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Urban factors and mental health symptoms in children of the Tokyo Early Adolescence Survey; impact of proximity to railway stations.

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Abstract

The study tested the hypothesis that proximity of home to railway stations is a positive predictor of mental health at age 10 years. Using the Tokyo Early Adolescence Survey, we examined relationships between distance from home to the nearest railway station and SDQ (Strengths and Difficulties Questionnaire) scores for hyperactivity/inattention, prosocial behaviour and emotional symptoms. Greater distance to the nearest railway station was associated with higher SDQ-derived hyperactivity/inattention scores in the unadjusted analysis across all 4052 analyzable children ($p= 0.031$), and in the fully adjusted analysis in boys ($\beta= 0.186$, 95% C.I. 0.001 to 0.372, $p= 0.049$) but not in girls ($\beta= 0.020$, 95% C.I. -0.146 to 0.185, $p= 0.817$). There were no associations with other SDQ-based outcomes. If replicated, these findings suggest that access to high-quality transit may be associated with improved hyperactivity/inattention outcomes in children living in urban environments.

Key words

Hyperactivity; inattention; proximity; transit; population-based; child

Word Count: 5061

Introduction

There is an evolving literature on the association of the proximity of place of residence to specific urban features with mental health. For example, a recent study undertaken in Toronto, Canada (Chen et al., 2017), has reported that living near major roads is associated with increased incidence of dementia. People residing within 50 metres of a major road had the greatest risk, with a hazard ratio of 1.07 compared with residents living more than 300 metres away, with the association being strongest in urban areas. Proximity to main roads has also been associated with an increased risk of depressive symptoms in adults (Orban et al., 2016). Conversely there have been several studies which have examined the putative beneficial effects on mental health of living close to green space, such as parks (Abraham et al., 2010; Gascon et al., 2015). However, a recent study has suggested that the association of access to green space with good mental health may be true only for higher income neighbourhoods and not apply to poorer urban areas (Hassen, 2016).

Attention Deficit and Hyperactivity Disorder (ADHD) is a common illness in children. A meta-analysis estimated the prevalence of ADHD in children at around 7.2% (95% CI 6.7-7.8) (Thomas et al., 2015). The aetiology of ADHD has a strong genetic component, with heritability of 76% based on twin studies. Some environmental factors have been found to influence ADHD symptoms in children (O'Neill et al., 2017; Palladino et al., 2019) such as parenting style, parental psychopathology and socioeconomic status. Depression in childhood is becoming a significant health concern for child welfare. The estimated prevalence of depression in children is about 3% before adolescence (Merikangas, He, Brody, et al., 2010) and about 8% from 13 to 18 years old (Center for Behavioral Health Statistics and Quality, 2017; Merikangas, He, Burstein, et al., 2010). Child depression has a high rate of recurrence, it is associated with increased suicide risk, poor academic and social outcomes and physical problems such as obesity (Center for Behavioral Health Statistics and Quality, 2017; Egger et al., 1999; Rohde et al., 2013). There is some evidence pointing to increased rates of depression late in life in adults exposed to urban environments in early childhood, but less is known about how characteristics of the urban environment influence children's symptoms.

Few previous papers have examined geographical aspects of the social determinants of children's mental health but there have been a small number of studies examining the association of proximity to urban features with either a diagnosis of ADHD or of its constituent symptoms of Hyperactivity and Inattention. Baumgardner and colleagues (2010), found that children with ADHD were significantly more likely to live far from a park and from an airport than controls, but this association varied by region (urban, suburban and rural), moreover the study was limited to households included in an integrated health insurance database and could not be extrapolated to the entire population. Proximity to roads was examined by Skrzypek and colleagues who found associations for living within a 100 metre radius of a higher traffic density road with sleep disorders and ADHD (Skrzypek et al., 2017). Other authors have examined the effects of green space. Taylor and colleagues found that activities involving outdoor green space reduced symptoms of ADHD in children as per parents' ratings. Two small experimental studies found positive effects on ADHD symptoms following a brief exposure to green space (Faber Taylor & Kuo, 2009; van den Berg & van den Berg, 2011).

