

Effects of screen time on preschool health and development

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Authors

Dr Tom Stewart, Auckland University of Technology
Associate Professor Scott Duncan, Auckland University of Technology
Dr Caroline Walker, University of Auckland
Dr Sarah Berry, University of Auckland
Professor Grant Schofield, Auckland University of Technology

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Disclaimer

The views and interpretations in this report are those of the researcher and are not the official position of the Ministry of Social Development.

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Explanation of terms and abbreviations

Screen exposure: Time a television is on in the same room as the child, whether they are watching or not.

Electronic media use: Time spent using a computer, laptop, tablet, smart phone, or any electronic gaming device.

Total screen time: Combined time spent watching television and/or using electronic media.

BMI: Body Mass Index

SDQ: Strengths and Difficulties Questionnaire

CI: Confidence Interval

Policy summary

"These findings represent the first evidence that adhering to the current screen time guidelines are linked to better health profiles in New Zealand children."

We are currently in the midst of a digital revolution. There is little doubt that New Zealand children have greater availability to personal screen-based devices than ever before. However, we also know that excessive use of screen-based devices in children can increase the likelihood of several adverse health and behavioural outcomes, such as obesity, short attention span, emotional problems, language difficulties, and poor sleep patterns. The 'new normal' of abundant access to personal electronic devices has made this area of policy particularly relevant and important for the healthy development of kiwi children.

In 2017, the Ministry of Health responded to the widespread concern about excessive screen exposure in our preschool children by releasing the first national screen time guidelines for under-fives: no sedentary screen time for children younger than two years and less than one hour each day for children aged between two and five years. These new screen time recommendations were guided by a technical advisory group that was chaired by A/Prof Duncan (principal investigator in the present study). Throughout this process, it was clear that any recommendations relating to screen time in preschoolers are currently limited by the rapidly-changing nature of screen usage in children, and limited research on how screen habits in young New Zealanders affect their development over time. This analysis provides further evidence on the importance of reducing screen time, and how the Government needs to prioritise this area for the healthy development of its children.

In this project, we have showed that the duration of screen use tends to increase as preschoolers age, with the largest proportional increases in electronic media use (eg computers, tablets, smart phones, gaming devices). NZ European ethnicity, lower socioeconomic deprivation, enforcing household screen time rules, and fewer televisions in the household were consistently associated with meeting the screen time guidelines at each time point. Children that did not adhere to the screen time guidelines at 24 months of age were more likely to be obese, have more illnesses, more visits to the doctor, lower physical motor skills, and exhibit hyperactivity problems at 54 months, which persisted when adjusted for ethnicity, sex, socioeconomic deprivation, and baseline (24-month) values.

These findings represent the first evidence that adhering to current screen time guidelines are linked to better health profiles in New Zealand children. This evidence helps address the wellbeing of all children – a key focus of the Government's Child Wellbeing Strategy. The next step is to examine how screen time patterns affect ongoing child health and development; fortunately, the Growing Up in NZ study will collect the data necessary for such analyses. Ongoing monitoring of the effects of personal screen-based devices will ensure that parents, health professionals, and educators will have the appropriate policy guidance to determine what level of screen time is acceptable for children.

Executive summary

The rapid proliferation of personal technology has provided our children with unprecedented access to screen-based devices for both educational and entertainment purposes. However, international research suggests that the excessive use of screen-based devices in children can increase the likelihood of several adverse health and behavioural outcomes, such as obesity, short attention span, emotional problems, language difficulties, and poor sleep patterns. As a consequence, the Ministry of Health has released guidelines stating that children aged 2-5 years should limit screen time to less than one hour per day, a target that was based largely on overseas evidence. It is therefore essential that the appropriateness of current guidelines for the promotion of healthy development in New Zealand preschoolers is investigated.

This research had three main aims: 1) to investigate the temporal trends in the duration and type of screen usage between 2 years and 4.5 years of age; 2) to examine the cross-sectional associations of screen time; and 3) to determine prospective associations between screen usage at 2 years of age and a range of health and behavioural outcomes at 4.5 years of age. The project utilised data collected in the Growing Up in New Zealand study – a contemporary longitudinal study that comprises data from approximately 6,000 children in the Auckland, Counties Manukau, and Waikato District Health Board regions. All screen time variables were assessed via parent-proxy report, and included television viewing time, electronic media use (eg tablets, smart phones, gaming devices, computers), and screen exposure (ie TV on in the same room as the child); a fourth measure of total screen time was also calculated. The health and behavioural outcome measures included body mass index, perceived body size, motor skills, general health, doctor visits, illnesses, accidents, emotional symptoms, hyperactivity, peer problems, and prosocial behaviour.

Results indicate that the temporal pattern of screen use tended to increase between 24 and 54 months, but varied by screen use type. NZ European ethnicity, lower socioeconomic deprivation, having household screen time rules, and fewer televisions in the household were consistently associated with meeting the screen time guidelines at each time point. Interestingly, families that had screen time rules but did not always enforce them were more likely to exceed the guidelines compared with having no rules at all. Children that did not adhere to the screen time guidelines at 24 months of age were more likely to be obese, have more illnesses, more visits to the doctor, lower physical motor skills, and exhibit hyperactivity problems at 54 months, which persisted when adjusted for ethnicity, sex, socioeconomic deprivation, and the corresponding health outcome at 24-month baseline. These findings provide insight into contemporary trends in preschooler screen use and longitudinal health and wellbeing in New Zealand, supporting the ongoing implementation of screen time guidelines.

Introduction

It is well-established that regular physical activity and time spent outdoors is beneficial for the physical, behavioural, and social development of young children (LeBlanc et al., 2012; Timmons et al., 2012). Counter to this, excessive time spent sedentary and using screen-based devices increases the likelihood of several adverse outcomes, such as obesity, emotional and attention problems, and impaired psychosocial health (Poitras et al., 2017). While most of this evidence is based on observational studies, a small number of interventions to reduce screen use are generally supportive of a causal effect (Wu, Sun, He, & Jiang, 2016). However, the causal pathways of these associations (eg diet quality, social interaction, physical activity) are less understood. It is known that physical activity and screen time behaviours established during early childhood are likely to track over time (Biddle, Pearson, Ross, & Braithwaite, 2010), so it is imperative that children develop healthy behaviour patterns early to set them on a trajectory towards good health and wellbeing throughout life. Governments in several countries, including Canada (Tremblay et al., 2017), Australia (Okely et al., 2017), USA (American Academy of Pediatrics, 2016), and New Zealand (Ministry of Health, 2017b), have developed national screen time guidelines for young children. The Active Play Guidelines for Under-fives (Ministry of Health, 2017b) – published by the Ministry of Health in 2017 – recommend no sedentary screen time for children younger than two years and less than one hour each day for children aged between two and five years. However, the vast majority of national and international data relating to screen time is based solely on television watching, and does not take into account the recent proliferation of computers or portable devices, such as tablets and smartphones. The rapidly changing digital environment surrounding the current generation of preschool children threatens the validity of existing knowledge and recommendations.

Despite the formation of national guidelines, many young children are still exposed to several hours of screen time per day. The 2016/2017 New Zealand Health Survey found that 38 % of children aged 2 to 4 years (inclusive) watched two or more hours of television every day (Ministry of Health, 2017a), yet it does appear that television viewing has been steadily declining since 2011. However, a new question introduced into the 2016/2017 New Zealand Health Survey assessed 'screen watching' rather than television use. This showed a staggering 67.2% of children aged 2– 4 years watched more than 2 hours of screen time per day (which is over the recommended screen time viewing guidelines for over fives) (Ministry of Health, 2017a). International studies examining the correlates of screen use suggest that child age (older children), ethnicity (minority groups), and child body size are commonly associated with higher screen use among preschool children (Carson & Kuzik, 2017; Duch, Fisher, Ensari, & Harrington, 2013; Hinkley, Salmon, Okely, & Trost, 2010). Parents can also influence their child's screen use patterns through modelling

(Lauricella, Wartella, & Rideout, 2015), and provision of the social (eg household screen time rules) and physical environments (eg availability of electronic devices) in the home (Salmon, Timperio, Telford, Carver, & Crawford, 2005). The New Zealand Health Survey showed that Māori and Pacific children aged 2 – 14 years were more likely to have two or more hours of screen use each day compared with children of other ethnicities, as were children living in the most socioeconomically deprived areas (Ministry of Health, 2015, 2017a). However, these statistics focus only on television viewing and may underestimate the total time spent in screen-based entertainment (Hinkley, Salmon, Okely, Crawford, & Hesketh, 2012), which was confirmed in the 2016/2017 New Zealand Health Survey (Ministry of Health, 2017a). Importantly, different types of screen use may have distinct determinants and sociodemographic profiles, and are not necessarily predictive of each other (Andrade-Gómez, García-Esquinas, Ortola, Martínez-Gómez, & Rodríguez-Artalejo, 2017).

Although understanding the correlates of screen time is a vital step in the development of effective strategies to manage children's overall screen time, there is still no firm consensus on the appropriate amount of total screen time that should be endorsed. There is added complexity as the use of screens can be beneficial for early learning, and can help prepare children for starting school where screen-based learning is ubiquitous. Interactive media such as learn-to-read apps and electronic books may increase early literacy skills by providing practice with letters, phonics, and word recognition (Kucirkova, 2014). Nonetheless, excessive participation in noneducational screen time is linked with poor physical health, including overweight and obesity, poor cardiorespiratory fitness, and elevated blood pressure (Hancox, Milne, & Poulton, 2004; Reilly, 2008; Shea et al., 1994). These behaviours may also predict lower cognitive skills and educational attainment (Hancox, Milne, & Poulton, 2005; Pagani, Fitzpatrick, Barnett, & Dubow, 2010; Zimmerman & Christakis, 2005), as well as behavioural and emotional problems (aggression, anxiety, reduced prosocial behaviour, and attention problems) during later childhood (Cheng et al., 2010; Mistry, Minkovitz, Strobino, & Borzekowski, 2007; Swing, Gentile, Anderson, & Walsh, 2010). This is particularly concerning as behavioural difficulties in early childhood can persist into adolescence and adulthood, and can place children at an increased risk of developing adverse mental health outcomes later in life (Hofstra, Van Der Ende, & Verhulst, 2002).

Considering the rapid increase in personal screens available to the current generation of young children, it is important to not only investigate the correlates of overall screen time, but also the longer-term health impact of high screen usage. The aims of this project are to: (1) investigate the temporal trends in the duration and type of screen usage between 2 years and 4.5 years of age; (2) examine the cross-sectional associations of screen time; and (3) determine prospective associations between screen usage at 2 years of age and a range of health and behavioural outcomes at 4.5 years-of-age. The proposed

analysis will use Growing Up in New Zealand data collected at the 24-month, 45-month, and 54-month time points to describe contemporary screen usage trends in detail, and explore longitudinal pathways between screen usage and a range of health and wellbeing indicators. This information is critical if we are to understand how the next generation of digital natives are interacting with personal technology, how this interaction affects their long-term health and development, and if our current screen time guidelines are suitable for promoting health and wellbeing in young New Zealanders.

Methods

Datasets

The data used in this report were collected as part of the Growing Up in New Zealand study: a contemporary longitudinal study which aims to provide a population relevant view of what it is like to be a child growing up in New Zealand in the 21st century. A total of 6,822 pregnant women with an estimated delivery date between April 2009 and March 2010 were recruited from the Auckland, Counties Manukau, and Waikato District Health Board regions. The study's design, conceptual framework, and recruitment procedures are described in detail elsewhere (Morton et al., 2013; Morton et al., 2014). Five data collection waves were conducted within the first five years of study commencement. This project utilises data collected across three of these waves: face-to-face-interviews at 24 months (DCW2) and 54 months (DCW5), as well as a brief telephone interview at 45 months (DCW4).

Measures

Screen use

All screen time variables were assessed via parent-proxy report and were monitored across all three time points. The child's mother was asked to report her child's screen time at 24 months by answering the following questions:

Thinking about the last weekday (ie yesterday/last Friday) how many hours did your child spend at home...

1. *...watching all types of TV, DVDs, and videos?*
2. *...using a computer or laptop, including children's computer systems, such as Leapfrog?*
3. *...playing with an electronic gaming system?*
4. *...with the TV on in the same room as your child, whether or not he/she was watching it?*

At the 45 and 54-month time points there were subtle differences in question phrasing, and the questions related to computer use and electronic gaming were combined:

Thinking about a usual weekday, approximately how many hours does your child spend at home...

