Refractive error and vision problems in children: association with increased sedentary behavior and reduced exercise in 9-year-old children in Ireland

Clare Quigley, FRCOphth,[a] Lina Zgaga, PhD,[b] Georgios Vartsakis, MRCSI,[c] and Gerry Fahy, FRCOphth[a]

PURPOSE To investigate whether refractive error and vision problems in children are associated with increased sedentary behavior and reduced participation in physical activity and sport and, secondarily, to examine the relationship between vision problems and body mass index.

METHODS This was a cross-sectional study of the first wave of the Growing Up in Ireland (GUI) Study, a nationally representative study of children in Ireland. Data was collected between August 2007 and May 2008. Body mass index (BMI) was calculated at the time of the interview. The presence of a vision problem requiring treatment, including refractive error, was detected by report of the primary care giver, usually the mother. Association between vision problems and sedentary behavior, physical activity, and level of participation in sports was investigated in adjusted regression analysis.

RESULTS A total of 8,568 children (mean age, 9 ± 0.13 years; 4,024 [48.68%] males) were included. The presence of refractive error or a vision problem was reported for 1,000 (11.68%) children. The majority of children had normal weight, but 1,497 (17.5%) were overweight, and 446 (5.2%) were obese. A positive association between vision problems and sedentary behavior ($P = 0.00089$) and an inverse association with exercise ($P = 0.01$) were found. Overall, vision problems were not associated with BMI.

CONCLUSIONS In this study cohort, refractive error and vision problems were associated with increased sedentary behavior and decreased physical activity, although no causal relationship was established. (J AAPOS 2019;23:159.e1-6)

Some evidence suggests that visual impairment is likely to lead to decreased physical activity (PA)[1,2] and difficulties participating in sports[2] in children; thus, it may indirectly contribute to increased adiposity. In children, PA has been inversely associated with myopia,[3,4] the most common[5] and increasing[6,7] vision problem worldwide. Blindness, as the extreme case of visual impairment, has been associated with greater reduction in PA levels compared to lesser vision impairment in children, suggesting a possible dose–response relationship.[8]

Author affiliations: [a]Department of Ophthalmology, Galway University Hospital, Ireland; [b]Department of Public Health and Primary Care, Trinity College Dublin, Ireland; [c]Ögonmottagning, Sahlgrenska Universitetssjukhuset, Mölndal, Sweden

Funding support: The GUI data collection has been funded by the Government of Ireland through the Office of the Minister for Children and Youth Affairs.

Submitted June 5, 2018.

Revision accepted December 30, 2018.

Published online May 16, 2019.

Correspondence: Clare Quigley, FRCOphth, Department of Ophthalmology, Galway University Hospital, Newcastle Rd, Galway, H91 YR71, Ireland (email: quigleyclare@gmail.com).

1091-8531/$36.00

https://doi.org/10.1016/j.jaapos.2018.12.011

Childhood adiposity is a major and increasing public health problem. Levels of childhood overweight in Europe have doubled from 1990 to 2008,[9] and most developing countries are reporting climbing rates.[10] Recent estimates place the rate of childhood overweight or obesity at 20% in Europe (2010)[11] and at 31.8% (2012)[12] in the United States.[13]

An association between vision problems, including refractive error, and decreased exercise and increased sedentary behavior would be an important factor in identifying children at risk for becoming overweight. Treatable vision problems in children are common, with a prevalence of 13%-23%.[14-16] Commonly encountered problems in 9-year-olds include refractive errors; in Western Europe, 15%-20% of children have refractive error,[17,18] including hyperopia, which decreases into adolescence,[19] myopia, which increases,[16,17] and astigmatism.[15] There is significant geographic variation; in particular, rates of myopia are epidemic in East and Southeast Asia.[7] Accurate epidemiologic estimates of refractive error are compounded by inconsistent threshold measurements used in different countries.[20] Other problems seen less commonly include amblyopia, affecting 1%-5%,[21-24] retinal pathology, and other causes.[25]

