched controls (10,772 \pm 3351 steps per day). Children with epilepsy reported engaging in significantly more screen time (99% CI: 0.5, 3.0, $p = <0.001$), and had a lower overall score for daily behavior (99% CI: 1.6, 8.1, $p < 0.001$; Table 2). Children with epilepsy were more likely to have a daily behavior score in the beginning stage (below the 17th percentile, $\chi^2 = 11.5$; $df = 3$, $p = 0.009$), and the proportion of children achieving the recommended daily behavior was lower ($\chi^2 = 5.9$; $df = 1$, $p = 0.01$) for children with epilepsy (6%) compared with that of their same age peers (24%).

3.4. Physical competence domain

Children with epilepsy had significantly lower agility and movement skill (99% CI: 0.4, 6.8; $p = 0.004$) and muscular endurance (99% CI: 0.7, 3.8; $p < 0.001$) than the matched population (Table 2). All other physical competence measures were similar (aerobic endurance, grip strength, flexibility, BMI z-score, and waist circumference).

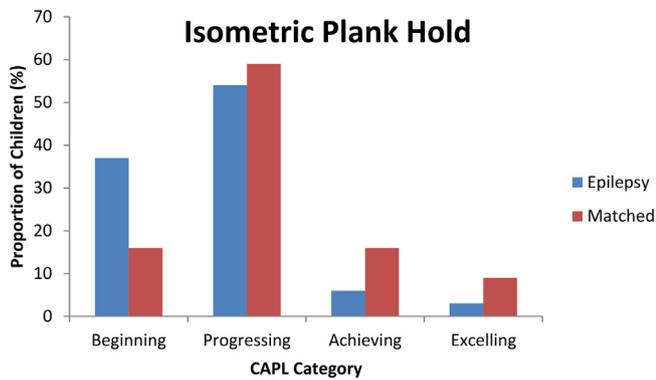


Fig. 1. Performance of an Isometric Plank Hold by Children With and Without Epilepsy.

A significantly higher percentage of children with epilepsy was below the 17th percentile (i.e., categorized in the beginning stage) for torso muscular endurance ($\chi^2 = 11.0$; $df = 3$; $p = 0.01$) and agility and movement skills ($\chi^2 = 8.5$; $df = 3$; $p = 0.04$) compared with matched peers without a health condition (Figs. 1 and 2).

3.5. Knowledge and understanding domain

The physical activity knowledge of children with epilepsy and their matched healthy peers was similar (Table 2; 99% CI of the difference: $-1.6, 0.8, p = 0.40$). There was no difference in knowledge based on the distribution by physical literacy stage ($\chi^2 = 2.4, df = 3, p = 0.50$).

3.6. Motivation and confidence domain

Children with epilepsy had higher motivation and confidence scores than their matched healthy peers (Table 2; 99% CI of the difference: $-2.7, -0.1, p = 0.005$). There was a trend for children with epilepsy to more often categorized in the excelling stage of physical literacy ($\chi^2 = 9.4; df = 3, p = 0.03$).

3.7. Physical literacy and age, sex, and body mass index

Multivariable regression models (Table 3) examined the impact of study group (children with epilepsy compared to matched peer population) on physical literacy total and domain scores, accounting for age, sex, and BMI (BMI is an indicator of over-/underweight, and is calculated as $\text{weight (kg)} / [\text{height (meters)}]^2$). Scores for epilepsy patients were significantly lower than healthy peers for daily behavior and higher than peers for motivation and confidence, although effect sizes were small for these relationships. Body mass index z-score ($-2z$ to $+2z$ represents the 95% CI) was associated with overall physical literacy (small effect) and physical competence (large effect). Physical

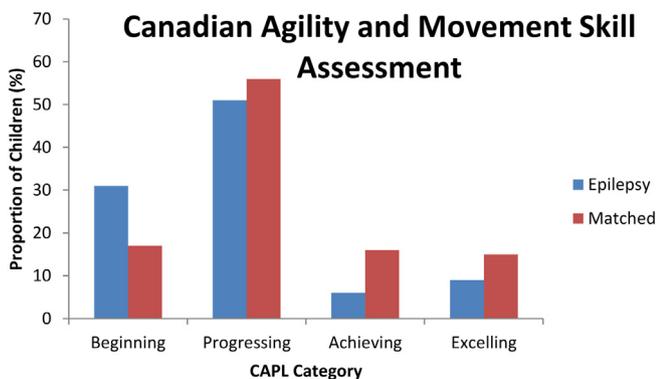


Fig. 2. Performance of the Canadian Agility and Movement Skill Assessment by Children With and Without Epilepsy.