1. *...watching television programming including free-to-air, online, and pay TV or DVDs either on TV or other media?*
2. *...using electronic media eg computer or laptop, including children's computer system such as Leapfrog, iPad, tablets, smart phones and any electronic gaming devices?*

3. *...with the TV on in the same room as your child, whether or not he/she was watching it?*

These questions (or variants of) have been used in several preschool studies in the past, and have shown adequate internal consistency and test-retest reliability (Carson et al., 2017). The second and third questions at the 24-month time point, which refer to computer use and electronic gaming systems were combined to be comparable with the later time points. Although the screen time questions at 24 months referred to the *last* weekday while the 45-month and 54-month time points referred to a *usual* weekday, these questions were deemed comparable. Responses to these questions were used to derive three distinct types of screen use: television viewing time, electronic media use, and screen exposure (ie TV on in the same room). A fourth measure of total screen time was calculated by summing television viewing time and electronic media use. All screen time measures were converted to hours per day.

Screen time associations

The selection of potential screen time correlates was guided by existing literature on the correlates of child screen use (Duch et al., 2013). Although screen time was monitored at 45 months, many sociodemographic, health, and behaviour variables were only available at the 24-month and 54-month time points due to the brevity of the 45-month data collection wave.

Household screen use rules

At the 24-month and 54-month time points, information about screen time rules was collected, but these were also phrased differently. At 24 months, the mother was asked several yes/no questions:

Thinking about your household, are there rules about...

1. *...what TV programmes your child can watch?*
2. *...how many hours of TV, videos, and DVDs your child can watch?*
3. *...when your child watches TV?*

If the response to any of these questions was "yes", they were also asked "How often do you make sure your child follows the rules about TV use?". This was reported on a 5-point Likert scale: ('All of The Time', 'Most of The Time', 'About Half The Time', 'Less Than Half The Time', 'Never'). Only two questions were asked at the 54-month time point: "In your household are there rules for your child about the amount of computer, TV, or DVD time they are allowed?" and "If so, how often does someone in your household make sure that your child follows these rules?", which was answered on the same 5-point Likert scale stated above. At the 24-month time point, the number of televisions the family owned was also collected.

Sociodemographic factors

Socioeconomic status was assessed using the New Zealand Deprivation Index at both the 24-month (NZDep2006) and 54-month (NZDep2013) time points. This index is assessed at the meshblock level (smallest census tract unit) by combining census data relating to income, home ownership, employment, qualifications, family structure, housing, access to transport and communications. The score is organised into deciles, where decile one represents the lowest areas of deprivation, and decile 10 indicates the most deprived 10% of areas in New Zealand (Atkinson, Salmond, & Crampton, 2014; Salmond, Crampton, & Atkinson, 2007). The child's ethnicity (as reported by the mother at 54 months) was categorised as NZ European, NZ Māori, Pacific, Asian, MELAA (Middle Eastern, Latin American or African), or Other. Several other factors were assessed, including age, sex, whether the child lived in an urban or rural area (eg rurality), and the number of siblings living in the same household as the child.

Health and behavioural outcomes

Several health and behavioural outcomes were selected to determine the associations between screen usage at 2 years of age and health at 4.5 years of age. Health and behavioural outcomes were chosen if they were collected at both 24-month and 54-month time points, and thus allowed prospective examination while adjusting for 24-month baseline scores. Each health and behavioural outcome was measured the same across both time points unless indicated below.

Health outcomes

The child's body size, as perceived by their mother, was reported on a 5-point Likert scale: ('Very underweight', 'Somewhat underweight', 'Normal weight', 'Somewhat overweight', or 'Very overweight'). However, it is common for parents to underestimate their child's overweight or obese status (Lundahl, Kidwell, & Nelson, 2014). Therefore, we also used objectively measured height divided by squared weight to calculate Body Mass Index (BMI). Age and sex-adjusted BMI Z-scores (standard deviation scores) were computed using the World Health Organization growth charts (WHO Multicentre Growth Reference Study Group & de Onis, 2006). These scores express body size as the number of standard deviations (or Z-scores) above or below the mean or median value of the reference population. Absolute scores below 2 were classified as normal or underweight, those above 2 were classified as overweight, and those above 3 were classified as obese.

Several questions related to general health, illnesses, and accidents were used to derive several measures of overall health and wellbeing. The child's general health was reported by the mother on a 5-point Likert scale: ('Excellent', 'Very good', 'Good', 'Fair', 'Poor'). Doctor visits were defined as the number of times

within the last 12 months that the child visited a GP or family doctor. Illnesses the child had experienced was reported by the child's mother, and included measles, chicken pox, mumps, meningitis, whooping cough, rheumatic fever, scarlet fever, and other. These were summed to derive a total illness score. Lastly, the total number of accidents or injuries for which the child was taken to a doctor, health centre, hospital or dentist was reported by the mother. The timeframe for these accidents was since birth (at 24 months) or since the child was two years old (at 54 months).

Physical motor skills were assessed using a series of 11 questions related to the child's ability to perform different physical tasks (eg kicking a ball, hopping on one leg for 3 hops, balancing on one foot for 10 seconds). Slightly different questions were asked at the 24-month and 54-month time points to reflect common developmental changes across this period. At the 24-month time point, questions were answered on 3-point Likert scale: ('Not yet', 'Sometimes', 'Often'), while a 5-point scale was used at 54 months: ('Never', 'Rarely', 'Sometimes', 'Often', 'Always').

Behavioural outcomes

Child emotional and behavioural factors were assessed using the strengths and difficulties questionnaire (SDQ). This is a widely-used self-report inventory behavioural screening questionnaire with high validity and reliability (Goodman, 1997). The SDQ contains five subscales, measuring conduct problems, emotional symptoms, hyperactivity/inattention, peer relationship problems, and prosocial behaviour. Each scale contains five items scored from 0 to 2, giving a subscale range of 0 to 10 (several prosocial behaviour questions are reversed-scored). As this report focused on predictors of clinically relevant behavioural difficulties, each SDQ subscale was further categorised into normal, borderline, or abnormal using established thresholds previously used in New Zealand children (Goodman, 1997; Ministry of Health, 2018). Children who fall within this the abnormal band, generally, have serious behavioural difficulties.

The scores from all scales apart from prosocial behaviour can be summed to derive a total difficulties score, however, at the 54-month time point one question was missing from the SDQ questionnaire, which prevented derivation of a conduct problem score, and by extension a total difficulties score. Analysis by the Growing Up in New Zealand team showed that accounting for this missing item via imputation or pro rata upscaling may cause biased results for the conduct score (External Data Release 2017: Reference and Process User Guide). Therefore, the remaining four subscale scores were used for analysis.

Data Analysis

The data in this project were analysed in two phases to align with the project aims. The first part examined the temporal trends in type and amount of screen use, as well as cross-sectional associations. The second part of the analysis

focused on prospectively examining child health and behavioural outcomes at 54 months, given screen usage at 24 months. This analysis was restricted to singleton cases (ie removal of 132 twins or triplets) to avoid the complexity of nested data. All analyses were performed in R version 3.4.3 (R Foundation for Statistical Computing, Vienna, Austria).

Screen time associations and temporal trends

Prior to modelling, variables were reclassified in cases where there were a low number of responses in some categories. The ethnicity categories 'MELAA', 'New Zealander' and 'Other' were excluded due to small numbers. This resulted in a final sample size of 5,241 children.

In the first instance, total screen time (summation of television viewing time and electronic media use) was treated as binary outcome, indicative of whether each participant had less than or greater than or equal to 1 hour of total screen time per day. This criterion was chosen to align with the current screen time recommendation for preschoolers set by the New Zealand Ministry of Health (Ministry of Health, 2017b). Sociodemographic variables that were associated with meeting or not meeting the screen time guidelines were explored using logistic regression. This was performed using the *glm* function with a binomial distribution and logit link function. Initially, unadjusted models were fit whereby each explanatory variable was modelled independently, before fitting multivariable, fully adjusted models. Variables that met a cut-off of $p < 0.1$ in simple regression models at any time point were included in multivariable models. Cases that contained missing values were omitted from analysis. Odds ratios and 95% confidence intervals were calculated, and p -values < 0.05 were treated as statistically significant. This modelling process was performed for the 24-month and 54-month time points separately.

Temporal trends (across 24 months, 45 months, and 54 months) in the amount and type of screen use were examined with linear mixed models that optimized the restricted maximum likelihood criterion using the *lmer* function in the *lme4* package (Bates, Maechler, Bolker, & Walker, 2014). Each screen time variable (television viewing time, electronic media use, screen exposure, and total screen time) was treated as a dependant variable, and time point as a fixed effect. The correlation among participant's repeated measurements was accounted for by specifying subject as a random effect. A square root transformation was applied to dependant variables to preserve homoscedasticity and normality of residuals. For each time point, estimated means (back-transformed to the response scale) and 95% confidence intervals were obtained from the *lsmeans* package, and p -values for all pairwise contrasts between time points were adjusted for multiple comparisons using the Tukey method.

Total screen time at 24 months and health at 54 months

The second part of the analysis focused on prospectively examining whether total screen time at 24 months of age explained various health and behavioural outcomes at 54 months of age. As health and behavioural outcomes were predominantly measured by multi-category ordered response, this was achieved using proportional odds ordinal logistic regression (using the *polr* function in the *MASS* package (Ripley et al., 2013)). Total screen time at 24 months was treated as a binary explanatory variable (meeting or exceeding the screen time guidelines) to ease the interpretation of results. Models using total screen time as a continuous predictor (in hours) were also fit, and result tables are presented as an appendix. Firstly, partially adjusted models were fit for each health or behavioural outcome, which were adjusted for the corresponding health or behavioural outcome at 24-month baseline (Hinkley et al., 2014). A second set of models were fit which were further adjusted for child ethnicity, sex, and socioeconomic deprivation (Hinkley et al., 2014). As the *polr* function does not output p-values by default, these were computed for each coefficient by comparing the t-value against the standard normal distribution, which is reasonably approximated in large samples.

The assumption underlying ordinal regression is that the relationship between each pair of levels in the response variable are the same. For example, the coefficients that describe the relationship between the lowest versus all higher categories of the response variable are the same as those that describe the relationship between the next lowest category and all higher categories (and so on). This is called the proportional odds assumption, and is the reason why these models only produce one set of coefficients. This assumption was checked prior to modelling using the *Hmisc* package, by assessing the difference between predicted logits for different levels of each explanatory variable.

To aid interpretation, model coefficients and 95% confidence intervals were exponentiated to produce proportional odds ratios. These are interpreted as the odds of the highest category applying versus the other categories combined, given that the other variables in the model are held constant. All categorical outcome variables were ordered so the highest level of the response was the most unfavourable. For example, when modelling body size (normal weight, overweight, obese), the odds ratio for a binary screen time variable can be interpreted as the odds of being obese at 54 months (relative to overweight and normal) when the screen time guidelines are exceeded at 24 months. Similarly, this could also be interpreted as the odds of being obese or overweight at 54 months (relative to being normal weight) when the screen time guidelines are exceeded at 24 months.

Results

Screen time descriptive information

Table 1 shows screen time descriptive statistics for the 24-month, 45-month, and 54-month time points. The mean and median for each type of screen use are presented. In general, TV viewing time increased from the 24-to 45-month time point, but decreased at 54 months. Screen exposure decreased across all time points, while the use of electronic media increased. The mean total screen time ranged from 1.66 hours at 24 months to 2.14 hours at 54 months. The temporal changes in screen use are explored in a latter section below.

