Impaired vision and physical activity in childhood and adolescence: findings from the Millennium Cohort Study

Lisanne Andra Horvat-Gitsels[a,b]; Mario Cortina-Borja[a]; Ameenat Lola Solebo[a,b,c]; Jugnoo Sangeeta Rahi[a,b,c,d,e]

Affiliations: [a] Population, Policy and Practice Research and Teaching Department, Great Ormond Street Institute of Child Health, University College London, London, UK; [b] Ulverscroft Vision Research Group, Great Ormond Street Institute of Child Health, University College London, London, UK; [c] Great Ormond Street Hospital for Children NHS Foundation Trust, London, UK; [d] Institute of Ophthalmology, University College London, UK; and [e] NIHR Moorfields Biomedical Research Centre London, UK.

Correspondence: Jugnoo S Rahi, UCL Great Ormond Street Institute of Child Health, 30 Guilford Street, London WC1N 1EH, UK, [j.rahi@ucl.ac.uk].

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SYNOPSIS

This contemporary birth cohort showed important differences in physical activity and broader engagement between children with normal vision and those with impaired vision, particularly in participation and self-confidence related to physical education and organised sports.

ABSTRACT

Background/Aims Investigate if impaired vision is associated with reduced levels and differences in types of physical activity (PA) to identify barriers or enablers to achieving healthy PA levels.

Methods Data from the Millennium Cohort Study of children born in the United Kingdom in 2000-01 and followed-up to age 14 years (*n*=11,571). Using parental report on eye conditions coded by clinicians, children were categorised as having no, unilateral, or bilateral impaired vision. Outcomes included objective accelerometer-derived time spent in moderate-to-vigorous physical activity (MVPA), and 16 PA types reported by parents, teachers, and/or participants, covering physical education (PE), organised sports, self-organised sports, and hobbies.

Results Overall, 50% of 7-year-olds and subsequently 41% as 14-year-olds achieved the internationally recommended level of ≥60 MVPA min/day, irrespective of vision status, and mainly attributable to PE and organised sports. Bilateral impaired vision (versus none) was associated with parent-reported difficulties with PE (aOR, 4.67; 95%CI, 2.31-9.41), self-rated poor ability in PE (3.21, 1.44-7.15), and *not* enjoy indoor PA (0.48, 0.26-0.88). Unilateral impaired vision was associated with both parent-rated difficulties (1.80, 1.26-2.59) and teachers' perception of low ability in PE (2.27, 1.57-3.28), and reduced odds of high participation in organised sports (0.77, 0.59-0.99). Age-related trajectories showed suboptimal PA in childhood tracked into adolescence, with no difference by vision status.

Conclusion Population-wide programmes to increase PA levels in children should pay special attention to those with impaired vision and include early interventions to encourage participation and confidence in PE and organised sports, starting in primary school and maintained afterwards.

INTRODUCTION

Physical activity (PA) has positive effects on psychosocial and cognitive outcomes in children and young people (CYP).[1,2] Levels of PA decline from early childhood onwards changing from short bursts of activity to more structured, organised sports.[3–5] High PA participation in early life predicts similar in later life,[6] which in turn is associated with decreased risks of chronic conditions and all-cause mortality.[1,2] Therefore, PA levels of CYP are important indicators and foundations of the current and future health of individuals and the population.

International guidelines for PA in CYP aged 5-18 years recommend ≥60 min/day of moderate-to-vigorous intensity physical activity (MVPA).[1,2] There are no specific guidelines for those with disabilities which impact the ability to participate in PA. There is increasing concern that CYP with impaired vision may be less active than those without.[7–10] Reasons include reduced access to appropriate or adapted opportunities, and perceived or actual limitations in functional vision,[8,11] with contradictory evidence on the impact of severity of impaired vision, sex, age, and school type.[8,10]

We hypothesised that children with impaired vision would differ in the amount of MVPA achieved and the types of PA from those with normal vision. We further hypothesised that subsequent age-related trajectories would further diverge during adolescence as children move from primary to secondary education. We report here our investigation using the Millennium Cohort Study (MCS), which offers unique opportunities for a holistic approach to understanding engagement in PA within and outside school by CYP, specifically whether those with impaired vision can achieve levels of MVPA equivalent to those without impaired vision, the types of PA that enable this, and the barriers to accessing and benefitting from PA.