In Ireland, screening for eye and vision problems in children begins by examination for red reflex in neonates, followed by vision testing in early primary school at age 4 or 5.[26] Recently in 2016, a further vision test of children at exit from primary school at age 11 or 12 was discontinued.[27] Data describing the commonly diagnosed eye conditions in children in Ireland is lacking; in Northern Ireland the prevalence of myopia < -0.50 DS is 18% and of hyperopia $> +2.00$ DS is 15% at 12 years old.[18]

In this study, we sought to examine whether associations exist between vision problems, including refractive error, and exercise, or sedentary behavior, in a large, well-characterized, and nationally representative cohort of 9-year-olds. Secondary aims were to examine if there was any evidence of association between vision problems and adiposity in this cohort.

Subjects and Methods

Data from the Growing Up in Ireland (GUI) study, the longitudinal study of 9-year-old children in Ireland, was used for the analysis. This is a nationally representative cohort selected through the primary school network: a random sample of schools was drawn and, subject to the school's participation, age-eligible children and their families were invited to participate in the study (invitation was weighted to ensure representativeness). Ethical approval was received from the Research Ethics Committee of the Department of Children and Youth Affairs of the Government of the Republic of Ireland. Data were collected under the Statistics Act of 1993. Data collection was completed in the 2007-2008 school year. After written informed consent was obtained from the primary care giver and from the study child, interviews with families were carried out by trained interviewers using a detailed questionnaire.[28] Details of the methodology of the data collection have been described elsewhere.[29,30] At the school level, a response rate of 82% was achieved, while at the household level (ie, eligible child selected within the school), 57% of children and their parents participated in the study.

Outcome Variables

Outcome variables of interest were levels of exercise and sedentary behavior, and body mass index (BMI). Exercise levels were derived from sports participation and physical activity frequency, taken from the child's response to the following questions, respectively: "How often do you play sport?" and "How often do you take exercise (eg, running, cycling, swimming) for 20 minutes or more?" The response options to both questions were "Never," "1-2 times a week," "3-4 times a week," and "Almost every day." The frequency of both physical activity and sport participation were added, and combined as a continuous single outcome variable—*exercise*—that was used in the analysis. Sedentary behavior was captured by the child's self-reported number of hours daily after school in a usual week spent watching television, reading for pleasure, using a computer, and playing video games.[29] BMI was calculated from height and weight measurements taken by the interviewers. Overweight was defined according to International Obesity Task Force (IOTF) cut-off points[31] as BMI of ≥19.46 for boys and ≥19.45 for girls. Obesity was defined as a BMI ≥23.38 for boys and ≥23.46 for girls.

Vision Problems

To detect the presence of a vision problem or refractive error, the primary care giver (usually the mother) was asked whether the study child currently had "any sort of sight problem requiring correction?" If yes, the question was followed by "Has the Study Child ever been given any treatment for the problem? If so, what?" Response options were as follows: treatment with glasses, patch, surgery, laser treatment, other, or no treatment.

Information on other covariates that are commonly considered in this context was extracted, including child demographic,[32] medical and behavioral variables, maternal,[32,33] socioeconomic,[32] and neighborhood variables.[34,35] These were used in adjusted analyses. The child variables included were sex and place of birth, in Ireland or elsewhere, presence of a chronic illness, and membership of a sports or fitness club. Parental factors assessed were maternal BMI (also measured at time of interview, with BMI <25 defined as normal or underweight, 25-29.9 as overweight, and ≥30 defined as obese); maternal education level (none or primary level through secondary level, to post-school qualifications, degrees, and postgraduate-level education); and primary and secondary caregiver's occupation(s) currently or previously, with the higher category of each used to derive the socioeconomic status (coded as professional managers, managerial and technical, nonmanual, skilled manual, semiskilled, unskilled, or unknown). The neighborhood factors included whether there were appropriate recreational facilities for a 9-year-old in the local area and whether the home was in a rural or urban location.