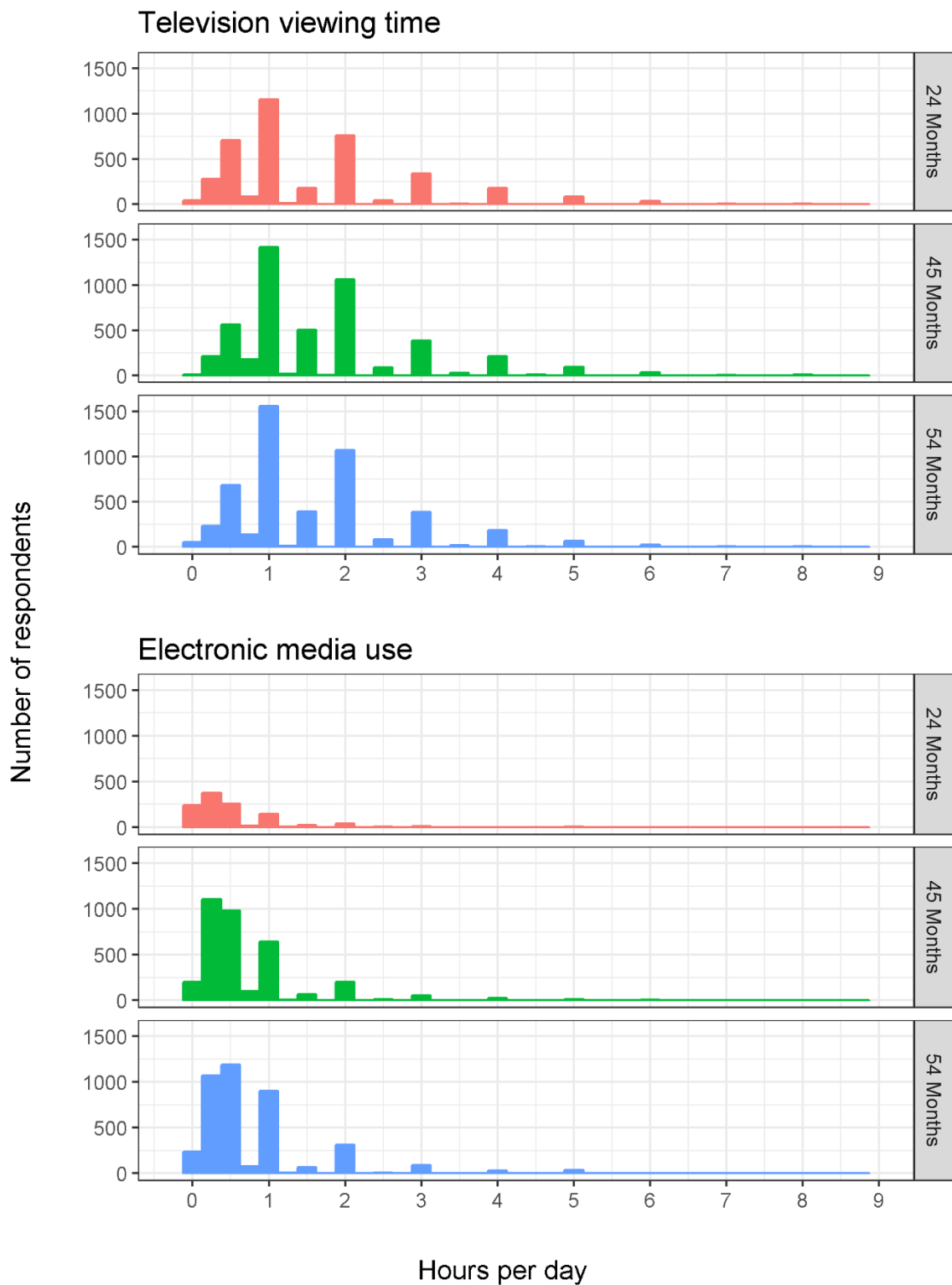
Table 1: Hours of screen use per day across all time points

		24-Months	45-Months	54-Months
TV viewing time	Mean	1.57 ± 1.31	1.67 ± 1.22	1.57 ± 1.18
	Median	1 (0.5, 2)	1.5 (1, 2)	1 (1, 2)
Electronic media	Mean	0.52 ± 0.78	0.72 ± 0.84	0.79 ± 0.79
	Median	0.25 (0.2, 0.5)	0.5 (0.25, 1)	0.5 (0.25, 1)
Screen exposure	Mean	2.97 ± 2.50	2.76 ± 2.08	2.62 ± 2.08
	Median	2 (1-4)	2 (1, 4)	2 (1, 4)
Total screen time	Mean	1.66 ± 1.44	2.13 ± 1.62	2.14 ± 1.61
	Median	1 (0.75, 2)	1.75 (1, 2.75)	1.75 (1, 3)

Means are presented as Mean ± SD. Medians are presented as Median (25th percentile, 75th percentile)

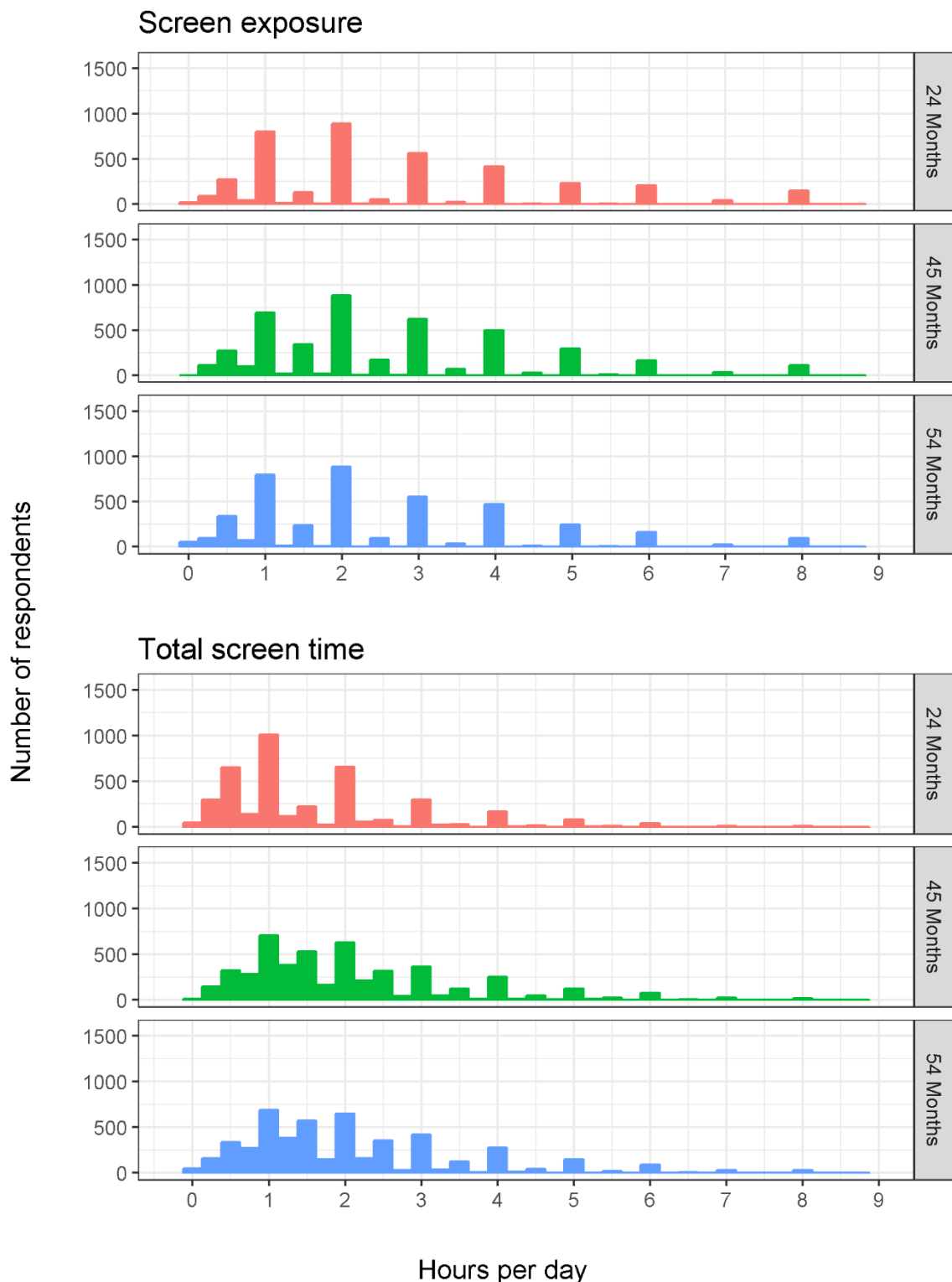
The distribution of reported television viewing time and electronic media use across all time points is presented in Figure 1. Responses are clustered around each hour, and to a lesser extent each 30-minute interval. Electronic media use at 24 months is also commonly reported as 15 minutes or 30 minutes per day. In general, the pattern of response is similar for the 45-month and 54-month time points, but differs at 24 months.

Figure 1: Distribution of TV viewing time and electronic media use for each time point



The distribution of reported screen exposure and total screen time across all time points is presented in Figure 2. Total screen time was less clustered around each 1-hour interval at the 45-month and 54-month time points compared with 24 months. As observed in the previous figure, the pattern of responses is similar for the 45-month and 54-month time points.

Figure 2: Distribution of screen exposure and total screen time for each time point



Screen time guideline adherence

The Active Play Guidelines for Under-fives (Ministry of Health, 2017b) suggest that children aged two years or older should limit total screen time to less than one hour per day. Table 2 presents the number and percentage of children (by sex and ethnicity) adhering to these recommendations. The proportion of children meeting these guidelines decreased from 44.4% at 24 months, to 18.4% at 54 months.

Table 2: Adherence to the screen time guidelines

		Met Guidelines	24-Months	45-Months	54-Months
Overall		Yes	2326 (44.4)	1044 (19.9)	963 (18.4)
		No	2915 (55.6)	4197 (80.1)	4278 (81.6)
Sex	Male	Yes	1158 (43.4)	508 (19.0)	465 (17.4)
		No	1512 (56.6)	2162 (81.0)	2205 (82.6)
	Female	Yes	1168 (45.4)	536 (20.9)	498 (19.4)
		No	1403 (54.6)	2035 (79.2)	2073 (80.6)
Ethnicity	NZ European	Yes	1521 (51.4)	671 (22.7)	670 (22.6)
		No	1438 (48.6)	2288 (77.3)	2289 (77.4)
	NZ Māori	Yes	285 (36.3)	120 (15.3)	75 (9.6)
		No	500 (63.7)	665 (84.7)	710 (90.5)
	Asian	Yes	263 (36.4)	133 (18.4)	118 (16.3)
		No	459 (63.6)	589 (81.6)	604 (83.7)
	Pacific	Yes	257 (33.2)	120 (15.5)	100 (12.9)
		No	518 (66.8)	655 (84.5)	675 (87.1)

Results presented as n (%).

Temporal trends in screen use

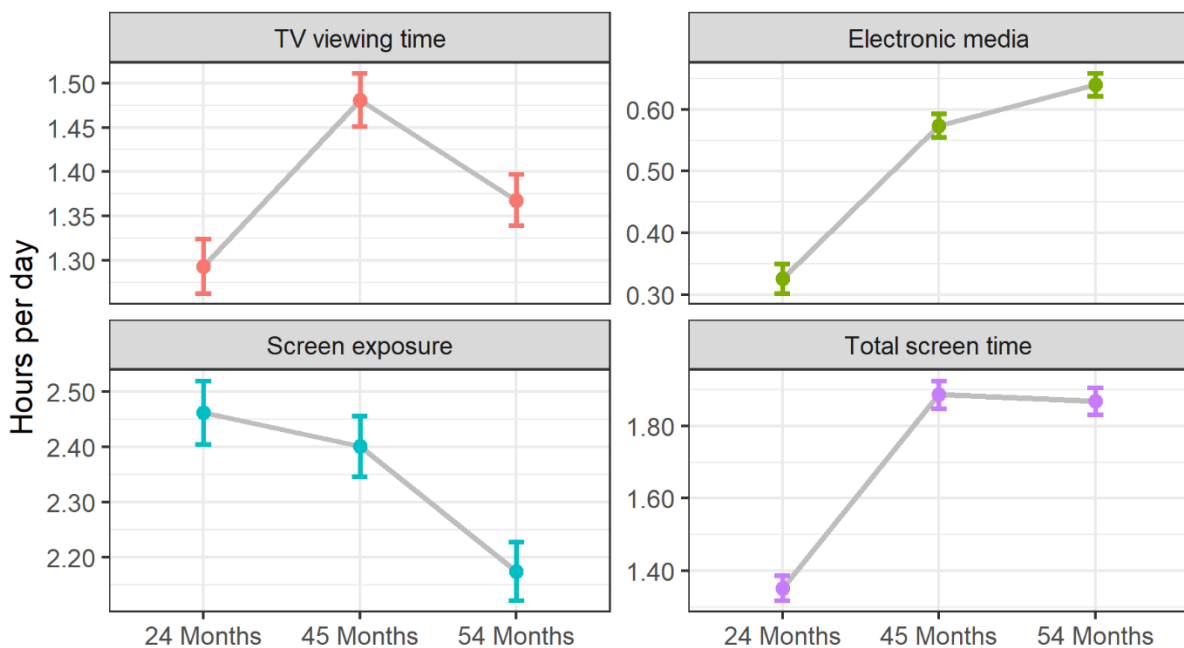
Temporal trends for each type of screen use are displayed in Figure 3. These are presented as estimated means and 95% CI obtained from mixed model analysis. Television viewing time increased from 1.29 hours (95% CI: 1.26, 1.32) at 24 months to 1.48 hours (95% CI: 1.45, 1.51) at 45 months, but then decreased to 1.37 hours (95% CI: 1.34, 1.40) at 54 months. All pairwise contrasts across time points were significant ($p < 0.001$).