Table 3

Multivariable models of physical literacy among children with epilepsy matched with healthy children accounting for age, gender, and body mass index z-score.

Higher overall physical literacy	Model adjusted $R^2 = 0.03^1$		
	Beta \pm SE	p	η^2
Older age	0.49 \pm 0.50	0.33	<0.01
Male gender ²	1.50 \pm 1.45	0.30	<0.01
Lower BMI z-score³	-1.23 \pm 0.51	0.02	0.02
Matched children	3.73 \pm 1.98	0.06	0.02
Higher daily behavior score	Model adjusted $R^2 = 0.06$		
	Beta \pm SE	p	η^2
Younger age	0.73 \pm 0.33	0.03	0.02
Male gender	0.97 \pm 0.95	0.31	<0.01
BMI z-score	0.42 \pm 0.34	0.21	<0.01
Matched children	4.59 \pm 1.30	<0.01	0.05
Higher physical competence score	Model adjusted $R^2 = 0.23$		
	Beta \pm SE	p	η^2
Older age	0.65 \pm 0.17	<0.01	0.06
Male gender	0.33 \pm 0.51	0.51	<0.01
Lower BMI z-score	-1.37 \pm 0.17	<0.01	0.20
Matched children	1.14 \pm 0.69	0.10	0.01
Higher knowledge & understanding score	Model adjusted $R^2 = 0.09$		
	Beta \pm SE	p	η^2
Older age	0.58 \pm 0.12	<0.01	0.09
Female gender	0.29 \pm 0.34	0.40	<0.01
BMI z-score	-0.21 \pm 0.12	0.09	0.01
Children with epilepsy	-0.35 \pm 0.47	0.46	<0.01
Higher motivation & confidence score	Model adjusted $R^2 = 0.03$		
	Beta \pm SE	p	η^2
Older age	0.02 \pm 0.13	0.91	<0.01
Male gender	0.40 \pm 0.37	0.28	<0.01
BMI z-score	-0.11 \pm 0.13	0.40	<0.01
Children with epilepsy	1.59 \pm 0.50	<0.01	0.04

Significant differences shown in bold.

^a Estimated marginal means for total Canadian Assessment of Physical Literacy (CAPL) score with age = 10.7 years and BMI z-score = 0.6 were as follows: Children with epilepsy 57.8 \pm 1.9 and matched children 61.5 \pm 0.8.

^b Gender was self-reported by the participants.

^c BMI = body mass index.

competence and knowledge scores increased with age (medium effect sizes), while daily behavior scores decreased with increasing age (small effect).

3.8. Physical literacy and clinical status

Physical literacy assessment results for children with epilepsy were evaluated relative to measures of clinical status (Table 4). Type of epilepsy, type of seizure and seizure frequency in the previous year, duration of epilepsy prior to physical literacy assessment, and number of antiepileptic medications were not associated with total physical literacy score or scores for the physical competence, motivation, knowledge, or daily behavior domains.

4. Discussion

Total physical literacy scores were significantly lower in children with epilepsy as compared with those in healthy matched controls, suggesting that these children have fewer personal resources to support a healthy active lifestyle. These findings align with the decreased participation in physical activities, as compared to sibling controls, that has previously been described among Canadian children and adolescents with epilepsy 5–17 years of age [15]. However, the aforementioned study evaluated patient- and parent-reported physical activity and

Table 4
Correlation of epilepsy type, seizure type, seizure frequency, epilepsy duration, and number of antiepileptic drugs (AEDs) with physical literacy measures in children with epilepsy.