Statistical Analysis

Data was assessed for normality prior to application of statistics tests. To test for the association of vision problems and sedentary behavior, exercise, and BMI, unadjusted logistic regression was first carried out, followed by adjusted multivariate logistic regression controlling for variables mentioned above. In the analysis for association of vision problems with exercise, the multivariate analysis excluded participation in a sports club. A stratified analysis was also conducted for BMI, to test the association of vision problems with BMI at different levels of sedentary behavior and exercise. For descriptive purposes, variables displayed in tables were included in t test and χ^2 tests to test for the association of continuous and categorical variables respectively with presence of a vision problem. Collinearity of independent covariates was assessed using variance inflation factors (VIF, reference value of 4), before interpreting the final output; there was no evidence for collinearity. Statistical analysis was carried out using R version 3.2.4 (https://www.r-project.org/).

Results

Of the 8,568 children (mean age, 9 ± 0.13 years; 4,024 males [48.68%]), there were 1,000 children (11.68%) with a reported vision problem (Table 1). The majority of children (5,927 [75.31%]) were normal weight; of the

Table 1. Presence of a vision problem and markers of sedentary behavior, exercise, and weight status

Study parameter (no. missing)	All, no. (%) (N = 8568)	Vision problem, no. (%)		P value[a]
		Present (N = 1000)	Not present (N = 7565)	
Sex, male (302)	4024 (48.68)	456 (47.35)	3566 (48.84)	0.4
Weight status[b] (698)				
Normal	5927 (75.31)	664 (72.02)	5262 (75.76)	<0.00001
Overweight	1497 (19.02%)	198 (21.48)	1298 (18.69)	
Obese	446 (5.67)	60 (6.51)	386 (5.56)	
Maternal weight[c] (332)				
Normal/underweight	4602 (55.88)	524 (54.64)	4077 (56.04)	<0.00001
Overweight	2450 (29.75)	287 (29.93)	2162 (29.72)	
Obese	1184 (15.04)	148 (15.43)	1036 (14.24)	
Maternal education				
None, primary, or lower secondary	1510 (17.62)	192 (19.2)	1317 (17.41)	<0.00001
Higher secondary or vocational/technical	2698 (31.49)	318 (31.8)	2379 (31.44)	
Non-degree	2123 (24.78)	230 (23)	1892 (25.01)	
Degree or postgraduate	2237 (26.11)	260 (26)	1977 (26.13)	
Socioeconomic status (458)				
Professional/manager	1172 (14.45)	136 (14.51)	1035 (14.43)	<0.00001
Managerial/technical	3317 (40.90)	358 (38.21)	2959 (41.26)	
Nonmanual/skilled manual	2882 (35.54)	350 (37.35)	2531 (35.29)	
Semiskilled/unskilled	739 (9.11)	93 (9.93)	646 (9.01)	
Exercise: physical activity and sport, times per week (50)				
<5	1026 (12.05)	124 (12.5)	902 (11.99)	<0.00001
5	1126 (13.22)	135 (13.61)	989 (13.15)	
6-7	3639 (42.72)	449 (45.26)	3190 (42.40)	
≥8	2727 (32.01)	284 (28.63)	2442 (32.46)	
Sedentary behavior, hours per day (6)				
<8	1856 (21.67)	199 (19.92)	1656 (21.90)	<0.00001
8-9	4300 (50.22)	477 (47.77)	3822 (50.55)	
10	1322 (15.44)	161 (16.11)	1161 (15.36)	
≥11	1084 (12.66)	162 (16.22)	922 (12.19)	

[a]Each variable tested for association with presence of a vision problem: χ^2 test for categorical data; *t* test for continuous data.
[b]Child overweight was defined as body mass index (BMI) of ≥19.46 for boys and ≥19.45 for girls; obesity, as a BMI of ≥23.38 for boys and ≥23.46 for girls.
[c]Maternal normal or underweight was defined as BMI of <25, overweight as BMI ≥25 and < 30; obese, as BMI ≥30.

remainder, 1,497 (19.02%) were overweight and 446 (5.67%) were obese. In children with vision problems or refractive error, the rates of overweight and obesity trended toward being significantly higher compared to those with no vision problem (21.48% vs 18.69% and 6.51% vs 5.56%, resp. [$P = 0.05$]).