Time spent using electronic media increased from 0.33 hours (95% CI: 0.30, 0.35) at 24 months to 0.57 hours (95% CI: 0.56, 0.59) at 45 months, and further increased to 0.64 hours (95% CI: 0.62, 0.66) at 54 months. All pairwise contrasts for electronic media use were significant ($p < 0.001$).

Screen exposure decreased from 2.46 hours (95% CI: 2.40, 2.52) at 24 months to 2.40 hours (95% CI: 2.35, 2.46) at 45 months; however, this was not a significant decline ($p = 0.135$). At 54 months, this decreased further to 2.17 hours (95% CI: 2.12, 2.23), which was significantly different from both previous time points (both $p < 0.001$).

Total screen time increased from 1.35 hours (95% CI: 1.32, 1.39) at 24 months to 1.89 hours (95% CI: 1.85, 1.93) at 45 months ($p < 0.001$). A slight decrease was observed at 54 months (1.87 hours, 95% CI: 1.83, 1.91) but was not significant ($p = 0.655$).

Figure 3: Temporal trends for amount and type of screen use



Note y-axis scale differs for each panel.

Cross-sectional screen time associations

Sociodemographic factors that were associated with meeting the screen time guidelines were modelled at 24 months and 54 months. Table 3 presents the sociodemographic characteristics of the sample at both time points. Note that several factor levels have been collapsed due to a small number of responses in some categories.

Table 3: Sociodemographic characteristics of the sample

Variable	Level	24 Months	54 Months
Age (years)		2.03 ± 0.17	4.50 ± 0.13
Sex	Male	2670 (50.9)	2670 (50.9)
	Female	2571 (49.1)	2571 (49.1)
Ethnicity	NZ European	2959 (56.5)	2959 (56.5)
	Asian	722 (13.8)	722 (13.8)
	NZ Māori	785 (15)	785 (15)
	Pacific	775 (14.8)	775 (14.8)
Siblings living at home	0	2051 (39.6)	785 (15)
	1	1836 (35.5)	2387 (45.6)
	2	795 (15.4)	1336 (25.5)
	3+	491 (9.5)	730 (13.9)
Deprivation	1–2	924 (18.6)	1041 (20.7)
	3–4	936 (18.8)	955 (19)
	5–6	876 (17.6)	861 (17.2)
	7–8	996 (20)	868 (17.3)
	9–10	1239 (24.9)	1292 (25.8)
Rurality	Rural	424 (8.5)	467 (9.3)
	Urban	4549 (91.5)	4550 (90.7)
Rule enforcement	No rules	754 (16.4)	1675 (32)
	Half the time or less	442 (9.6)	330 (6.3)
	Most of the time	2086 (45.4)	1606 (30.7)
	All of the time	1316 (28.6)	1625 (31)
TVs owned	1	2976 (58.9)	
	2	1567 (31)	
	3+	513 (10.1)	

Presented as mean ± SD or n (%) where appropriate. The number of TVs owned was not collected at 54 months. Missing data for each variable not presented in table.

A binary variable indicative of meeting the screen time guidelines (less than 1 hour of total screen time per day) was then regressed on the sociodemographic factors presented in Table 3 (for each time point separately). These models were fit individually for each variable before one multivariable (fully adjusted) model was fit. Table 4 presents the results of this analysis for the 24-month time point. The odds ratios are interpreted as the odds of exceeding the screen time recommendation at 24-months, relative to the reference group. Asian, Māori,

and Pacific children were more likely to exceed the screen time recommendations compared with NZ European children, even after adjustment for all other variables. Living in areas of higher socioeconomic deprivation and owning more than one TV were also associated with exceeding the guidelines. Children in households where screen time rules were enforced all of the time were 33% less likely to exceed 1 hour of screen time per day. Interestingly, families that had screen time rules but did not always enforce them were more likely to exceed the guidelines compared with having no rules at all.

Table 4: Odds of exceeding the screen time recommendation at 24 months

		Unadjusted			Fully adjusted		
		OR	(95% CI)	p	OR	(95% CI)	p
Sex	Male	REF			REF		
	Female	0.92	(0.82–1.03)	0.13	0.89	(0.78–1)	0.06
Ethnicity	NZ European	REF			REF		
	Asian	1.85	(1.56–2.19)	< 0.01	1.81	(1.49–2.21)	< 0.01
	NZ Māori	1.86	(1.58–2.18)	< 0.01	1.53	(1.26–1.86)	< 0.01
	Pacific	2.13	(1.81–2.52)	< 0.01	1.73	(1.39–2.15)	< 0.01
Siblings living at home	No siblings	REF			REF		
	1 sibling	1.09	(0.96–1.23)	0.2	1.05	(0.91–1.21)	0.48
	2 siblings	0.96	(0.81–1.13)	0.6	0.89	(0.73–1.07)	0.2
	3+ siblings	1.26	(1.04–1.55)	0.02	1.02	(0.8–1.29)	0.89
Deprivation	1--2	REF			REF		
	3--4	1.13	(0.94–1.35)	0.19	1.09	(0.89–1.33)	0.4
	5--6	1.27	(1.06–1.53)	0.01	1.08	(0.88–1.33)	0.44
	7--8	1.77	(1.47–2.12)	< 0.01	1.35	(1.1–1.66)	< 0.01
	9--10	2.14	(1.8–2.55)	< 0.01	1.38	(1.12–1.7)	< 0.01
Rurality	Rural	REF			REF		
	Urban	1.29	(1.06–1.58)	0.01	0.91	(0.73–1.14)	0.43
Screen rules	No rules	REF			REF		
	Half the time or less	2.02	(1.55–2.63)	< 0.01	1.8	(1.38–2.37)	< 0.01
	Most of the time	1.06	(0.89–1.26)	0.51	1.25	(1.04–1.49)	0.02
	All of the time	0.57	(0.47–0.68)	< 0.01	0.67	(0.56–0.81)	< 0.01
TVs Owned	0-1 TV	REF			REF		
	2 TVs	1.53	(1.35–1.73)	< 0.01	1.4	(1.22–1.6)	< 0.01
	3+ TVs	2.47	(2.01–3.04)	< 0.01	1.9	(1.52–2.4)	< 0.01

The first level of each variable is the reference category. All variables were included in the fully adjusted model. Statistically significant p-values (< 0.05) are bolded.

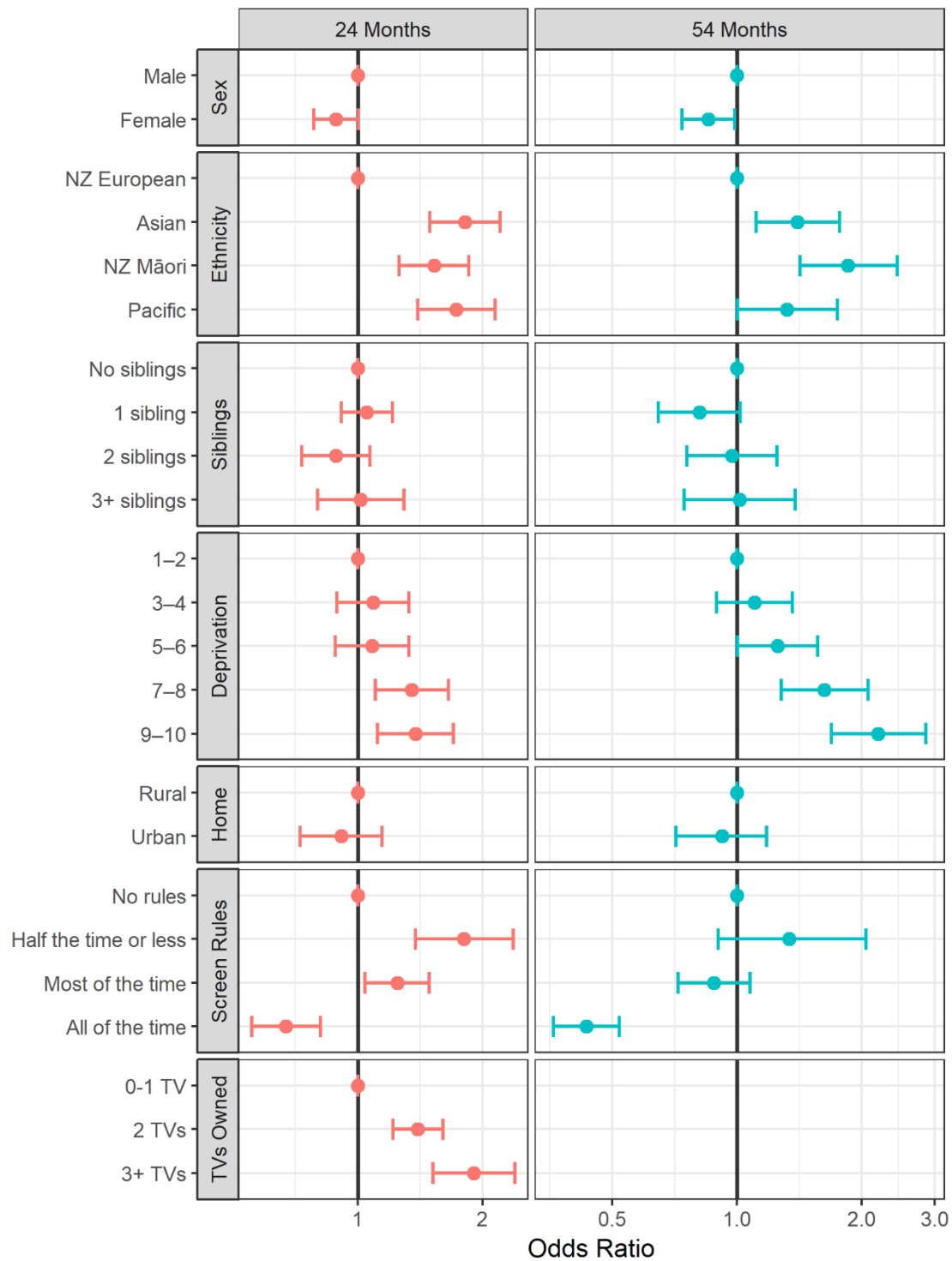
Table 5 displays the odds of exceeding the screen recommendation at 54 months. The associations among guideline adherence, ethnicity, and deprivation that were present at 24 months are still evident at 54 months. Children from families where screen time rules were enforced all of the time were 57% less likely (95% CI: 48%, 64%) to exceed the screen time guidelines than those with no rules. Figure 3 displays a visual representation of the fully adjusted models for both time points.

Table 5: Odds of exceeding the screen time recommendation at 54 months

		Unadjusted			Fully adjusted		
		OR	(95% CI)	p	OR	(95% CI)	p
Sex	Male	REF			REF		
	Female	0.88	(0.76–1.01)	0.07	0.85	(0.74–0.99)	0.03
Ethnicity	NZ European	REF			REF		
	Asian	1.5	(1.21–1.87)	< 0.01	1.4	(1.11–1.77)	< 0.01
	NZ Māori	2.77	(2.17–3.59)	< 0.01	1.85	(1.42–2.44)	< 0.01
	Pacific	1.98	(1.58–2.49)	< 0.01	1.32	(1–1.75)	0.05
Siblings	No siblings	REF			REF		
	1 sibling	0.71	(0.57–0.88)	< 0.01	0.81	(0.65–1.02)	0.07
	2 siblings	0.9	(0.71–1.14)	0.39	0.97	(0.76–1.25)	0.83
	3+ siblings	1.25	(0.94–1.66)	0.13	1.01	(0.75–1.38)	0.93
Deprivation	1--2	REF			REF		
	3--4	1.15	(0.93–1.41)	0.19	1.1	(0.89–1.36)	0.36
	5--6	1.38	(1.11–1.72)	< 0.01	1.25	(1–1.57)	0.05
	7--8	1.89	(1.5–2.38)	< 0.01	1.62	(1.28–2.07)	< 0.01
	9--10	2.93	(2.34–3.68)	< 0.01	2.19	(1.69–2.85)	< 0.01
Rurality	Rural	REF			REF		
	Urban	1.09	(0.85–1.38)	0.5	0.92	(0.71–1.18)	0.51
Screen rules	No rules	REF			REF		
	Half the time or less	1.55	(1.06–2.34)	0.03	1.34	(0.9–2.04)	0.16
	Most of the time	0.86	(0.71–1.04)	0.11	0.88	(0.72–1.07)	0.21
	All of the time	0.43	(0.36–0.51)	< 0.01	0.43	(0.36–0.52)	< 0.01

The first level of each variable is the reference category. All variables were included in the fully adjusted model. Statistically significant p-values (< 0.05) are bolded.

Figure 4: Odds of exceeding the screen time recommendation



The first level of each variable is the reference category. Results obtained from the respective fully adjusted models from Tables 4 and 5. Note that TVs Owned was not collected at the 54-month time point.