METHODS

Study design

The MCS is a longitudinal survey of 18,818 participants born in 2000-01 in the UK, which intentionally oversampled families from socio-economically deprived backgrounds and ethnic minorities to ensure adequate numbers for the analysis of these typically hard to reach groups.[12–14] This makes this cohort well suited for research on impaired vision, as the risk of childhood visual impairment is higher amongst those from lower socio-economic and ethnic minority groups.[15] Every 2-3 years, data were collected about development and family socioeconomic circumstances.

Our previous work[16,17] identified MCS participants with eye conditions at ages 3-7 years by which age impaired vision would have manifested in most children.[15] This was used as the baseline status and for follow up until age 14 when the last PA data were collected.

The MCS received research ethics approval from the relevant Committees[12] and parents gave informed consent for each survey and physical measure taken.[12]

Ophthalmic data

The MCS has not yet included a biomedical physical examination (thus no measurement of acuity) of participants. Information about vision and eye conditions is available from detailed parental reports at ages 3, 5, and 7 years using a combination of open and closed-ended questions designed by ophthalmic clinicians to capture any problems with eyesight or eyes, which eye(s) affected, age when first suspected, any treatment undertaken and formal certification for sight impairment. Responses were coded by ophthalmologists in our research team based on a conservative and hierarchical approach that required diagnosis, types of treatment and age at treatment to match consistently. Coding was based on the International Classifications of Diseases (ICD) and extended taxonomy applied in our previous research on childhood blindness,[15] which has been successfully validated.[16,17] We categorised participants into those with eye conditions causing impaired vision and those without (i.e. normal vision was assumed) by age 7 years (eTable 1). We further differentiated bilateral from unilateral impaired vision as both a proxy for severity and as a way of distinguishing the impact of overall impaired vision from the impact of loss of stereo (3D) vision, i.e. depth perception.

Physical activity data

These comprised reports from participants themselves, their parents/carers and their teachers on various, independent, dimensions relating to engagement with and participation in PA and objectively measured PA (see eTable 2 for questions used in this analysis with coding; entire questionnaires available at https://cls.ucl.ac.uk/cls-studies/millennium-cohort-study/).

Participants reported on their level of enjoyment playing sports inside and outside, at age 7, and physical education (PE) at ages 7 and 11; frequency of playing sports outside school, at age 11; and frequencies of achieving ≥60 min/day of MVPA and watching live sports, and their level of agreement with the statement "I am good at PE", at age 14.

Parents reported their children's level of difficulties with PE, reasons for attending a sports class less frequently than weekly, frequency of going to the park/playground with parents, level of enjoyment of PA, and having spectated a professional sporting event in the past year, all at age 7; frequencies of attending a sports class, being physically active with parents, and siblings or friends, all at ages 7 and 11; and level of encouragement by the London 2012 Olympics and Paralympics to take part in sports, at age 11.

Finally, teachers (England and Wales) reported on the participant's ability in PE at age 11. With frequencies reported at multiple ages, the last was compared with the first and this age-related trajectory was coded as more, same, or less active.

Accelerometer data were collected in activity monitoring tasks at ages 7 and 14 years, each with age-appropriate validated procedures described elsewhere.[18–21] Everyone was eligible to participate at age 7, whereas at age 14 a random 80% sample of those living in England plus all in Northern Ireland, Scotland and Wales were eligible. At age 7, an Actigraph GT1M uniaxial accelerometer recorded activity in counts every 15 seconds, which was worn for 7 consecutive days.[18,19] Whilst at age 14, a GENEActiv Orginal triaxial accelerometer recorded the mean acceleration Euclidean Norm Minus One (ENMO) every 5 seconds, which was worn on one randomly assigned weekday and one weekend day.[20,21] Participants had to have activity data of ≥10 hours on ≥2 days to ensure reliable measures.[18] The average min/day spent in MVPA was derived (pre-coded); >2240 accelerometer counts/min at age 7 and ENMO>100mg for >80%/min.