	Total CAPL	Physical competence	Motivation	Knowledge	Behavior
Epilepsy type (self-limited/chronic)	−0.07	0.01	0.09	−0.18	−0.10
<i>p</i> value	0.69	0.98	0.61	0.31	0.58
Seizure type in previous year (tonic-clonic/not tonic-clonic)	0.19	0.04	0.09	−0.09	0.22
<i>p</i> value	0.27	0.82	0.62	0.60	0.21
Seizure frequency in previous year (≤ 3 seizures/ > 3 seizures)	−0.06	−0.28	−0.03	0.14	0.06
<i>p</i> value	0.75	0.12	0.86	0.45	0.75
Epilepsy duration (< 24 months/ ≥ 24 months)	0.05	0.01	−0.22	−0.07	0.15
<i>p</i> value	0.77	0.98	0.21	0.67	0.39
AED number at testing (≤ 1 AED/ > 1 AED)	−0.16	−0.05	−0.27	0.05	−0.13
<i>p</i> value	0.35	0.78	0.12	0.79	0.46

BMI, and did not include objective patient testing. Furthermore, the participants appear to suffer from more severe forms of epilepsies than the children in our study: 24% versus 3% were treated with three or more anticonvulsants. Additionally, a higher percentage of children in our study were considered to have a generally self-limiting, age-dependent form of epilepsy (i.e., childhood absence epilepsy, childhood epilepsy with centrottemporal spikes, or childhood occipital epilepsy): 49% versus 33%. Epilepsy duration was also shorter in our study (less than 2 years in 43%, as compared with only 28% in the Wong and Wirrell study). We can only hypothesize that children with more severe forms of epilepsy, and those with longer disease duration, may have even more pronounced physical literacy deficits than the children that we tested.

Within our group of overall mildly affected children with epilepsy, physical literacy scores did not differ between children with presumed self-limiting and those with chronic forms of epilepsy. We also did not find differences in physical literacy between children with four or more seizures per year and three or less seizures per year, or between children treated with more than one anticonvulsant and those on one or no anticonvulsant. In accordance, children with epilepsy have reported similar involvement in physical activity even when they had had recent severe seizures and regardless of their type of epilepsy [15]. We hypothesize that in our cohort of relatively mildly affected children, the impact of the epilepsy diagnosis was more relevant than the actual disease burden. Historically, people with epilepsy were often advised against participating in sports and exercise [9]. Fear and overprotection, or ignorance about the benefits and importance of childhood physical activity, may have increased sedentary screen time or decreased opportunities for activities requiring greater strength or skills. Future studies are planned to examine the development of physical literacy deficits in previously healthy children with epilepsy and the role of parental concerns. It is encouraging that our study demonstrated that children with epilepsy, regardless of clinical status, are knowledgeable about, and motivated to participate in a physically active lifestyle. This suggests that these children would likely engage in, and therefore benefit from, interventions designed to develop age-appropriate levels of strength or movement skill.

Based on study inclusion criteria, none of the children with epilepsy in our study had physical or cognitive disabilities that would be expected to limit their physical activity. Nevertheless, only 11% achieved the recommended level of physical literacy expected to be associated with optimal health. By contrast, 30% of the matched population of children without known health conditions achieved the recommended level. The largest discrepancy in the proportion of children achieving recommended physical literacy domain scores occurred for daily behavior, with 6% of children with epilepsy and 24% of matched controls achieving the recommended score.

Studies in adult patients with epilepsy have demonstrated less frequent sport participation, poorer aerobic endurance, muscle-strength endurance, and physical flexibility [10,11,14]. Our study confirms those findings for children with epilepsy, even for those who will likely outgrow their epilepsy during adolescence. In these children with

self-limiting forms of epilepsies, the lack of physical activity and physical literacy may in fact have more significant impacts on the children's general health than the epilepsy itself. It is well-established that decreased physical activity during childhood impacts normal childhood growth and development. Active play is the foundation for childhood socialization, and as such, physical activity is highly correlated with childhood quality of life [34]. For young children, health-related quality of life is directly related to motor competence. Physical activity increases readiness for academic learning [18]. Bone density and growth are dependent on weight-bearing physical activity. Motor skill development is an important correlate of health, and through physical activity children develop spatial awareness (over, under, around, etc.) and understand physical concepts (force, power, energy, etc.) [35]. The physical health benefits of physical activity are widely recognized, including decreased atherosclerosis risk, reduced health risks of a sedentary lifestyle (e.g., diabetes, obesity, cancer), and maintenance of a healthy body weight. Physical activity also provides important emotional health benefits, including improved perceived well-being, self-efficacy, self-esteem, and academic/cognitive performance [18].