Screen time at 24 months and health at 54 months

The third aim of this project was to prospectively examine health and behavioural outcomes at 54 months given screen time at 24 months. Table 6 displays the frequencies of health and behavioural outcomes that were used during modelling. As with the sociodemographic variables, several factor levels have been collapsed due to a small number of responses in some categories. The outcomes have been ordered so the highest (last) level of each variable is the most unfavourable for health or behaviour.

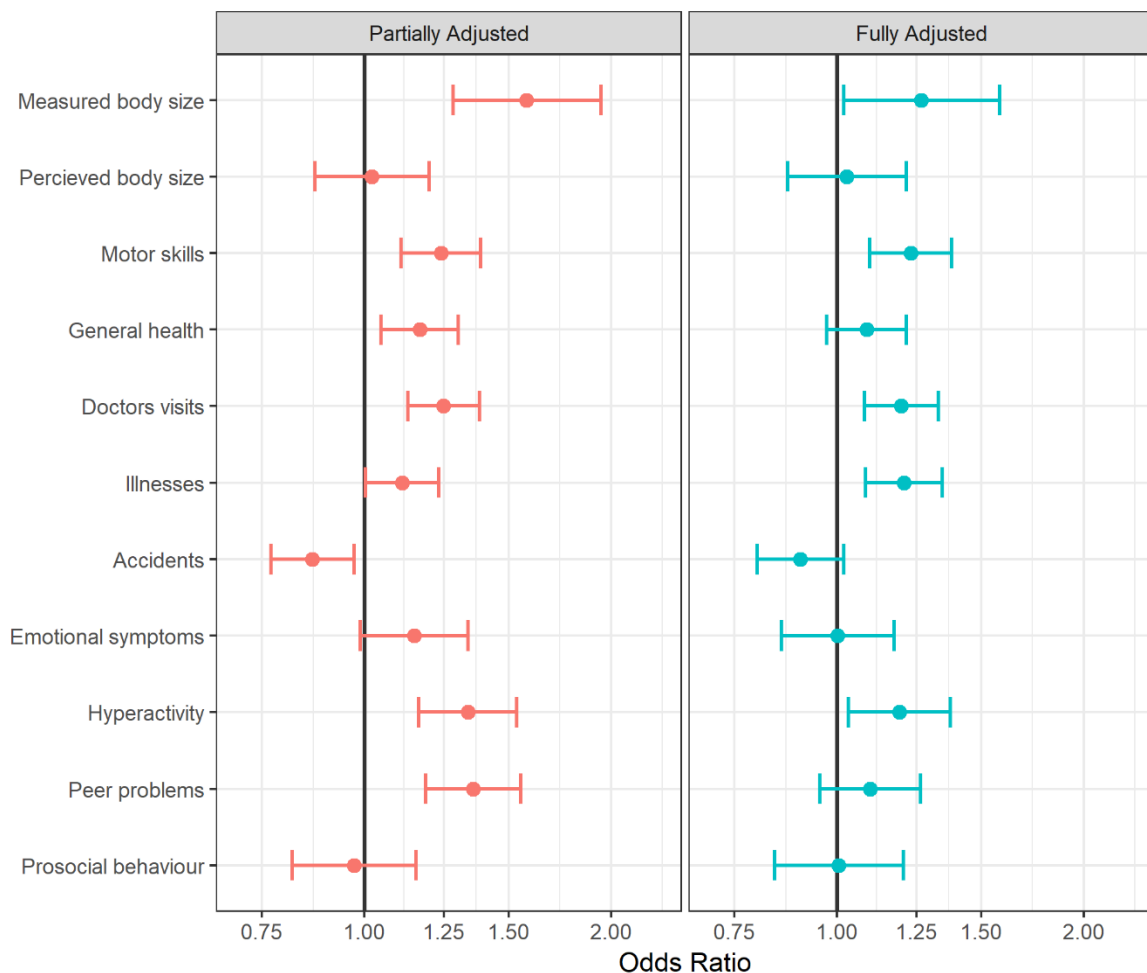
Table 6: Health outcome frequencies at both time points

Outcome	Level	24 Months	54 Months
Objectively measured body size	Normal or under	3308 (78.4)	4242 (87.1)
	Overweight	692 (16.4)	452 (9.3)
	Obese	221 (5.2)	176 (3.6)
Parent perceived body size	Underweight	478 (9.4)	518 (9.9)
	Normal weight	4222 (82.9)	4453 (85.0)
	Overweight	395 (7.8)	266 (5.1)
Motor skills	32-33 42-44	3401 (70.4)	1934 (40.0)
	30-31 39-41	974 (20.2)	1364 (28.2)
	<30 <39	458 (9.5)	1541 (31.9)
General health	Excellent	2658 (52.2)	2644 (50.5)
	Very good	1722 (33.8)	1821 (34.8)
	Good or worse	716 (14.1)	775 (14.8)
Total doctor visits	0	109 (2.2)	292 (5.6)
	1	371 (7.3)	655 (12.6)
	2	708 (14.0)	1018 (19.5)
	3	766 (15.1)	856 (16.4)
	4	699 (13.8)	723 (13.9)
	5+	2410 (47.6)	1666 (32.0)
Total illnesses	0	3677 (72.7)	1391 (26.6)
	1	1251 (24.8)	1514 (28.9)
	2+	127 (2.5)	2334 (44.6)
Total accidents	0	3664 (72.0)	3473 (66.5)
	1	1052 (20.7)	1264 (24.2)
	2+	374 (7.4)	487 (9.3)
Emotional symptoms	Normal	3682 (72.3)	4248 (81.1)
	Borderline	686 (13.5)	448 (8.6)
	Abnormal	726 (14.3)	545 (10.4)
Hyperactivity	Normal	3657 (71.8)	4013 (76.6)
	Borderline	645 (12.7)	535 (10.2)
	Abnormal	791 (15.5)	693 (13.2)
Peer problems	Normal	3138 (61.6)	3885 (74.1)
	Borderline	858 (16.9)	635 (12.1)
	Abnormal	1097 (21.5)	721 (13.8)
Prosocial behaviour	Normal	3259 (64.0)	4591 (87.6)
	Borderline	835 (16.4)	461 (8.8)
	Abnormal	999 (19.6)	189 (3.6)

Note different bins for motor skills at 24 Months and 54 Months due to the 3-point and 5-point Likert scales, respectively. Missing data for each variable not presented in table.

Figure 5 depicts the results from partially adjusted (adjusted for baseline health) and fully adjusted (further adjusted for sex, ethnicity, and socioeconomic deprivation) ordinal regression models. As screen time was treated as a binary explanatory variable, these results represent the odds of observing the highest (unfavourable) outcome category (relative to the other categories; see Table 6 for category list) when exceeding the screen time guidelines at 24 months. After adjusting for baseline health, sex, ethnicity, and deprivation, those exceeding the screen time recommendation at 24 months were more likely to be obese, exhibit lower physical motor skills, have more illnesses and visits to the doctor, and display hyperactivity problems at 54 months.

Figure 5: Odds of unfavourable health at 54 months when exceeding guidelines at 24 months



The complete set of results from fully adjusted models are presented in Appendices 1 and 2. Please note that Appendix 2 was included to permit alternative interpretation of the odds variables; the results from both appendices essentially lead to the same overall conclusions.

The links between unfavourable health and all three individual components of screen time are presented in Table 7. Results are interpreted as the odds of

observing the highest (unfavourable) health or behaviour outcome category at 54 months (see Table 6), for every additional hour of total screen time at 24 months (while other variables held constant). There were a number of significant associations for TV viewing time and screen exposure, but no significant associations for electronic media use, suggesting the effects of screen time on unfavourable health in children may not be uniform across all components of screen time.

Table 7: Odds of unfavourable health at 54 months for 1-hour increase in TV viewing time, electronic media, and screen exposure at 24 months

	Outcome variable	OR	(95% CI)	Pr(> t)
TV viewing time	Objectively-measured body size	1.11	(1.01–1.20)	0.03
	Parent perceived body size	1.01	(0.94–1.09)	0.82
	Motor skills	1.07	(1.02–1.13)	0.01
	General health	1.04	(0.98–1.09)	0.14
	Total doctor visits	1.07	(1.02–1.12)	0.01
	Total illnesses	1.03	(0.98–1.08)	0.28
	Total accidents	0.99	(0.93–1.04)	0.60
	Emotional symptoms	1.01	(0.95–1.08)	0.66
	Hyperactivity	1.08	(1.02–1.14)	0.01
	Peer problems	1.06	(1.00–1.12)	0.04
	Prosocial behaviour	1.01	(0.94–1.09)	0.77
Electronic media	Objectively measured body size	1.14	(0.81–1.53)	0.42
	Parent perceived body size	1.10	(0.89–1.35)	0.37
	Motor skills	1.04	(0.89–1.23)	0.55
	General health	0.89	(0.74–1.05)	0.21
	Total doctor visits	1.15	(0.99–1.36)	0.09
	Total illnesses	0.93	(0.79–1.08)	0.33
	Total accidents	0.98	(0.83–1.17)	0.84
	Emotional symptoms	1.03	(0.83–1.23)	0.79
	Hyperactivity	0.97	(0.81–1.15)	0.76
	Peer problems	1.01	(0.84–1.18)	0.92
	Prosocial behaviour	0.93	(0.66–1.20)	0.65
Screen exposure	Objectively measured body size	1.06	(1.01–1.11)	< 0.01
	Parent perceived body size	0.99	(0.95–1.03)	0.67
	Motor skills	1.05	(1.02–1.08)	< 0.01
	General health	1.04	(1.01–1.07)	0.01
	Total doctor visits	1.04	(1.02–1.07)	< 0.01
	Total illnesses	1.03	(0.98–1.07)	0.28
	Total accidents	0.98	(0.94–1.01)	0.12
	Emotional symptoms	1.03	(0.99–1.06)	0.12
	Hyperactivity	1.06	(1.04–1.10)	< 0.01
	Peer problems	1.05	(1.02–1.08)	< 0.01
	Prosocial behaviour	0.98	(0.94–1.03)	0.48

Screen time measured on continuous scale (hours). Adjusted for sex, ethnicity, socioeconomic deprivation, and corresponding baseline outcome. Significant odds are bolded.

Discussion

This study utilised data collected in the Growing Up in New Zealand study to examine the temporal trends in screen use, cross-sectional associations with screen time guideline adherence, and prospective health and behavioural outcomes at 54 months given screen use at 24 months of age. Our results indicate that the temporal patterns of screen use tended to increase between 24 and 54 months, but varied by screen use type. Ethnicity, socioeconomic deprivation, household screen time rules, and the number of televisions in the household were consistently associated with meeting the screen time guidelines at each time point. Children that did not adhere to the screen time guidelines at 24 months of age were more likely to be obese, have more illnesses and doctor visits, lower physical motor skills, and exhibit hyperactivity problems at 54 months, which persisted when adjusted for ethnicity, sex, socioeconomic deprivation, and the corresponding health or behavioural outcome at 24 months. These findings provide insight into contemporary trends in preschooler screen use and longitudinal health and wellbeing, and can contribute to evidence-based policy relating to screen use in early childhood.

Temporal trends among types of screen use

Daily screen time increased by an average of 0.54 hours (32 minutes) from 24 months to 45 months, which was driven by increases in both television watching and electronic media use. Television viewing declining from 45 to 54 months, but the use of electronic media continued to rise. This meant that there was no change in total screen time between 45 and 54 months, but the composition of this screen use shifted. The downward trend in television viewing is consistent with the 2016/2017 New Zealand Health survey (Ministry of Health, 2015, 2017a), and previous international research, which has shown the number of children exceeding television viewing recommendations steadily decreased between 2002 and 2014, while the time spent using computers (and overall screen time) had increased significantly (Sigmundova et al., 2017). This apparent shift is indicative of the changing landscape of screen-based entertainment brought on by technological advance over the last decade. Despite increased availability of alternate forms of media, television viewing is still the most prominent form of screen use in this age group, but it is likely this will change with age. The 2014 Children's Media Use Study (Broadcasting Standards Authority, 2015) commissioned by NZ On Air and the Broadcasting Standards Authority also found television viewing was the most popular form of screen use in preschoolers, but at least 30% used computers or tablets to access the internet, and 18% used smartphones. The use of YouTube and social media apps like Facebook also increase significantly by the time children are 12-14 years old (Broadcasting Standards Authority, 2015). This highlights the

importance of collecting information about other forms of media rather than just television viewing alone.