Statistical analyses

Analyses were conducted in R version 3.5.3.[22] Sampling weights were used to adjust for MCS survey design and attrition over time.[23,24] Participants from multiple births were excluded from the analyses because their interview and accelerometer data could not be accurately linked.[25] Missing data patterns were investigated by logistic regression to understand the selection bias in those with reported PA data and reliable accelerometer data obtained after activity monitoring tasks.

We adjusted the analyses for potential confounders, including the participant's sex, ethnicity, body mass index (BMI), physical limiting longstanding illness (such as cerebral palsy), maternal education, household income, and astronomically-defined season when the accelerometer was worn (eTable 1).[9,26–28] School type was of special interest and recoded as "mainstream" or "special education".

Chi-squared tests tested differences in proportions of impaired vision by baseline characteristics and reported PA types. Independent, adjusted logistic and ordinal regression models for reported PA types were fitted to test the hypothesis whether children with impaired vision differ in the types and corresponding levels of PA from those with normal vision and that subsequent age-related trajectories further diverge. Adjusted quantile regression models[29] for median MVPA at ages 7 and 14 were fitted to investigate whether CYP with impaired vision can achieve levels of MVPA equivalent to those with normal vision and the types of PA that enable or form a barrier to this. The resulting conditional models refer to the outcome's median and work on the original scale with no need for transformations on the non-normal distribution of MVPA. Interactions between impaired vision and sex were included in the final models if significant at 0.05. Collinearity was assessed via variance inflation factors from R library `car`.[30] All model assumptions were satisfied.

RESULTS

Study population

The cohort consisted of 11,571 children aged 7 years with follow-up shown in Figure 1. The overall proportion of children with eye conditions that caused unilateral impaired vision was 48 per 1000 (95% CI, 44-53) and bilateral 6 per 1000 (4-7). The impaired vision group had a higher proportion of children with physical limiting longstanding illness, attending special education, lower maternal educational attainment, and lower household income (Table 1).

Table 1: Sociodemographic characteristics of the study sample by vision status.

Characteristic	Category	Impaired vision			χ^2 global (weighted*) *p*-value
		No (weighted* %)	Unilateral (weighted* %)	Bilateral (weighted* %)	
Sex	Girls	5405 (49)	279 (50)	43 (55)	0.620
	Boys	5529 (51)	281 (50)	34 (45)	
Ethnicity	Black, African, or Caribbean	305 (3)	11 (1)	[a]	NA
	South Asian	887 (6)	33 (5)	[a]	
	White	9468 (88)	502 (91)	[a]	
	Other	274 (3)	13 (2)	[a]	
Physical limiting longstanding illness	No	9672 (88)	459 (81)	54 (71)	<0.001
	Yes	1262 (12)	101 (19)	23 (29)	
BMI	Healthy weight	8594 (80)	426 (79)	55 (73)	0.612
	Overweight	1567 (14)	79 (14)	14 (22)	
	Obese	640 (6)	38 (7)	5 (5)	
School type	Mainstream	10819 (100)	548 (99)	72 (95)	<0.001
	Special education	55 (<1)	9 (1)	5 (5)	
Maternal education	A-levels or higher	4249 (36)	183 (30)	25 (33)	0.015
	O-levels	5023 (48)	271 (51)	32 (42)	
	None	1645 (15)	103 (19)	20 (25)	
Household income	Median or higher	4197 (40)	171 (31)	21 (33)	0.003
	Poor	3485 (32)	184 (34)	31 (41)	
	Very poor	2951 (28)	193 (35)	22 (27)	
Total	Rate (95% CI)	946 per 1000 (941 to 951)	48 per 1000 (44 to 53)	6 per 1000 (4 to 7)	<0.001

[a] Not provided to avoid potential disclosure; *weighted for survey design.