Of note, although children with epilepsy in our study tended to have slightly lower step counts compared with their peers, they had significantly higher reported daily screen time. A negative correlation between screen time and health-related quality of life has recently been described for children with epilepsy [6]. Therefore, we suggest that a reduction of screen time in children with epilepsy should be considered a high priority intervention target in order to promote a healthier lifestyle in those children. Further research is also required to confirm whether the daily physical activity of children with epilepsy (as measured in our study by step counts) differs from their healthy peers. Although our patients did not differ significantly from the matched control group, we do not know whether the groups were comparable on psychosocial factors (e.g., parent support, community design) that are thought to be important determinants of childhood physical activity. The average step count among the matched controls in our study ($10,772 \pm 3351$ steps per day) was somewhat lower than reported in previous research with Canadian children [36,37]. The 99% CI of the difference between groups, which ranged from 400 to over 2500 steps per day, also suggests that there may be an important if not statistically significant difference.

Despite similar step counts, we measured lower muscular endurance and decreased agility in children with epilepsy, as compared with their healthy peers. We hypothesize that this might be secondary to decreased engagement in sports activities, where muscular strength and endurance, as well as agility, would be trained. Previously, it has been shown that teens with epilepsy participate in fewer group and total sports activities as compared with their siblings without epilepsy [15]. Core muscular endurance deficits, as measured in our study via the plank protocol [30], may decrease spinal column stability and contribute to an increased risk of injury [38,39].

Several limitations to our study exist. Patients were excluded if they had a syndrome or disability that prevented completion of the study protocol or if their current medical status limited vigorous physical

activity. Therefore, children with epilepsy and comorbidities like cognitive delays or physical disabilities were not tested. Our patient cohort consisted of relatively mildly affected children with overall low seizure frequency, including no or infrequent tonic–clonic seizures, short disease duration, low anticonvulsant burden, and age-related, often self-limiting epilepsy diagnoses in 49% of the cohort (Table 1). This likely constitutes a recruitment bias; more severely affected children and their parents may have been less willing to undergo physical literacy testing. Furthermore, experience with other similar studies in children with chronic health problems have revealed that in general, less active children are less likely to volunteer for physical activity assessment studies. Our findings of similar step counts and higher motivation scores among patients with epilepsy in comparison with matched peers suggest that our participants with epilepsy may have been biased towards children who are more active. We can only hypothesize that the physical literacy of the overall population of children with epilepsy, including those with more severe forms or motivation similar to or lower than peers, would be even lower. To address this knowledge gap, studies utilizing a brief screening tool for the assessment of physical literacy in the general population of children with epilepsy are currently being piloted.

Overall, we have shown that school-aged, preadolescent children with epilepsy, including those with age-related, self-limiting forms often considered as benign, have significantly lower levels of physical literacy than their peers. Long-term negative effects of decreased physical literacy in childhood may surpass and outlive the health impacts of the seizure disorder itself. Evaluating potential etiologies for this low level of physical literacy will be part of future projects, with the long-term goal of promoting physical literacy in children with epilepsy, thereby facilitating a healthier lifestyle. Increased physical activity in children with epilepsy may improve their general long-term health, decrease anxiety and depression, improve self-esteem and social integration, and even boost neurocognitive skills.

Declaration of interest

None.

Acknowledgments

We thank all of the children and their families for their enthusiastic participation in this research study and Drs. Doja, Humphreys, McMillan, Sell, Venkateswaran, and Whiting for the opportunity to approach their patients, as well as our librarian Margaret Sampson for her invaluable assistance.

Funding

This work was supported by the Children's Hospital of Eastern Ontario Research Institute.