Sedentary behavior was positively associated and exercise negatively associated with the presence of a vision problem or refractive error on adjusted analysis ($P = 0.001$ and $P = 0.01$ resp.) See Table 2. Spending ≥11 hours per day at sedentary activities before or after school on a usual weekday was reported in 1,084 (12.66%) overall; this was higher among those with a vision problem (16.22% [$P = 0.00089$]) compared to 12.19% in those without. Overall, 2,727 children (32.01%) reported exercise frequency of 8 or more times per week; this was lower (28.63%) among those with a vision problem, compared to 32.46% among those without.

On unadjusted analysis, BMI was associated with presence of a vision problem ($P = 0.04$); however, this association was no longer significant on adjustment for covariates ($\beta = 0.08596$; $P = 0.40959$). On stratified analysis among children according to level of sedentary behavior, the positive association of vision problems with BMI was found at the highest levels of sedentary behavior (≥11 hours of sedentary activities outside school/day; $\beta = 0.6022$; $P = 0.035$), whereas the association was not detected at

Table 2. Association of presence of vision problem and sedentary behavior, exercise, and body mass index (BMI) after adjustment for relevant covariates

Covariate		Adjusted analysis	
		β coefficient	P value
Sedentary behavior[a]	Hours of sedentary activity on typical weekday	0.20383	0.0009
Exercise[b]	Frequency of sports and physical activities per week	−0.130453	0.01
BMI[c]	Overall	0.08596	0.4

[a]Adjusted for child sex, BMI, presence of chronic medical illness, place of birth in Ireland, membership of a sports or fitness club, maternal education level, maternal BMI, socioeconomic status of household, urban type neighborhood, and presence of good recreational facilities locally.
[b]Adjusted for variables listed above, excluding membership of a sports or fitness club.
[c]Adjusted for variables listed above, excluding BMI.

lower levels of sedentary behavior (<11 hours per day of sedentary activities). See Table 3. Although nonsignificant, a similar trend was observed in adjusted analysis ($\beta = 0.52494$; $P = 0.09$). On stratified analysis according to exercise, there was no association of BMI.

Other covariates that showed a significant positive association with markers of sedentary behavior on adjusted analysis included male sex, higher BMI, higher maternal BMI, and urban-type neighborhood, and an inverse association was observed with higher maternal education and child membership of a sports club (eSupplement 1, available at jaapos.org). Association of exercise was observed with male sex, place of birth in Ireland, and good local recreational facilities, and an inverse association was found with study child BMI, presence of medical illness, and urban-type neighborhood (eSupplement 2, available at jaapos.org). Positive association with higher child BMI was observed with socioeconomic status and maternal BMI, and inverse association was present with male sex, reported good recreational facilities locally, and higher maternal education (Supplement 3, available at jaapos.org). At highest sedentary behavior, sports, and PA levels, the association of BMI with other covariates did not increase in significance as was observed with vision problems or refractive error (eSupplements 4 and 5, available at jaapos.org).

Discussion

We found that children with vision problems or refractive error spent significantly more time engaged in sedentary activities and significantly less time engaged in exercise. Overall, there was no association between vision problems and BMI; however, an association between vision problems or refractive error and BMI was observed in children at the highest levels of sedentary behavior. The most inactive children in particular were at risk of being more overweight in the presence of a vision problem. Examination of the direction of causality between vision and physical activity was outside the scope of this study; however, there are several possible causes behind the association we found. Presence of a vision problem or refractive error may be associated with other behaviors, including less sports participation, which increases the likelihood of overweight. This subgroup of children who carry out the most sedentary behavior would already be at greater risk of overweight.