Levels and trajectories of reported PA dimensions

Fewer than 1% of participants had missing reported PA data at a given age (eTable 3). The levels and age-related trajectories of reported PA dimensions are presented in eTable 4. Adjusted regression models (Table 2) indicated self-reported frequencies of achieving ≥60 min/day of MPVA did not vary by vision status. Both groups with impaired vision had higher odds than those with normal vision to have parent-reported difficulties in participating in PE irrespective of school type: unilateral (OR, 1.80; 95% CI, 1.26-2.59) and bilateral (4.67, 2.31-9.41), respectively. Children with unilateral impaired vision, compared to those with normal vision, were more likely to be rated by teachers as having low ability in PE (2.27, 1.57-3.28). They were also less likely to participle in organised sports (0.77, 0.59-0.99). Children with bilateral impaired vision were more likely than those with normal vision to self-rate their ability in PE as poor (3.21, 1.44-7.75) and were less likely to *not* enjoy indoor PA (0.48, 0.26-0.88).

Table 2: Adjusted odds of reported physical activity types associated with vision status.

Physical activity outcome[a]	Age period	Level	Impaired vision	
			Unilateral aOR (95%CI)[b]	Bilateral aOR (95%CI)[b]
Self-reported				
Hobby – indoor PA enjoyment	Child	A lot	Ref.	Ref.
		Little/none	0.99 (0.81, 1.23)	**0.48 (0.26, 0.88)**
Hobby – outdoor PA enjoyment	Child	A lot	Ref.	Ref.
		Little/none	1.05 (0.84, 1.32)	0.81 (0.42, 1.59)
PE – enjoyment	Child	A lot	Ref.	Ref.
		Little/none	1.52 (0.75, 1.23)	0.96 (0.80, 2.88)
	Child → Adol.	Same / more	Ref.	Ref.
		Less	0.99 (0.66, 1.95)	1.13 (0.25, 3.96)
PA outside school	Adol.	< Weekly	Ref.	Ref.
		Weekly	1.28 (1.00, 1.63)	1.32 (0.69, 2.54)
		Most days	0.84 (0.66, 1.05)	0.76 (0.40, 1.42)
MVPA ≥60 min/day	Adol.	<3 days/week	Ref.	Ref.
		3-4 days/week	1.00 (0.76, 1.32)	0.97 (0.47, 2.00)

		5-7 days/week	0.85 (0.64, 1.13)	0.94 (0.44, 2.01)
PE – self-concept being good	Adol.	Agree / strongly agree	Ref.	Ref.
		Disagree	0.89 (0.64, 1.25)	1.10 (0.50, 2.43)
		Strongly disagree	1.47 (0.94, 2.31)	**3.21 (1.44, 7.15)**
Hobby – watching sports	Adol.	< Monthly	Ref.	Ref.
		Monthly	0.98 (0.73, 1.32)	0.69 (0.29, 1.61)
		Weekly	1.07 (0.71, 1.62)	1.47 (0.51, 4.22)
Parent-reported				
PE – difficulty with	Child	No	Ref.	Ref.
		Some/great	**1.80 (1.26, 2.59)**	**4.67 (2.31, 9.41)**
Self-organised sports – park	Child	<Monthly	Ref.	Ref.
		Monthly	1.19 (0.96, 1.48)	1.59 (0.91, 2.81)
		Weekly	0.93 (0.75, 1.15)	0.76 (0.42, 1.37)
Hobby – spectating sports	Child	No	Ref.	Ref.
		Yes	0.93 (0.73, 1.20)	1.18 (0.62, 2.27)
Organised sports	Child	< Weekly	Ref.	Ref.
		1-2 days/week	1.00 (0.84, 1.26)	1.03 (0.58, 1.70)
		3-7 days/week	**0.77 (0.59, 0.99)**	0.74 (0.17, 1.21)
	Child → Adol.	Same / more	Ref.	Ref.
		Less	1.01 (0.74, 1.31)	0.98 (0.45, 2.23)
Self-organised sports – parents	Child	< Monthly	Ref.	Ref.
		Monthly	0.62 (0.72, 1.12)	1.05 (0.80, 1.21)
		Weekly	0.90 (0.33, 1.19)	0.99 (0.61, 1.83)
	Child → Adol.	Same / more frequently	Ref.	Ref.
		Less frequently	0.65 (0.79, 1.33)	1.03 (0.35, 1.21)
Self-organised sports – siblings/peers	Child	< Weekly	Ref.	Ref.
		1-2 days/week	1.05 (0.91, 1.12)	0.96 (0.89, 1.09)
		3-7 days/week	0.96 (0.89, 1.09)	0.99 (0.73, 1.27)
	Child → Adol.	Same / more frequently	Ref.	Ref.
		Less frequently	1.35 (0.77, 1.30)	1.00 (0.70, 2.60)
Hobby – Olympics	Adol.	Not encouraged	Ref.	Ref.
		Encouraged	0.84 (0.66, 1.06)	0.98 (0.53, 1.82)
Teacher-reported				
Ability in PE	Adol.	Average / above average	Ref.	Ref.
		Below average	**2.27 (1.57, 3.28)**	0.28 (0.06, 1.25)