References

- [1] Nakken KO, Bjorholt PG, Johannessen SI, Loyning T, Lind E. Effect of physical training on aerobic capacity, seizure occurrence, and serum level of antiepileptic drugs in adults with epilepsy. *Epilepsia* 1990;31:88–94.
- [2] Nakken KO. Physical exercise in outpatients with epilepsy. *Epilepsia* 1999;40:643–51.
- [3] McAuley JW, Long L, Heise J, Kirby T, Buckworth J, Pitt C, et al. A prospective evaluation of the effects of a 12-week outpatient exercise program on clinical and behavioral outcomes in patients with epilepsy. *Epilepsy Behav* 2001;2:592–600.
- [4] Pimentel J, Tojal R, Morgado J. Epilepsy and physical exercise. *Seizure* 2015;25:87–94.
- [5] Eom S, Lee MK, Park JH, Lee D, Kang HC, Lee JS, et al. The impact of a 35-week long-term exercise therapy on psychosocial health of children with benign epilepsy. *J Child Neurol* 2016;31:985–90.
- [6] Rauchenzauner M, Hagn C, Walch R, Baumann M, Haberlandt E, Fruhwirth M, et al. Quality of life and fitness in children and adolescents with epilepsy (EpiFit). *Neuropediatrics* 2017;48:161–5.
- [7] Nakken KO, Loyning A, Loyning T, Gloersen G, Larsson PG. Does physical exercise influence the occurrence of epileptiform EEG discharges in children? *Epilepsia* 1997;38:279–84.
- [8] Tremblay MS, Carson V, Chaput JP, Connor GS, Dinh T, Duggan M, et al. Canadian 24-hour movement guidelines for children and youth: an integration of physical activity, sedentary behaviour, and sleep. *Appl Physiol Nutr Metab* 2016;41:S311–27.
- [9] Capovilla G, Kaufman KR, Perucca E, Moshe SL, Arida RM. Epilepsy, seizures, physical exercise, and sports: a report from the ILAE task force on sports and epilepsy. *Epilepsia* 2016;57:6–12.
- [10] Bjorholt PG, Nakken KO, Rohme K, Hansen H. Leisure time habits and physical fitness in adults with epilepsy. *Epilepsia* 1990;31:83–7.
- [11] Steinhoff BJ, Neussus K, Thegeder H, Reimers CD. Leisure time activity and physical fitness in patients with epilepsy. *Epilepsia* 1996;37:1221–7.
- [12] Howard GM, Radloff M, Sevier TL. Epilepsy and sports participation. *Curr Sports Med Rep* 2004;3:15–9.
- [13] Kobau R, Cui W, Zack MM. Adults with an epilepsy history fare significantly worse on positive mental and physical health than adults with other common chronic conditions—estimates from the 2010 National Health Interview Survey and patient reported outcome measurement system (PROMIS) Global Health scale. *Epilepsy Behav* 2017;72:182–4.
- [14] Jalava M, Sillanpää M. Physical activity, health-related fitness, and health experience in adults with childhood onset epilepsy: a controlled study. *Epilepsia* 1997;38:424–9.
- [15] Wong J, Wirrell E. Physical activity in children/teens with epilepsy compared with that in their siblings without epilepsy. *Epilepsia* 2006;47:631–9.
- [16] McNamara NA, Romanowski EMF, Olson DP, Shellhaas RA. Bone health and endocrine comorbidities in pediatric epilepsy. *Semin Pediatr Neurol* 2017;24:301–9.
- [17] Besag F, Aldenkamp A, Caplan R, Dunn DW, Gobbi G, Sillanpää M. Psychiatric and behavioural disorders in children with epilepsy: an ILAE task force report. *Epileptic Disord* 2016;18(Suppl. 1):1–86.
- [18] Donnelly JE, Lambourne K. Classroom-based physical activity, cognition, and academic achievement. *Prev Med* 2011;52(Suppl. 1):S36–42.
- [19] Pugh MJ, Copeland LA, Zeber JE, Cramer JA, Amuan ME, Cavazos JE, et al. The impact of epilepsy on health status among younger and older adults. *Epilepsia* 2005;46:1820–7.
- [20] Gordon KE, Dooley JM, Brna PM. Epilepsy and activity—a population-based study. *Epilepsia* 2010;51:2254–9.