Vision problems are not typically thought of as determinants of physical activity or sedentary behavior. Analyses that have examined population level characteristics associated with inactivity and overweight in children have not previously assessed vision problems in general as correlates, to our knowledge.[36,37]

Small cohort studies suggest an association of vision problems with overweight and reduced physical activity; reported prevalence of obesity in children with either auditory or uncorrectable vision problems is 18.4% in the United States[38]; in children and adolescents who are blind or visually impaired, reported activity levels are low.[1,39] The rise in incidence of myopia in children has been investigated in recent years,[40] and length of time spent indoors, associated with less activity and more sedentary behavior, appears to be the most important risk factor.[41,42] Equally, increased time spent outdoors has been found to be associated with less myopia development in children.[43] In Singapore, which has the highest rate of childhood myopia worldwide at 43.4% of 9-year-olds,[44] the Health Promotion Board provides parents with advice to increase their time spent at sports and exercise to reduce the risk of myopia developing and worsening.[45]

Vision problems may reduce the ability to participate in physical activity and/or sports by affecting balance, confidence, and depth perception. In children who require spectacles and wear them versus children who do not require spectacles, there are increased injuries when playing sports.[46] Corrected refractive error versus normal vision without refractive error is associated with less depth perception and peripheral vision among adolescent athletes,[47] which may contribute to our observed association. Children who wear spectacles may also be less likely to participate in group sporting activities, as they are more likely to be bullied than their peers.[48] Spectacle wear is modifiable; contact lenses[18] versus spectacles have been found to increase physical activity participation and confidence in children and adolescents,[49,50] and the fitting of these lenses in children is not associated with increased adverse events, such as infection, compared with fitting contact lenses in older adolescents.[51]

It was not possible to determine the direction of the effect. Indeed, some evidence suggests that the relationship between vision problems and PA may be inverse: physical inactivity has been implicated in increasing prevalence of some vision problems, including in myopia, where time spent outdoors is protective.[52] Finally, it is possible that the relationship is bidirectional; if this is the case, need for early intervention is even more critical in order to break this vicious cycle.

Increasing physical activity may have beneficial effects for these children. Those who have vision impairments who are more active are less overweight.[8] Policymakers may need to consider reduction of sedentary behavior also as a goal, a strategy which has been found to reduce BMI in children,[53] which may provide a distinct focus from PA guidelines that are generally better known by parents and children than screen-time guidelines.[54] In Singapore, increased outdoor time is advocated to reduce myopia development.[52] In 2000, a review of eye services provided to children in Dublin and surrounding counties resulted in a recommendation for visual screening in children to be standardized and provided at three age points in primary school[55]; however, visual testing after initial screening in primary was dropped. Developing guidelines for and reinstating further screening may be beneficial.

We assessed vision problems and refractive error at the population level for the association with risk factors

Table 3. Association of presence of vision problem and body mass index (BMI) after adjustment for relevant covariates and stratified by physical activity or sedentary behavior levels

BMI stratified by sedentary activity and physical activity levels[a]	n (%)	Unadjusted analysis		Adjusted analysis	
		β coefficient	P value	β coefficient	P value
Physical activity or sport, times per week					
<5	1026 (12.05)	0.21	0.5	0.00	0.9
5	1126 (13.22)	0.23	0.4	0.12	0.7
6-7	3639 (42.72)	0.10	0.5	−0.10	0.5
≥8	2727 (32.01)	0.32	0.07	0.28	0.1
Sedentary behavior, hours per day					
<8	1856 (21.67)	0.02	0.9	−0.27	0.2
8-9	4300 (50.22)	0.13	0.4	0.08	0.6
10	1322 (15.44)	0.07	0.8	−0.03	0.9
≥11	1084 (12.66)	0.60	0.04	0.52	0.09