The amount of screen time we observed (1.35 hours at 24 months and 1.87 hours at 54 months) is consistent with figures observed in Australian preschoolers (mean age 4.5 years), whose parents reported they had a total screen time (television and electronic media use) of 1.89 hours per day (Hinkley et al., 2012). However, this study averaged screen time across weekdays and weekend days, which may be significant as preschoolers in Belgium were shown to have 1.23 hours of screen time on weekdays but this doubled to 2.33 hours on weekend days (Cardon & De Bourdeaudhuij, 2008). Nonetheless, the screen time we observed is considerably lower than the 3.6 hours seen in US preschool children (Tandon, Zhou, Lozano, & Christakis, 2011). Evidently, screen time is already consumed at a significant level at two years of age, which also suggests that many children exceed the zero-screen-time recommendation proposed for those under two. A recent systematic review of 22 studies found that the proportion of toddlers meeting the zero screen time recommendation ranged from 2.3% to 83.0%, and children were already engaging in high levels of screen time by age two (Downing, Hnatiuk, & Hesketh, 2015). This was further demonstrated in a recent UK study, which stated daily television time was almost 1-hour at 6 months old, but increased to 2.1 hours by 36 months (Barber et al., 2017).

Screen time associations

There were no differences in total screen time between males and females at 24 months, but at 54 months, females were 15% less likely (95% CI: 1%, 26%) to exceed the screen time guidelines compared to males. In Australia, male preschoolers have tended to have more screen time than girls, but the magnitude of difference is also small (Hinkley et al., 2012). A recent review concluded that sex was not consistently associated with preschooler's screen time (Duch et al., 2013). Clearer associations were seen among ethnic groups, with Māori, Pacific and Asian children all more likely than NZ European children to exceed the screen time guidelines at 24-months and 54 months. This is comparable with previous research in New Zealand which suggests Māori and Pacific children are more likely to have higher screen time (Ministry of Health, 2015, 2017a), and other international research which consistently shows ethnic minorities have higher screen use (Carson & Kuzik, 2017; Duch et al., 2013). A recent New Zealand study examining screen time behaviours in obese older children (aged 5-16) in the Taranaki region showed no difference in total screen time or guideline adherence between Māori and NZ Europeans (Anderson et al., 2017). Although this may suggest that any differences present at a young age may disappear as the child develops, this study had a relatively small sample size, and only included obese participants. Lastly, children living in areas with higher deprivation were twice as likely to exceed screen guidelines at 54 months than those living in the lowest two deciles of deprivation.

This trend is evident in the NZ Health Survey (for children aged 2-14) (Ministry of Health, 2017a), in several European countries (De Decker et al., 2012), and Canada (Carson & Kuzik, 2017), but was deemed inconclusive in a recent review (Duch et al., 2013).

The social and physical environment within the home setting can shape screen time behaviours. Preschoolers in families where screen time rules were consistently enforced were 33% and 57% less likely to exceed the recommendations at 24 months and 54 months, respectively. Parental restriction of child television time, including rule setting, is commonly associated with lower television viewing time among preschool-aged children (Cillero & Jago, 2010). However, only 25.5% and 29.8% of parents at 24 and 54 months (respectively) enforced screen rules consistently, and the number of parents with no rules increased from 15.9% at 24 months to 32.5% at 54 months. It is possible that families that have no screen rules may feel no need to place such restrictions as screen time behaviour is not problematic. Nevertheless, investigating factors related to the implementation and enforcement of rules in households will be an interesting area of exploration. One recent study proposed that parents who perceived restricting screen time as important, and those with greater self-efficacy for restricting screen time were both associated with screen time restriction (Lampard, Jurkowski, & Davison, 2012). Parental understanding and beliefs about screen use are important components of a child's screen environment (Barber et al., 2017). Through interviews, it was deduced that many parents feel a positive component of screen time is the "babysitter" aspect, which gives parents a window of opportunity to pursue other tasks (Hesketh, Hinkley, & Campbell, 2012). An understanding of these factors is important, as rules are one of the few modifiable factors that are consistently associated with screen use.

Screen time and health

We examined the prospective health outcomes at 54 months as a result of exceeding the screen time guidelines at 24 months. One of the strongest associations was between screen usage and objectively-measured body size: the odds of moving from 'normal weight' to 'overweight' or 'obese' at 54 months were 1.27 (95% CI: 1.02, 1.58) greater when screen time recommendations were exceeded at 24 months (after adjustment for baseline health, sex, ethnicity, and deprivation). This has important implications for child health promotion, and indicates that adhering to screen time guidelines at two years of age may protect against the development of overweight and obesity in later years. It should be noted, however, that the prevalence of overweight and obesity was considerably lower in the Growing Up in New Zealand sample (16.4% and 5.2% at 24 months; 9.3% and 3.6% at 54 months) when compared with the New Zealand population (20% and 12.3% of 2-4-year-olds overweight and obese, respectively (Ministry of Health, 2017a)). Given the apparent link

between time spent on screens and body size in children, the relatively low levels of overweight and obesity in this sample may have resulted in underestimation of screen usage when compared with the general population. Nonetheless, differences in obesity prevalence (and potentially screen usage) are unlikely to have biased our evaluation of longitudinal associations, which are less dependent on representativeness.

Our findings also showed that children who exceeded the screen time guidelines were 1.23 times (95% CI: 1.1, 1.38) more likely to fall in the lowest category of physical motor skills at 54 months even when adjusting for the degree of existing motor skills at 24 months of age. This is concerning as low motor skills can have long-term repercussions: the development of motor skill competence is a primary underlying mechanism that promotes engagement in physical activity across the lifespan (Stodden et al., 2008). A recent study found that four-year-old children with low motor skill performance were less active than children with better-developed motor skills (Williams Harriet et al., 2012). Higher screen time at 2 years old has also been associated with significantly lower performance in the standing long jump test (a measure of explosive leg strength) when children reached eight years of age (Fitzpatrick, Pagani, & Barnett, 2012). This relationship between motor skill performance and physical activity could be important to the health of children, particularly in obesity prevention.

Literature on screen time and more general measures of health and wellbeing is relatively scarce. We demonstrated that a child's general health was more likely to be in the 'good or worse' category (as opposed to excellent, or very good) at 54 months, when exceeding the 24-month screen guidelines, but this was no longer significant after adjustment for sex, ethnicity, and deprivation. On the other hand, children exceeding the 24-month guidelines were 1.2 times more likely to report 5+ visits to the doctor, and 1.21 times more likely to suffer from at least two illnesses at 54 months. It is possible that children with lower screen time are generally more active and have healthier behaviour patterns overall. For example, high screen time has been associated with higher consumption of soft drinks and unhealthy snacks (Pagani et al., 2010). Models that were not adjusted for sociodemographic factors showed children with more screen time had less accidents. Despite not remaining significant after adjustment, this may be suggestive of less time spent in explorative or risky play, which has further implications for child health and development.

When looking at behavioural and emotional outcomes, children were more likely to fall into the abnormal category of peer problems, hyperactivity and emotional symptoms (borderline significant) when unadjusted for sociodemographic characteristics. However, only hyperactivity remained significant after adjustment, where children were 1.2 times (95% CI: 1.03–1.37) more likely to fall into the abnormal category. Although emotional and peer problems were not significant in adjusted models, a large (n = 16,864) multicounty study in Europe showed the risk of adverse peer and emotional problems in children ranged from a 1.2 to 2-

fold increase for each additional hour of screen use (Hinkley et al., 2014). Higher screen time was also associated with unfavourable scores on the conduct subscale of the SDQ in the UK Millennium Cohort Study (n=11,014), but not with the other SDQ subscales (Parkes, Sweeting, Wight, & Henderson, 2013). Although several of our behavioural and emotional outcomes are suggestive of association, these trends may become more apparent with longer follow-up durations. A prospective study with a 10-year follow-up demonstrated clear effects of childhood screen use on detrimental health and wellbeing in early adolescence, including social isolation, aggression, and antisocial behaviour, after controlling for potential confounders (Pagani, Lévesque-Seck, & Fitzpatrick, 2016).

An advantage of the present study was that we were able to examine the longitudinal relationships between health outcomes and individual screen time components. Of note were the relatively weak associations between electronic media use and long-term outcomes. It is possible that the form of screen time does not contribute to the same adverse effects on physical and mental development. Alternatively (or in addition), the relatively low amount of time spent on electronic media (approximately one-third of TV watching time) may mean that most children do not reach a daily time threshold that triggers negative effects. Further investigation of the effects of these individual screen time components at later years is clearly warranted.

Conclusions

We are clearly amid a digital revolution, with portable devices widely available at home and in education settings. This was seen with the changing composition of screen use, which shifts from an early age. Given that only 18.4% of children were meeting the screen time guidelines at 54 months, and the negative health implications we observed, a population-level understanding of such risks remains essential for promoting child development. The long-term risks associated with higher levels of early screen exposure may chart developmental pathways toward unhealthy dispositions in adolescence and adulthood. Collectively, the observed sociodemographic correlates of screen time draw attention to some groups of individuals that may be in most need of intervention. More specifically, preschoolers from ethnic minority groups, those from families with inconsistent screen time rules, and those living in areas of higher deprivation seem to be more vulnerable to higher screen usage. Despite few of these being modifiable factors, understanding these correlates may be useful for developing tailored interventions (ethnicity, socioeconomic indicators). Our findings also support the ongoing implementation of national guidelines for screen time in children. However, as parents often find screen time beneficial, family-based interventions that consider broader attitudinal factors around child screen time may be necessary to encourage parents to monitor and restrict screen use when required.

Limitations and future directions

There were several limitations with the present work. Firstly, there were several variables with a significant number of missing observations (see Appendix 3), particularly objectively measured body size at the 24 months (18.8% missing). It is possible this missingness may have introduced systematic bias into the body size results.

Secondly, many of the measures used were self/proxy reported, which exposes the data to recall limitations and social desirability bias. Although the screen time measures are used widely and have shown good reliability, the actual validity of these measures is not known. Unfortunately, no suitable objective measure of screen time for population studies currently exists. Simply reporting the amount of television time or electronic media use is not ideal because it does not capture screen use on a finely tuned scale, nor does it capture the quality (eg educational, entertainment, violent material), or context (eg at home or early childhood education) of this screen time. The use of interactive media, such as smartphones and tablets by young children is increasing rapidly. Research regarding the impact of this portable and instantly accessible source of screen time on learning, behaviour, and family dynamics has lagged considerably behind its rate of adoption, so future work should consider these factors in more detail.

Thirdly, the parental role is particularly important during a child's early life, when parents are responsible for most of their child's experiences. Beyond screen time rules, this report did not focus on how parent-child factors are related to screen time, as this work is currently being performed as part of a PhD study within the Growing Up in New Zealand team. Even so, available literature (Napier, 2014) suggests that excessive screen use may substantially disrupt the quantity and quality of parent-child interactions, which are essential for developing secure attachments.

Lastly, modelling the trends in the current study with data from future waves will be beneficial, particularly when the cohort start school and technological proficiency becomes advantageous to learning. It is also unclear if these relationships with health and behaviour persist over the longer term. Looking ahead, the 8-year data collection wave will feature objective assessment of physical activity and sedentary behaviour using paired accelerometers, which can be used to derive complex yet precise physical activity and movement profiles. When combined with screen time, this would allow us to delve deeper into the existing uncertainties around the effects of screen usage, providing even greater resolution and clarity about how much screen time our children should receive.

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Appendix 1: Adjusted models from prospective analyses–binary response

As screen time was treated as a binary explanatory variable, these results represent the odds of observing the highest (unfavourable) outcome category (relative to the other categories) when exceeding the screen time guidelines at 24 months.