PA, physical activity; PE, physical education at school; MVPA, moderate-to-vigorous physical activity.

[a] Independent outcomes with their own regression model.

[b] Odds ratio (OR) weighted for survey design and adjusted for sex, ethnicity, physical limiting longstanding illness, body mass index, school type, maternal education and household income. Associations with *p*<0.05 in **bold**.

Despite these differences at age 7 years, the age-related trajectories from 7 to 11 years in organised sports, self-organised sports, and enjoyment of PE were not significantly different by vision status. There was no significant interaction between impaired vision and sex in their association with PA.

The relative importance of the reasons given by parents for low levels of participation in organised sports by their children at age 7 years varied considerably by vision status (Figure 2). Physical limitations (21%), illness (16%) and fear of injury (10%) were the most frequently cited reasons for children with bilateral visual impairment, whereas financial costs and time restraints were the most frequently cited barriers by those with unilateral or no impaired vision.

Accelerometer-measured PA

At age 7, the subsample with reliable accelerometer data consisted of fewer boys, fewer children from ethnic minorities and/or lower socioeconomic background and/or with long-standing illnesses as well as being more active (eTable 5). At age 14, the selection bias was minimal as none of the adolescent's characteristics –including impaired vision– were significantly associated with accelerometer data reliability (eTable 6). There were reliable accelerometer data for 50% (*n*, 5823) of participants at age 7 and 33% (3819) at age 14, but only 19% (2243) had data at both ages, affecting the numbers of bilateral impaired vision the most (eTable 7). Therefore, data were analysed cross-sectionally. Analyses were not adjusted for school type because <10 participants attending special education had accelerometer data.

The adjusted regression models (Table 3) showed that at age 7 and 14 years, there were no significant differences in time/day spent in MPVA between those with normal vision and those with impaired vision. The recommended level of ≥60 min/day of MVPA was achieved by 50% of all 7-year-olds and 41% of all 14-year olds. With no difference by vision status in the amount of MVPA achieved, all CYP had similar associations with reported levels of PA in other dimensions. At age 7 years, the amount of MPVA was positively associated with spectating professional sports (regression coef in min/day, 2.7; 95%CI, 0.5, 4.9) and enjoying outdoor PA (2.4; 0.4, 4.4) and negatively associated with parent-reported having difficulties with PE (-4.4; -0.7, -8.1). Furthermore, compared to autumn, children were the most active in the spring (10.8; 8.1, 13.5) and summer (6.1; 4.3, 7.9) and least in the winter (-3.1; -0.6, -5.6). At age 14 the amount of MVPA achieved was positively associated with high levels of self-reported MVPA (12.7; 5.3, 20.1), organised PA outside school (12.0; 4.0, 20), and organised sports (8.2; 0.2, 16.2), but negatively associated with teacher-rated low ability in PE (-8.3; -0.3, -16.3).

Table 3: Adjusted effects associated with median time (min/day) spent in objectively moderate-to-vigorous physical activity.