[a]Adjusted for sex, presence of chronic medical illness, place of birth in Ireland, membership of a sports or fitness club, maternal education level, maternal BMI, socioeconomic status of household, urban type neighborhood, and presence of good recreational facilities locally.

for increased adiposity in children; we confirmed an association with sedentary activities and an inverse association with physical activities. Strengths of the study include the large, nationally representative sample and the detailed information on markers for physical activity and sedentary behavior, with adjustment for relevant covariates. Sedentary behavior is an increasingly important public health issue, which is highlighted as an area that requires further research.[56] Limitations include the cross-sectional study design; a lack of information specifying exactly which vision problem the children had, how severe it was (including visual acuity), and for how long it was present; whether treatment for the vision problem was successful; and the patient-reported nature of the data. In assessing activity levels of children, we also lack of accelerometer data to verify sedentary behavior.

Overall, 9-year-old children with vision problems or refractive error in Ireland are more likely to spend more time at sedentary activities and less time at physical activities. Future studies are needed to examine what drives this association and to investigate whether the observed relationship is linked to particular visual problems. Children and their parents attending ophthalmology clinics may benefit from initiatives designed to encourage increasing physical and reducing sedentary activities to reduce their risk of both vision loss and overweight.

References

1. Aslan UB, Calik BB, Kitis A. The effect of gender and level of vision on the physical activity level of children and adolescents with visual impairment. Res Dev Disabil 2012;33:1799-804.
2. Bener A, Al-Mahdi HS, Vachhani PJ, Al-Nufal M, Ali AI. Do excessive internet use, television viewing and poor lifestyle habits affect low vision in school children? J Child Health Care 2010;14:375-85.
3. Pärssinen O, Kauppinen M, Viljanen A. The progression of myopia from its onset at age 8-12 to adulthood and the influence of heredity and external factors on myopic progression: a 23-year follow-up study. Acta Ophthalmol 2014;92:730-39.
4. Saxena R, Vashist P, Tandon R, et al. Prevalence of myopia and its risk factors in urban school children in Delhi: the North India Myopia Study (NIM Study). PLoS One 2015;10:e0117349.
5. Williams KM, Bertelsen G, Cumberland P, et al. European Eye Epidemiology (E(3)) Consortium. Increasing prevalence of myopia in Europe and the impact of education. Ophthalmology 2015;122:1489-97.
6. Vitale S, Sperduto RD, Ferris FL 3rd. Increased prevalence of myopia in the United States between 1971-1972 and 1999-2004. Arch Ophthalmol 2009;127:1632-9.
7. Morgan IG, Ohno-Matsui K, Saw SM. Myopia. Lancet 2012;379:1739-48.
8. Greguol M, Gobbi E, Carraro A. Physical activity practice, body image and visual impairment: a comparison between Brazilian and Italian children and adolescents. Res Dev Disabil 2014;35:21-6.
9. World Health Organization. World Health Statistics 2014, https://www.who.int/gho/publications/world_health_statistics/2014/en/. Accessed April 2, 2018.
10. Yang Z, Huffman SL. Nutrition in pregnancy and early childhood and associations with obesity in developing countries. Matern Child Nutr 2013;9(Suppl 1):105-19.
11. Ahrens W, Pigeot I, Pohlabeln H, et al. IDEFIS consortium. Prevalence of overweight and obesity in European children below the age of 10. Int J Obes (Lond) 2014;38(Suppl 2):S99-107.
12. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of childhood and adult obesity in the United States, 2011-2012. JAMA 2014;311:806-14.
13. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of obesity and trends in body mass index among US children and adolescents, 1999-2010. JAMA 2012;307:483-90.
14. Donnelly UM, Stewart NM, Hollinger M. Prevalence and outcomes of childhood visual disorders. Ophthalmic Epidemiol 2005;12:243-50.
15. Hashemi H, Yekta A, Jafarzadehpur E, et al. High prevalence of refractive errors in 7 year old children in Iran. Iran J Public Health 2016;45:194-202.
16. McCullough SJ, O'Donoghue L, Saunders KJ. Six year refractive change among white children and young adults: Evidence for significant increase in myopia among white UK children. PLoS One 2016;11:e0146332.
17. Sapkota YD, Adhikari BN, Pokharel GP, Poudyal BK, Ellwein LB. The prevalence of visual impairment in school children of upper-middle socioeconomic status in Kathmandu. Ophthalmic Epidemiol 2008;15:17-23.
18. O'Donoghue L, McClelland JF, Logan NS, Rudnicka AR, Owen CG, Saunders KJ. Refractive error and visual impairment in school children in Northern Ireland. Br J Ophthalmol 2010;94:1155-9.
19. Hirsch MJWF. Prevalence of refractive anomalies. In: Grosvenor T, Flom MC, eds. Refractive Anomalies: Research and Clinical Applications. Boston: Butterworth-Heinemann; 1991:15-38.