Body size (objectively measured)

		Estimate	Std. Error	Pr(> t)	OR	(95% CI)
Screen guidelines	Yes	REF				
	No	0.24	0.11	0.034	1.27	(1.02–1.58)
Sex	Male	REF				
	Female	-0.14	0.11	0.185	0.87	(0.7–1.07)
Ethnicity	NZ European	REF				
	NZ Māori	0.69	0.15	< 0.01	2.00	(1.49–2.68)
	Pacific	1.17	0.15	< 0.01	3.23	(2.41–4.32)
	Asian	-0.37	0.21	0.076	0.69	(0.45–1.03)
Deprivation	1--2	REF				
	3--4	-0.19	0.20	0.330	0.82	(0.55–1.22)
	5--6	0.11	0.19	0.573	1.14	(0.77–1.62)
	7--8	0.21	0.18	0.247	1.23	(0.87–1.77)
	9--10	0.42	0.18	0.020	1.53	(1.07–2.19)
Baseline	Normal or underweight	REF				
	Overweight	1.62	0.12	< 0.01	5.07	(4.04–6.37)
	Obese	2.24	0.16	< 0.01	9.39	(6.79–12.93)

Body size (perceived by parent)

		Estimate	Std. Error	Pr(> t)	OR	(95% CI)
Screen guidelines	Yes	REF				
	No	0.03	0.08	0.743	1.03	(0.87–1.21)
Sex	Male	REF				
	Female	0.38	0.08	< 0.01	1.46	(1.24–1.72)
Ethnicity	NZ European	REF				
	NZ Māori	-0.03	0.13	0.818	0.97	(0.75–1.25)
	Pacific	0.51	0.14	< 0.01	1.67	(1.26–2.2)
	Asian	-0.62	0.12	< 0.01	0.54	(0.42–0.68)
Deprivation	1--2	REF				
	3--4	-0.11	0.13	0.416	0.90	(0.69–1.17)
	5--6	-0.18	0.14	0.198	0.84	(0.64–1.1)
	7--8	-0.05	0.14	0.704	0.95	(0.73–1.24)
	9--10	0.09	0.14	0.514	1.10	(0.83–1.45)
Baseline	Underweight	REF				
	Normal	2.10	0.11	< 0.01	8.18	(6.54–10.23)
	Overweight	3.80	0.18	< 0.01	44.76	(31.28–63.91)

Motor skills

		Estimate	Std. Error	Pr(> t)	OR	(95% CI)
Screen guidelines	Yes	REF				
	No	0.21	0.06	< 0.01	1.23	(1.1–1.38)
Sex	Male	REF				
	Female	0.15	0.06	< 0.01	1.17	(1.04–1.31)
Ethnicity	NZ European	REF				
	NZ Māori	-0.05	0.09	0.582	0.95	(0.8–1.13)
	Pacific	0.16	0.10	0.093	1.17	(0.97–1.42)
	Asian	-0.24	0.09	< 0.01	0.79	(0.66–0.94)
Deprivation	1--2	REF				
	3--4	0.06	0.09	0.499	1.06	(0.89–1.28)
	5--6	0.09	0.09	0.315	1.10	(0.91–1.32)
	7--8	0.26	0.09	< 0.01	1.29	(1.08–1.56)
	9--10	0.08	0.10	0.426	1.08	(0.89–1.31)
Baseline	32-33	REF				
	30-31	0.76	0.07	< 0.01	2.15	(1.87–2.47)
	<30	1.49	0.10	< 0.01	4.44	(3.62–5.46)

General health (parent rated)

		Estimate	Std. Error	Pr(> t)	OR	(95% CI)
Screen guidelines	Yes	REF				
	No	0.08	0.06	0.149	1.09	(0.97–1.22)
Sex	Male	REF				
	Female	-0.11	0.06	0.052	0.90	(0.8–1)
Ethnicity	NZ European	REF				
	NZ Māori	0.23	0.08	< 0.01	1.26	(1.06–1.48)
	Pacific	0.09	0.09	0.344	1.09	(0.91–1.31)
	Asian	0.62	0.08	< 0.01	1.86	(1.57–2.19)
Deprivation	1--2	REF				
	3--4	-0.06	0.09	0.485	0.94	(0.78–1.12)
	5--6	0.10	0.09	0.286	1.10	(0.92–1.33)
	7--8	0.24	0.09	0.010	1.27	(1.06–1.52)
	9--10	0.14	0.09	0.148	1.15	(0.95–1.38)
Baseline	Excellent	REF				
	Very good	0.85	0.06	< 0.01	2.33	(2.07–2.63)
	Good or worse	1.51	0.08	< 0.01	4.54	(3.86–5.35)

Total doctor visits

		Estimate	Std. Error	Pr(> t)	OR	(95% CI)
Screen guidelines	Yes	REF				
	No	0.18	0.05	< 0.01	1.20	(1.08–1.33)
Sex	Male	REF				
	Female	-0.06	0.05	0.220	0.94	(0.85–1.04)
Ethnicity	NZ European	REF				
	NZ Māori	0.35	0.08	< 0.01	1.41	(1.21–1.66)
	Pacific	0.07	0.09	0.392	1.08	(0.91–1.27)
	Asian	0.28	0.08	< 0.01	1.32	(1.13–1.55)
Deprivation	1--2	REF				
	3--4	-0.13	0.08	0.114	0.88	(0.74–1.03)
	5--6	-0.04	0.09	0.608	0.96	(0.81–1.13)
	7--8	0.07	0.08	0.437	1.07	(0.9–1.26)
	9--10	0.02	0.09	0.796	1.02	(0.86–1.21)
Baseline	0	REF				
	1	0.87	0.21	< 0.01	2.39	(1.59–3.6)
	2	1.22	0.20	< 0.01	3.40	(2.31–5)
	3	1.78	0.20	< 0.01	5.92	(4.03–8.72)
	4	1.95	0.20	< 0.01	7.01	(4.76–10.34)
	5+	2.60	0.19	< 0.01	13.41	(9.23–19.52)

Total reported illnesses

		Estimate	Std. Error	Pr(> t)	OR	(95% CI)
Screen guidelines	Yes	REF				
	No	0.19	0.05	< 0.01	1.21	(1.08–1.34)
Sex	Male	REF				
	Female	-0.15	0.05	< 0.01	0.86	(0.78–0.96)
Ethnicity	NZ European	REF				
	NZ Māori	0.15	0.08	0.064	1.17	(0.99–1.38)
	Pacific	-0.32	0.09	< 0.01	0.72	(0.61–0.86)
	Asian	-0.50	0.08	< 0.01	0.60	(0.51–0.71)
Deprivation	1--2	REF				
	3--4	-0.06	0.09	0.476	0.94	(0.79–1.11)
	5--6	0.05	0.09	0.605	1.05	(0.88–1.25)
	7--8	-0.09	0.09	0.327	0.92	(0.77–1.09)
	9--10	-0.16	0.09	0.074	0.85	(0.71–1.02)
Baseline	0	REF				
	1	0.40	0.06	< 0.01	1.50	(1.32–1.7)
	2+	0.52	0.18	< 0.01	1.68	(1.19–2.39)

Total reported accidents

		Estimate	Std. Error	Pr(> t)	OR	(95% CI)
Screen guidelines	Yes	REF				
	No	-0.10	0.06	0.097	0.90	(0.8–1.02)
Sex	Male	REF				
	Female	-0.22	0.06	< 0.01	0.81	(0.72–0.91)
Ethnicity	NZ European	REF				
	NZ Māori	-0.02	0.09	0.787	0.98	(0.81–1.17)
	Pacific	-0.15	0.10	0.129	0.86	(0.7–1.04)
	Asian	-0.61	0.10	< 0.01	0.54	(0.44–0.66)
Deprivation	1--2	REF				
	3--4	0.11	0.10	0.260	1.12	(0.92–1.35)
	5--6	0.05	0.10	0.586	1.06	(0.87–1.29)
	7--8	0.02	0.10	0.859	1.02	(0.84–1.24)
	9--10	-0.03	0.10	0.753	0.97	(0.79–1.18)
Baseline	0	REF				
	1	0.54	0.07	< 0.01	1.72	(1.49–1.98)
	2+	1.17	0.11	< 0.01	3.21	(2.59–3.98)

Emotional symptoms

		Estimate	Std. Error	Pr(> t)	OR	(95% CI)
Screen guidelines	Yes	REF				
	No	0.00	0.08	0.979	1.00	(0.86–1.17)
Sex	Male	REF				
	Female	0.00	0.08	0.978	1.00	(0.86–1.17)
Ethnicity	NZ European	REF				
	NZ Māori	0.49	0.11	< 0.01	1.63	(1.3–2.03)
	Pacific	1.04	0.11	< 0.01	2.84	(2.27–3.55)
	Asian	0.17	0.12	0.162	1.19	(0.93–1.51)
Deprivation	1--2	REF				
	3--4	-0.08	0.14	0.571	0.92	(0.7–1.22)
	5--6	-0.12	0.14	0.415	0.89	(0.67–1.18)
	7--8	0.14	0.14	0.317	1.15	(0.88–1.49)
	9--10	0.21	0.13	0.116	1.24	(0.95–1.61)
Baseline	Normal	REF				
	Borderline	0.83	0.10	< 0.01	2.28	(1.86–2.8)
	Abnormal	1.66	0.09	< 0.01	5.24	(4.35–6.3)

Hyperactivity

		Estimate	Std. Error	Pr(> t)	OR	(95% CI)
Screen guidelines	Yes	REF				
	No	0.17	0.07	0.017	1.19	(1.03–1.37)
Sex	Male	REF				
	Female	-0.35	0.07	< 0.01	0.70	(0.61–0.81)
Ethnicity	NZ European	REF				
	NZ Māori	0.44	0.10	< 0.01	1.55	(1.27–1.88)
	Pacific	0.42	0.11	< 0.01	1.52	(1.24–1.88)
	Asian	-0.15	0.12	0.186	0.86	(0.68–1.07)
Deprivation	1--2	REF				
	3--4	0.22	0.13	0.075	1.25	(0.98–1.6)
	5--6	0.15	0.13	0.247	1.16	(0.9–1.49)
	7--8	0.46	0.12	< 0.01	1.58	(1.25–2.01)
	9--10	0.57	0.12	< 0.01	1.77	(1.4–2.25)
Baseline	Normal	REF				
	Borderline	0.94	0.10	< 0.01	2.57	(2.12–3.09)
	Abnormal	1.52	0.08	< 0.01	4.58	(3.88–5.4)

Peer problems

		Estimate	Std. Error	Pr(> t)	OR	(95% CI)
Screen guidelines	Yes	REF				
	No	0.09	0.07	0.197	1.10	(0.95–1.26)
Sex	Male	REF				
	Female	-0.17	0.07	0.011	0.84	(0.73–0.96)
Ethnicity	NZ European	REF				
	NZ Māori	0.68	0.10	< 0.01	1.97	(1.62–2.4)
	Pacific	1.06	0.10	< 0.01	2.88	(2.35–3.53)
	Asian	0.76	0.10	< 0.01	2.13	(1.75–2.59)
Deprivation	1--2	REF				
	3--4	0.15	0.13	0.256	1.16	(0.9–1.51)
	5--6	0.14	0.13	0.297	1.15	(0.89–1.49)
	7--8	0.55	0.12	< 0.01	1.73	(1.35–2.21)
	9--10	0.73	0.12	< 0.01	2.07	(1.62–2.64)
Baseline	Normal	REF				
	Borderline	0.73	0.09	< 0.01	2.07	(1.73–2.47)
	Abnormal	1.19	0.08	< 0.01	3.28	(2.8–3.84)

Prosocial behaviour

		Estimate	Std. Error	Pr(> t)	OR	(95% CI)
Screen guidelines	Yes	REF				
	No	0.00	0.09	0.963	1.00	(0.84–1.2)
Sex	Male	REF				
	Female	-0.73	0.09	< 0.01	0.48	(0.4–0.58)
Ethnicity	NZ European	REF				
	NZ Māori	-0.09	0.14	0.507	0.91	(0.69–1.19)
	Pacific	-0.18	0.15	0.239	0.84	(0.62–1.12)
	Asian	-0.13	0.14	0.364	0.88	(0.67–1.15)
Deprivation	1--2	REF				
	3--4	0.07	0.15	0.611	1.08	(0.81–1.44)
	5--6	0.06	0.15	0.681	1.07	(0.79–1.44)
	7--8	0.16	0.15	0.266	1.18	(0.88–1.58)
	9--10	0.21	0.15	0.167	1.24	(0.92–1.67)
Baseline	Normal	REF				
	Borderline	0.96	0.12	< 0.01	2.60	(2.07–3.26)
	Abnormal	1.44	0.10	< 0.01	4.24	(3.47–5.17)

Appendix 2: Adjusted models from prospective analyses—continuous response

Screen odds are interpreted as the odds of observing the highest (unfavourable) health or behaviour outcome category at 54-months, for every additional hour of total screen time at 24-months (while other variables held constant).