Independent variables	Category	Accelerometer MVPA @age child		Accelerometer MVPA @age adolescent	
		coeff (se)[a]	*p*-value	coeff (se)[a]	*p*-value
Exposure					
Impaired vision @age child	No	Ref.		Ref.	
	Unilateral	-1.3 (1.9)	0.491	5.4 (5.8)	0.350
	Bilateral	-3.6 (4.9)	0.468	-3.0 (9.5)	0.878
Accelerometer related					
Season @age child/adolescent	Autumn	Ref.		Ref.	
	Spring	**10.8 (1.4)**	**<0.001**	-0.1 (4.5)	0.988
	Summer	**6.1 (0.9)**	**<0.001**	0.8 (5.0)	0.878
	Winter	**-3.1 (1.3)**	**0.018**	-1.1 (5.5)	0.847
Self-reported PA					
Hobby – indoor PA enjoyment @age child	Little/none	Ref.		Ref.	
	A lot	-0.5 (0.8)	0.515	-2.4 (2.6)	0.359
Hobby – outdoor PA enjoyment @age child	Little/none	Ref.		Ref.	
	A lot	**2.4 (1.0)**	**0.015**	-1.6 (2.7)	0.561

PE – enjoyment @age child/adolescent	Little/none	Ref.		Ref.	
	A lot	1.8 (0.9)	0.059	-0.5 (3.9)	0.906
PA outside school @age adolescent	<Weekly			Ref.	
	Weekly			1.7 (4.0)	0.660
	Most days			**12.0 (4.1)**	**0.004**
MVPA ≥60 min/day @age adolescent	<3 days/week			Ref.	
	3-4 days/week			3.5 (3.2)	0.280
	5-7 days/week			**12.7 (3.8)**	**0.001**
PE – self-concept being good @age adolescent	Agree / strongly agree			Ref.	
	Disagree			-2.5 (3.5)	0.473
	Strongly disagree			-2.3 (6.2)	0.710
Hobby - watching sports @age adolescent	<Monthly			Ref.	
	Monthly			2.9 (3.2)	0.357
	Weekly			3.6 (5.1)	0.476
Parent-reported PA					
PE – difficulty @age child	No	Ref.		Ref.	
	Some/great	**-4.4 (1.9)**	**0.022**	0.2 (5.0)	0.971
Self-organised sports – park @age child	<Monthly	Ref.		Ref.	
	Monthly	-0.2 (1.1)	0.863	-0.7 (4.5)	0.873
	Weekly	0.0 (1.0)	0.986	-3.5 (3.9)	0.367
Hobby - spectating sports @age child	No	Ref.		Ref.	
	Yes	**2.7 (1.1)**	**0.011**	0.8 (3.1)	0.793
Organised sports @age child/adolescent	<Weekly	Ref.		Ref.	
	1-2 days/week	-0.1 (1.1)	0.900	2.1 (3.5)	0.537
	3-7 days/week	2.4 (1.2)	0.052	**8.2 (4.1)**	**0.044**
Self-organised sports - parents @age child/adolescent	<Monthly	Ref.		Ref.	
	Monthly	-1.7 (1.5)	0.272	-1.7 (3.4)	0.624
	Weekly	-1.8 (1.5)	0.221	-3.7 (4.1)	0.372
Self-organised sports - siblings/peers @age child/adolescent	<Weekly	Ref.		Ref.	
	1-2 days/week	1.4 (2.0)	0.489	3.0 (4.7)	0.524
	3-7 days/week	2.6 (1.7)	0.134	0.2 (4.0)	0.954
Hobby - Olympics @age adolescent	Not encouraged			Ref.	
	Encouraged			2.3 (2.9)	0.416
Teacher-reported PA					
Ability in PE @age adolescent	Average / above average			Ref.	

	Below average			**-8.3 (4.1)**	**0.042**

PA, physical activity; PE, physical education at school; MVPA, moderate-to-vigorous physical activity.

[a] Regression coefficient and standard error (sed). Models were fitted with weights for survey design and adjusted for all listed covariates with most up-to-date information given the age the outcome variable was measured and sex, ethnicity, physical limiting longstanding illness, body mass index, maternal education and household income. Associations with $p<0.05$ in **bold**.