20. Organisation WH. Elimination of avoidable visual disability due to refractive errors: report of an informal planning meeting, Geneva, 3-5 July 2000. Geneva; 2000.
21. Attebo K, Mitchell P, Cumming R, Smith W, Jolly N, Sparkes R. Prevalence and causes of amblyopia in an adult population. Ophthalmology 1998;105:154-9.
22. Chia A, Lin X, Dirani M, et al. Risk factors for strabismus and amblyopia in young Singapore Chinese children. Ophthalmic Epidemiol 2013;20:138-47.
23. Friedman DS, Repka MX, Katz J, et al. Prevalence of amblyopia and strabismus in white and African American children aged 6 through 71 months the Baltimore Pediatric Eye Disease Study. Ophthalmology 2009;116:2128-2134.e1-2.
24. Pai AS, Wang JJ, Samarawickrama C, et al. Prevalence and risk factors for visual impairment in preschool children the sydney paediatric eye disease study. Ophthalmology 2011;118:1495-500.
25. Goggin M, O'Keefe M. Childhood blindness in the Republic of Ireland: a national survey. Br J Ophthalmol 1991;75:425-9.
26. HSE. Hearing and vision tests for children. HSE, https://www.hse.ie/eng/health/az/h/hearing-and-vision-tests-for-children/. Accessed April 2, 2018.
27. Cullen P. HSE ends routine eye screening for fifth and sixth class pupils. Irish Times; 2016. May 9.
28. Questionnaires for Wave 1 of the Nine-Year Cohort of Growing Up In Ireland. 2010. http://www.ucd.ie/issda/static/documentation/esri/GUI-Questionnaire9YearCohort.pdf. Accessed April 2, 2018.
29. Williams JGS, Doyle E, Harris E, Layte R, McCoy S, et al. The Lives of 9-Year-Olds. Report 1. In: Affairs OotmfCaY; 2009. Dublin.
30. Williams JGS, Doyle E, Harris E, et al. Growing up in Ireland: national longitudinal study of children: the lives of 9-year-olds. Dublin: Office of the Minister for Children and Youth Affairs, 2009; 2009.
31. Shields M, Tremblay MS. Canadian childhood obesity estimates based on WHO, IOTF and CDC cut-points. Int J Pediatr Obes 2010;5:265-73.
32. Keane E, Layte R, Harrington J, Kearney PM, Perry IJ. Measured parental weight status and familial socio-economic status correlates with childhood overweight and obesity at age 9. PLoS One 2012;7:e43503.
33. Sijtsma A, Sauer PJ, Corpeleijn E. Parental correlations of physical activity and body mass index in young children–he GECKO Drenthe cohort. Int J Behav Nutr Phys Act 2015;12:132.
34. Cohen DA, Ashwood JS, Scott MM, et al. Public parks and physical activity among adolescent girls. Pediatrics 2006;118:e1381-9.
35. Roemmich JN, Epstein LH, Raja S, Yin L. The neighborhood and home environments: disparate relationships with physical activity and sedentary behaviors in youth. Ann Behav Med 2007;33:29-38.
36. Bauman AE, Reis RS, Sallis JF, Wells JC, Loos RJ, Martin BW. Lancet Physical Activity Series Working Group. Correlates of physical activity: why are some people physically active and others not? Lancet 2012;380:258-71.
37. Gomes TN, dos Santos FK, Zhu W, Eisenmann J, Maia JA. Multilevel analyses of school and children's characteristics associated with physical activity. J Sch Health 2014;84:668-76.