Body size (objectively measured)

		Estimate	Std. Error	Pr(> t)	OR	(95% CI)
Screen time (hours)		0.10	0.04	< 0.01	1.11	(1.03–1.19)
Sex	Male	REF				
	Female	-0.14	0.11	0.185	0.87	(0.7–1.07)
Ethnicity	NZ European	REF				
	NZ Māori	0.68	0.15	< 0.01	1.97	(1.46–2.64)
	Pacific	1.14	0.15	< 0.01	3.13	(2.33–4.21)
	Asian	-0.43	0.21	0.045	0.65	(0.42–0.98)
Deprivation	1--2	REF				
	3--4	-0.21	0.20	0.295	0.81	(0.55–1.2)
	5--6	0.10	0.19	0.597	1.11	(0.76–1.61)
	7--8	0.20	0.18	0.282	1.22	(0.85–1.75)
	9--10	0.40	0.18	0.028	1.49	(1.05–2.14)
Baseline	Normal or underweight	REF				
	Overweight	1.63	0.12	< 0.01	5.11	(4.07–6.42)
	Obese	2.25	0.16	< 0.01	9.51	(6.88–13.1)

Body size (perceived by parent)

		Estimate	Std. Error	Pr(> t)	OR	(95% CI)
Screen time (hours)		0.02	0.03	0.607	1.02	(0.96–1.08)
Sex	Male	REF				
	Female	0.38	0.08	< 0.01	1.46	(1.24–1.72)
Ethnicity	NZ European	REF				
	NZ Māori	-0.03	0.13	0.798	0.97	(0.75–1.25)
	Pacific	0.50	0.14	< 0.01	1.65	(1.25–2.19)
	Asian	-0.63	0.12	< 0.01	0.53	(0.42–0.68)
Deprivation	1--2	REF				
	3--4	-0.11	0.13	0.412	0.90	(0.69–1.16)
	5--6	-0.18	0.14	0.196	0.84	(0.64–1.1)
	7--8	-0.05	0.14	0.688	0.95	(0.72–1.24)
	9--10	0.09	0.14	0.534	1.09	(0.83–1.44)
Baseline	Underweight	REF				
	Normal	2.10	0.11	< 0.01	8.17	(6.53–10.22)
	Overweight	3.80	0.18	< 0.01	44.78	(31.3–63.93)

Motor skills

		Estimate	Std. Error	Pr(> t)	OR	(95% CI)
Screen time (hours)		0.09	0.02	< 0.01	1.09	(1.05–1.14)
Sex	Male	REF				
	Female	0.16	0.06	< 0.01	1.17	(1.05–1.31)
Ethnicity	NZ European	REF				
	NZ Māori	-0.06	0.09	0.466	0.94	(0.79–1.11)
	Pacific	0.12	0.10	0.199	1.13	(0.94–1.37)
	Asian	-0.27	0.09	< 0.01	0.77	(0.64–0.92)
Deprivation	1--2	REF				
	3--4	0.06	0.09	0.551	1.06	(0.88–1.27)
	5--6	0.09	0.09	0.333	1.10	(0.91–1.32)
	7--8	0.25	0.09	< 0.01	1.28	(1.07–1.54)
	9--10	0.06	0.10	0.541	1.06	(0.88–1.28)
Baseline	32-33	REF				
	30-31	0.76	0.07	< 0.01	2.15	(1.87–2.47)
	<30	1.48	0.10	< 0.01	4.39	(3.58–5.4)

General health (parent rated)

		Estimate	Std. Error	Pr(> t)	OR	(95% CI)
Screen time (hours)		0.02	0.02	0.282	1.02	(0.98–1.06)
Sex	Male	REF				
	Female	-0.11	0.06	0.052	0.90	(0.81–1)
Ethnicity	NZ European	REF				
	NZ Māori	0.23	0.09	< 0.01	1.26	(1.07–1.49)
	Pacific	0.08	0.09	0.362	1.09	(0.91–1.3)
	Asian	0.62	0.09	< 0.01	1.85	(1.57–2.19)
Deprivation	1--2	REF				
	3--4	-0.07	0.09	0.477	0.94	(0.78–1.12)
	5--6	0.10	0.09	0.287	1.10	(0.92–1.33)
	7--8	0.24	0.09	< 0.01	1.27	(1.06–1.52)
	9--10	0.14	0.09	0.152	1.15	(0.95–1.38)
Baseline	Excellent	REF				
	Very good	0.85	0.06	< 0.01	2.33	(2.07–2.63)
	Good or worse	1.51	0.08	< 0.01	4.54	(3.86–5.35)

Total doctor visits

		Estimate	Std. Error	Pr(> t)	OR	(95% CI)
Screen time (hours)		0.07	0.02	< 0.01	1.07	(1.03–1.12)
Sex	Male	REF				
	Female	-0.06	0.05	0.241	0.94	(0.85–1.04)
Ethnicity	NZ European	REF				
	NZ Māori	0.34	0.08	< 0.01	1.40	(1.19–1.64)
	Pacific	0.05	0.09	0.555	1.05	(0.89–1.25)
	Asian	0.26	0.08	< 0.01	1.29	(1.1–1.51)
Deprivation	1--2	REF				
	3--4	-0.14	0.08	0.102	0.87	(0.74–1.03)
	5--6	-0.05	0.09	0.583	0.95	(0.81–1.13)
	7--8	0.06	0.08	0.494	1.06	(0.9–1.25)
	9--10	0.01	0.09	0.913	1.01	(0.85–1.2)
Baseline	0	REF				
	1	0.87	0.21	< 0.01	2.39	(1.59–3.59)
	2	1.23	0.20	< 0.01	3.41	(2.32–5.01)
	3	1.78	0.20	< 0.01	5.93	(4.04–8.73)
	4	1.95	0.20	< 0.01	7.05	(4.79–10.4)
	5+	2.60	0.19	< 0.01	13.42	(9.24–19.52)

Total reported illnesses

		Estimate	Std. Error	Pr(> t)	OR	(95% CI)
Screen time (hours)		0.04	0.02	0.026	1.04	(1.01–1.09)
Sex	Male	REF				
	Female	-0.15	0.05	< 0.01	0.86	(0.78–0.96)
Ethnicity	NZ European	REF				
	NZ Māori	0.16	0.08	0.057	1.17	(1–1.38)
	Pacific	-0.32	0.09	< 0.01	0.72	(0.61–0.86)
	Asian	-0.50	0.08	< 0.01	0.60	(0.51–0.71)
Deprivation	1--2	REF				
	3--4	-0.06	0.09	0.469	0.94	(0.79–1.11)
	5--6	0.04	0.09	0.622	1.05	(0.88–1.25)
	7--8	-0.09	0.09	0.334	0.92	(0.77–1.09)
	9--10	-0.16	0.09	0.074	0.85	(0.71–1.02)
Baseline	0	REF				
	1	0.41	0.06	< 0.01	1.50	(1.33–1.7)
	2+	0.52	0.18	< 0.01	1.68	(1.19–2.39)

Total reported accidents

		Estimate	Std. Error	Pr(> t)	OR	(95% CI)
Screen time (hours)		-0.02	0.02	0.298	0.98	(0.93–1.02)
Sex	Male	REF				
	Female	-0.21	0.06	< 0.01	0.81	(0.72–0.91)
Ethnicity	NZ European	REF				
	NZ Māori	-0.03	0.09	0.763	0.97	(0.81–1.16)
	Pacific	-0.15	0.10	0.131	0.86	(0.7–1.05)
	Asian	-0.61	0.10	< 0.01	0.54	(0.44–0.66)
Deprivation	1--2	REF				
	3--4	0.11	0.10	0.259	1.12	(0.92–1.35)
	5--6	0.05	0.10	0.588	1.06	(0.87–1.28)
	7--8	0.02	0.10	0.869	1.02	(0.84–1.23)
	9--10	-0.03	0.10	0.752	0.97	(0.79–1.18)
Baseline	0	REF				
	1	0.54	0.07	< 0.01	1.72	(1.49–1.98)
	2+	1.17	0.11	< 0.01	3.21	(2.59–3.98)

Emotional symptoms

		Estimate	Std. Error	Pr(> t)	OR	(95% CI)
Screen time (hours)		0.01	0.03	0.590	1.01	(0.96–1.07)
Sex	Male	REF				
	Female	0.00	0.08	0.958	1.00	(0.86–1.17)
Ethnicity	NZ European	REF				
	NZ Māori	0.48	0.11	< 0.01	1.61	(1.29–2.02)
	Pacific	1.03	0.12	< 0.01	2.81	(2.24–3.52)
	Asian	0.16	0.12	0.189	1.18	(0.92–1.5)
Deprivation	1--2	REF				
	3--4	-0.08	0.14	0.563	0.92	(0.7–1.22)
	5--6	-0.12	0.15	0.404	0.89	(0.67–1.18)
	7--8	0.13	0.14	0.333	1.14	(0.88–1.49)
	9--10	0.21	0.13	0.126	1.23	(0.95–1.6)
Baseline	Normal	REF				
	Borderline	0.82	0.10	< 0.01	2.28	(1.85–2.8)
	Abnormal	1.65	0.09	< 0.01	5.22	(4.34–6.28)

Hyperactivity

		Estimate	Std. Error	Pr(> t)	OR	(95% CI)
Screen time (hours)		0.07	0.02	< 0.01	1.07	(1.02–1.12)
Sex	Male	REF				
	Female	-0.35	0.07	< 0.01	0.71	(0.62–0.81)
Ethnicity	NZ European	REF				
	NZ Māori	0.43	0.10	< 0.01	1.53	(1.25–1.87)
	Pacific	0.40	0.11	< 0.01	1.49	(1.2–1.84)
	Asian	-0.18	0.12	0.125	0.84	(0.66–1.05)
Deprivation	1--2	REF				
	3--4	0.22	0.13	0.078	1.25	(0.98–1.6)
	5--6	0.14	0.13	0.260	1.16	(0.9–1.49)
	7--8	0.45	0.12	< 0.01	1.56	(1.23–1.99)
	9--10	0.56	0.12	< 0.01	1.75	(1.38–2.22)
Baseline	Normal	REF				
	Borderline	0.94	0.10	< 0.01	2.55	(2.11–3.07)
	Abnormal	1.51	0.08	< 0.01	4.52	(3.83–5.33)

Peer problems

		Estimate	Std. Error	Pr(> t)	OR	(95% CI)
Screen time (hours)		0.05	0.02	0.023	1.05	(1.01–1.1)
Sex	Male	REF				
	Female	-0.17	0.07	0.012	0.84	(0.73–0.96)
Ethnicity	NZ European	REF				
	NZ Māori	0.67	0.10	< 0.01	1.95	(1.6–2.38)
	Pacific	1.04	0.10	< 0.01	2.82	(2.3–3.46)
	Asian	0.73	0.10	< 0.01	2.08	(1.71–2.54)
Deprivation	1--2	REF				
	3--4	0.15	0.13	0.260	1.16	(0.9–1.51)
	5--6	0.14	0.13	0.311	1.14	(0.88–1.49)
	7--8	0.54	0.12	< 0.01	1.71	(1.34–2.19)
	9--10	0.71	0.12	< 0.01	2.04	(1.61–2.61)
Baseline	Normal	REF				
	Borderline	0.72	0.09	< 0.01	2.05	(1.71–2.45)
	Abnormal	1.17	0.08	< 0.01	3.24	(2.76–3.79)

Prosocial behaviour

		Estimate	Std. Error	Pr(> t)	OR	(95% CI)
Screen time (hours)		0.00	0.03	0.963	1.00	(0.94–1.06)
Sex	Male	REF				
	Female	-0.73	0.09	< 0.01	0.48	(0.4–0.58)
Ethnicity	NZ European	REF				
	NZ Māori	-0.09	0.14	0.508	0.91	(0.69–1.19)
	Pacific	-0.18	0.15	0.243	0.84	(0.62–1.12)
	Asian	-0.13	0.14	0.368	0.88	(0.67–1.15)
Deprivation	1--2	REF				
	3--4	0.07	0.15	0.612	1.08	(0.81–1.44)
	5--6	0.06	0.15	0.682	1.06	(0.79–1.44)
	7--8	0.16	0.15	0.267	1.18	(0.88–1.58)
	9--10	0.21	0.15	0.169	1.24	(0.92–1.67)
Baseline	Normal	REF				
	Borderline	0.96	0.12	< 0.01	2.60	(2.07–3.26)
	Abnormal	1.44	0.10	< 0.01	4.24	(3.47–5.17)

Appendix 3: Missing observations for each variable

	24 Months	54 Months
Sex	0 (0)	0 (0)
Ethnicity	0 (0)	0 (0)
Siblings	68 (1.3)	3 (0.1)
Deprivation	270 (5)	224 (4.1)
Rurality	268 (4.9)	224 (4.1)
Screen rules	643 (11.9)	5 (0.1)
Objectively measured body size	1020 (18.8)	356 (6.6)
Parent perceived body size	146 (2.7)	4 (0.1)
Motor skills	408 (7.5)	402 (7.4)
General health	145 (2.7)	1 (0)
Total doctor visits	178 (3.3)	2 (0)
Total illnesses	186 (3.4)	2 (0)
Total accidents	151 (2.8)	17 (0.3)
Emotional symptoms	147 (2.7)	0 (0)
Hyperactivity	148 (2.7)	0 (0)
Peer problems	148 (2.7)	0 (0)
Prosocial behaviour	148 (2.7)	0 (0)

Presented as n (%)