DISCUSSION

Fewer than half of all CYP in this UK population-based cohort study achieved the recommended amount of MVPA (accelerometer-assessed) at 7 and 14 years. Impaired vision was not associated with either self-rated or objectively measured amount of MPVA. However, there were important differences in the types and broader engagement with PA between those with normal vision and those with impaired vision. These were mainly evident in terms of participation and self-confidence in relation to PE and organised sports. There were no significant differences by vision status in age-related 'trajectories' of reported PA dimensions: those achieving good PA levels in childhood continued to do so as adolescents. PA types positively associated with the amount of MVPA levels (i.e. enablers) in early childhood were spectating professional sporting events, enjoying outdoor PA, and spring and summer months. Whilst in adolescence, these were higher frequencies of MVPA in general and outside school, and organised sports. Notably, both parental perception of children's difficulties and lower teacher-ratings of ability in PE were associated with lower amounts of MPVA (i.e. perceived barriers).

This study's strengths are the sample size of CYP with unilateral or bilateral impaired vision in a representative birth cohort and the holistic approach. This enabled an investigation of the full picture of engagement in PA by covering a range of PA types from structured school PE and organised sports to semi-structured self-organised sports and PA-related hobbies, and by capturing the perspectives of the participants themselves, as well as parents and educators. The levels of PA types were measured at specific ages, instead of summarised for age groups,[7–10,28] and at multiple ages allowing to assess age-related trajectories of PA by impaired vision for the first time. Furthermore, accelerometer data at two ages in a subset of more physically active children allowed investigation of whether the recommended amount of MVPA *could* be achieved in childhood and adolescence, and the PA types that enabled this and the barriers to accessing and benefitting from PA at those developmental stages.

Study limitations include the potential for misclassification of vision status through the use of parental reports of eye conditions and thereby may cause bias in the associations, although the risk is low as the coding has been validated previously[16,17] and the proportions of childhood vision impairment found in this study align with expectations from population studies utilising clinical assessment of visual acuity.[27] Although accelerometer data yield an objective measurement of MVPA,[31] selection bias resulted in a healthier and more active subcohort and there may be underestimations of activities like swimming and cycling,[26] which might well differ substantially with impaired vision. There may therefore be true differences in objective MVPA levels between CYP with normal vision and those with impaired vision that our study did not ascertain, although the similar levels of self-reported MVPA in the overall cohort suggest that bias is limited. Common issues in cohort studies are attrition and missing data. Here, attrition was dealt with by sampling weights,[23] whilst missing responses of reported PA types were negligible and patterns in missing accelerometer data were thoroughly investigated. Regression models adjusted for the key confounders reported in other studies,[9,26–28] yet as in all observational studies, potential residual confounding cannot be excluded. The focus of health guidance is levels of MVPA, as the corollary of sedentary behaviour time for which there are no accepted clinically meaningful levels. Finally, we were unable to model the direct effect of the amount of MVPA in childhood on levels in adolescence by vision status due to the limited number of participants with impaired vision having reliable accelerometer data at both ages. This would be important to investigate in the future.

Our findings that the level of MVPA decline during the transition from childhood to adolescence reflects the global trend reported by the World Health Organization (WHO)[32] and longitudinal studies.[3–5] The limited prior research on the association between impaired vision and accelerometer-measured daily time spent in MVPA is inconsistent, ranging from 18 min/day less to no significant difference compared to those with normal vision.[7,9,28] This variation might be explained by differences in categorising those with impaired vision,[7,9,28] selection bias, and generally CYP having insufficient levels of PA to ascertain differences.[32]