38. Chen AY, Kim SE, Houtrow AJ, Newacheck PW. Prevalence of obesity among children with chronic conditions. Obesity (Silver Spring) 2010;18:210-13.
39. Greguol M, Gobbi E, Carraro A. Physical activity practice among children and adolescents with visual impairment—influence of parental support and perceived barriers. Disabil Rehabil 2015;37:327-30.
40. Dolgin E. The myopia boom. Nature 2015;519:276-8.
41. Jones LA, Sinnott LT, Mutti DO, Mitchell GL, Moeschberger ML, Zadnik K. Parental history of myopia, sports and outdoor activities, and future myopia. Invest Ophthalmol Vis Sci 2007;48:3524-32.
42. Rose KA, Morgan IG, Ip J, et al. Outdoor activity reduces the prevalence of myopia in children. Ophthalmology 2008;115:1279-85.
43. Dirani M, Tong L, Gazzard G, et al. Outdoor activity and myopia in Singapore teenage children. Br J Ophthalmol 2009;93:997-1000.
44. Tan DT. The future is near: focus on myopia. Singapore Med J 2004;45:451-5.
45. Board HP. Childhood myopia - the role of parents. 2016. http://www.healthhub.sg/live-healthy/143/childhood_myopia_parents_role. Accessed August 21, 2016.
46. Sundblad G, Saartok T, Engström LM, Renström P. Injuries during physical activity in school children. Scand J Med Sci Sports 2005;15:313-23.
47. Chang ST, Liu YH, Lee JS, See LC. Comparing sports vision among three groups of soft tennis adolescent athletes: Normal vision, refractive errors with and without correction. Indian J Ophthalmol 2015;63:716-21.
48. Horwood J, Waylen A, Herrick D, Williams C, Wolke D. Common visual defects and peer victimization in children. Invest Ophthalmol Vis Sci 2005;46:1177-81.
49. Plowright AJ, Maldonado-Codina C, Howarth GF, Kern J, Morgan PB. Daily disposable contact lenses versus spectacles in teenagers. Optom Vis Sci 2015;92:44-52.
50. Walline JJ, Gaume A, Jones LA, et al. Benefits of contact lens wear for children and teens. Eye Contact Lens 2007;33:317-21.
51. Walline JJ, Lorenz KO, Nichols JJ. Long-term contact lens wear of children and teens. Eye Contact Lens 2013;39:283-9.
52. He M, Xiang F, Zeng Y, et al. Effect of time spent outdoors at school on the development of myopia among children in China: A randomized clinical trial. JAMA 2015;314:1142-8.
53. Azevedo LB, Ling J, Soos I, Robalino S, Ells L. The effectiveness of sedentary behaviour interventions for reducing body mass index in children and adolescents: systematic review and meta-analysis. Obes Rev 2016;17:623-35.
54. LeBlanc A. Why are children sedentary: an examination using the International Study of Childhood Obesity, Lifestyle and the Environment. Appl Physiol Nutr Metab 2016;41:790.
55. Eastern Regional Health Authority. Development of Ophthalmic Services for Children in Dublin, Kildare and Wicklow. 2000. http://hdl.handle.net/10147/46615. Accessed April 4, 2018.
56. Arundell L, Fletcher E, Salmon J, Veitch J, Hinkley T. The correlates of after-school sedentary behavior among children aged 5-18 years: a systematic review. BMC Public Health 2016;16:58.