- [21] Ablah E, Haug A, Konda K, Tinius AM, Ram S, Sadler T, et al. Exercise and epilepsy: a survey of Midwest epilepsy patients. *Epilepsy Behav* 2009;14:162–6.
- [22] Cui W, Zack MM, Kobau R, Helmers SL. Health behaviors among people with epilepsy—results from the 2010 National Health Interview Survey. *Epilepsy Behav* 2015;44:121–6.
- [23] Tedrus GMAS, Sterca GS, Pereira RB. Physical activity, stigma, and quality of life in patients with epilepsy. *Epilepsy Behav* 2017;77:96–8.
- [24] Volpato N, Kobashigawa J, Yasuda CL, Kishimoto ST, Fernandes PT, Cendes F. Level of physical activity and aerobic capacity associate with quality of life in patients with temporal lobe epilepsy. *PLoS One* 2017;12:e0181505.
- [25] ParticipACTION. Canada's physical literacy consensus statement. <http://www.participaction.com/canadas-physical-literacy-consensus-statement/>; 2015.
- [26] Longmuir PE, Boyer C, Lloyd M, Boiarskaia E, Zhu W, Tremblay MS. The Canadian Assessment of Physical Literacy: methods for children in grades 4 to 6 (8 to 12 years). *BMC Public Health* 2015;15:767.
- [27] Longmuir PE, Boyer C, Lloyd M, Borghese M, Knight E, Saunders TJ, et al. Canadian agility and movement skill assessment: validity, objectivity, and reliability evidence for children 8 to 12 years of age. *J Sport Health Sci* 2017;6:231–40.
- [28] Meredith MD, Welk G. *FitnessGram & ActivityGram: test administration manual*. Dallas, Texas: The Cooper Institute; 2010.
- [29] Canadian Society for Exercise Physiology. *Physical activity training for health (CSEP-PATH)*. Ottawa, Ontario: Canadian Society for Exercise Physiology; 2013.
- [30] Boyer C, Tremblay MS, Saunders TJ, McFarlane A, Borghese M, Lloyd M, et al. Feasibility, validity and reliability of the plank isometric hold as a field-based assessment of torso muscular endurance for children 8 to 12 years of age. *Pediatr Exerc Sci* 2013;25:407–22.
- [31] Hay JA. Adequacy in and predilection for physical activity in children. *Clin J Sport Med* 1992;2:192–201.
- [32] Garcia AW, Broda MA, Frenn M, Coviak C, Pender NJ, Ronis DL. Gender and developmental differences in exercise beliefs among youth and prediction of their exercise behavior. *J Sch Health* 1995;65:213–9.
- [33] Francis CE, Longmuir PE, Boyer C, Andersen LB, Barnes JD, Boiarskaia E, et al. The Canadian assessment of physical literacy: development of a model of children's capacity for a healthy, active lifestyle through a Delphi process. *J Phys Act Health* 2016;13:214–22.
- [34] Wu XY, Han LH, Zhang JH, Luo S, Hu JW, Sun K. The influence of physical activity, sedentary behavior on health-related quality of life among the general population of children and adolescents: a systematic review. *PLoS One* 2017;12:e0187668.
- [35] Timmons BW, Naylor PJ, Pfeiffer KA. Physical activity for preschool children—how much and how? *Can J Public Health* 2007;98(Suppl. 2):S122–34.
- [36] Tudor-Locke C, Craig CL, Cameron C, Griffiths JM. Canadian children's and youth's pedometer-determined steps/day, parent-reported TV watching time, and overweight/obesity: the CANPLAY surveillance study. *Int J Behav Nutr Phys Act* 2011;8:66.
- [37] Vander Ploeg KA, Wu B, McGavock J, Veugelers PJ. Physical activity among Canadian children on school days and nonschool days. *J Phys Act Health* 2012;9:1138–45.
- [38] Cowley PM, Fitzgerald S, Sottung K, Swensen T. Age, weight, and the front abdominal power test as predictors of isokinetic trunk strength and work in young men and women. *J Strength Cond Res* 2009;23:915–25.
- [39] McGill SM, Grenier S, Kavcic N, Cholewicki J. Coordination of muscle activity to assure stability of the lumbar spine. *J Electromyogr Kinesiol* 2003;13:353–9.