In our study, PE was the type of PA with the greatest participation and engagement differences between CYP with normal and those with impaired vision. These were independent of school type, suggesting that educational setting, e.g. special schools with more tailored PE provision creating a ‘level playing field’, is not the explanation. Differences between schools with respect to geographic location and funding i.e. resources for physical activity may not have been captured by our adjusted sociodemographic variables, warranting future research to further understand the potential impact of characteristics of schools where higher PA levels are achieved. Our findings that CYP with impaired vision *can* achieve the same levels of MPVA as those with normal vision but that they themselves, their parents and their teachers feel they are less able to participate in PE, may usefully raise awareness about the value of meeting the needs of all students and removing barriers to participation.[33,34] This includes the potential value of boosting the confidence of students with impaired vision in their abilities and using sport and mobility instruments appropriately as well as building in the extra time they require to adequality access curricular activities.[35,36] Future qualitative research would help identify the specific challenges faced by individuals. The finding that those with unilateral impairment, but not with bilateral impairment, were more likely to be rated as having lower ability in PE by their teachers is interesting. Teachers ratings may reflect their adjusted expectations of what children with bilateral impaired vision can do but equally also a lack of awareness of the potential impact of reduced stereovision in unilateral vision impairment. This warrants further attention, given the association with MVPA levels in adolescence.

Organised sport could be classified as the most important PA type to participate in and engage with in childhood as it predicts longer-term health-related PA.[6,37] Inactivity can be more harmful to individuals with a disability than to those without[1,2] and those with impaired vision may need more PA to become fitter.[10] An explanation for our finding that those with unilateral impairment, but not with bilateral impairment, were less likely to participate in organised sport may be attributable to the 'disability paradox',[38–40] whereby those with bilateral impairment simply adjust their expectations in terms of the types of outdoor sport in which they engage, limiting themselves to sports in which potential barriers have been addressed e.g. only playing sports with other children with impaired vision and/or using special equipment. By contrast, children with unilateral impaired vision, most likely due to amblyopia, might be expected to participate in the same sports as those without impaired vision but be concerned to do so due to perceived risks to the unaffected eye, impracticality or social impact of wearing patches or spectacles.[41,42] Based on our findings of the reasons for low participation level in organised sports, interventions to ensure CYP with impaired vision can access and benefit from PA could usefully focus on creating a safe environment and more active indoor PA, whilst population-wide interventions could focus on the financial and time costs to families.

Our study shows for the first time that there is no difference between CYP with normal vision and those with impaired vision in the participation levels of self-organised sports with parents and siblings or peers and PA-related hobbies, except that children with bilateral impaired vision prefer indoor activities. This suggests that these activities could be the most inclusive, benefitting all CYP.

CONCLUSIONS

Our findings show that on average CYP with impaired vision are not achieving recommended levels of MVPA required for optimal health. However, they *can* achieve levels equivalent to those without impaired vision and their age-related trajectories of PA do not diverge during adolescence as children move from primary to secondary education. CYP with impaired vision accessed their greatest opportunities for PA outside provision at school in organised sports. Potential barriers to their engagement in PE are their own self-confidence and teacher concerns – both of which may in turn reflect a lack of appropriate provision. Interventions to improve PA levels in CYP with impaired vision should encourage participation in organised sports and PE at school. Population-wide public health programmes remain a high priority if UK children are to achieve the recommended daily level of MVPA. The particular needs of children with impaired vision should not be forgotten in this national drive.

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LAHG contributed to the design of the study, and was accountable for data analysis and interpretation, preparation of the manuscript and final manuscript approval. MCB contributed

to the data analysis and interpretation, and critical revision of the manuscript. ALS contributed to the design of the study, data interpretation, and critical revision of the manuscript. JSR was accountable for the design of the study, data interpretation, and critical revision of the manuscript. All authors share accountability for all aspects of the work and have approved for the final version to be published.

Data sharing Data are freely available from the UK Data Service, https://beta.ukdataservice.ac.uk/datacatalogue/series/series?id=2000031#!/access-data. For this study, we utilised the first six surveys (MCS1-6 SN:4683, 5350, 5795, 6411, 7464, and 8156). We had special access privileges as co-investigators on the CLOSER grant to the original parental report on eye conditions (variable EYEX in MCS2-4). Access is otherwise obtained via https://www.closer.ac.uk/study/millennium-cohort-study/. Information on eye conditions was included in the coding of longstanding illness (variable CLSI in MCS2-4) that is present in the freely available survey data from the UK Data Archive. The longstanding illness is based on the International Statistical Classification of Diseases and Related Health Problems 10th version (ICD-10).

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