Duncan et al, examined the impact of proximity to several urban features on other aspects of adolescent mental health in Boston higher school students. They concluded that the built environment may have depressogenic effects, which can vary by gender and race or ethnicity although in general these effects are small (Duncan et al., 2013). They also highlighted that some observations were in the opposite direction to their expectations, for example they report a significant interaction between density of subway stops and the 'other' (biracial, multiracial or races/ethnicities other than white, black, Hispanic or Asian) category when predicting depressive symptoms, whereby in this group a higher density of subways stops within a 400 metre buffer was associated with an increase in depressive symptoms. They advocated for further research, which might better characterize the observed associations including those in the unexpected direction.

In the present study, conducted in a cohort of children aged around 10 years and resident in suburban areas in the Tokyo Metropolitan area, Japan, we examined the association of proximity of home to railway stations and mental health outcomes relating to hyperactivity, emotional symptoms and pro-social behaviour. Hyperactivity/inattention and emotional difficulties were selected because they gave a broad scope of children's mental state with respect to constituent symptoms of ADHD, depression and to a lesser extent, anxiety disorders. Given the lack of research on how proximity to nodes of transport may affect positive behaviour in children, we also included the prosocial behaviour subscale. We consider that railway stations represent both nodes of connectivity which allow access to high quality (frequent, rapid and safe) public transport, but also are typically surrounded by key places where people meet, socialize, engage in shopping, have coffee or meals or undertake other leisure activities. Accessible places such as community centres, coffee shops, restaurants, bars, cafes and shopping areas, which allow individuals to enjoy company and socialization make up an environment known as 'third place' (Oldenburg, 1999) in contrast to 'first place' (home) and ‘second place’ (work). A national telephone survey of a probability sample of 477 adults in the United States suggested an association between the perceived availability of third place and quality of life (Jeffres et al., 2009). While the term was originally coined to describe the appeal of such places to creative adults in the age range 18 – 50 years, it is likely that the benefits of such locations are also applicable to younger persons, especially in neighbourhoods which are safe and walkable. Thus, we anticipate that people of all ages, including the 10-year-old participants in the present study, may benefit from proximity to a railway station and its immediate surroundings, whether or not they are regular users of the available train services.

Aims/objectives/hypothesis

The study was designed to examine the hypothesis that proximity of home to railway stations is a positive predictor of mental health at age 10 years. In formulating this hypothesis, we have considered both the potential benefits for children’s mental health of proximity to stations through access to “third place” and to transportation, as well as counterbalancing issues such as exposure to air pollution and noise that might be associated with poor mental health. More specifically, we hypothesized that proximity to railway stations would be associated with lower scores for hyperactivity and for emotional problems, and higher scores for prosocial behaviour ascertained using the Strengths and Difficulties Questionnaire (SDQ).

Statement about ethics

The Tokyo Early Adolescence Survey (T-EAS) has received ethical approval from the Tokyo Metropolitan Institute of Medical Science (12-35), the University of Tokyo (10057), and SOKENDAI (Graduate University of Advanced Studies) (2012002).

Methods

Sample - Tokyo Early Adolescence Survey

We used data from a large population-based survey conducted in Japan, the Tokyo Early Adolescence Survey. The T-EAS is a multidisciplinary cross-sectional survey that focuses on health and development through puberty (Author et al., 2019; Author et al., 2016). The survey was conducted between October 2012 and January 2015. We recruited participants from three municipalities (Setagaya-ku, Mitaka-shi, and Chofu-shi) in the metropolitan area of Tokyo. Well-trained interviewers visited participants at home to obtain assent from the children and written informed consent from the caregivers. T-EAS participants included 4,478 children (2,100 girls and 2,378 boys) born between September 2002 and August 2004, and their primary caregivers. Among the consenting 4478 pairs of children and the caregivers, 386 (8.6%) were excluded from the study due to their moving away from the three municipalities. As a result, 4092 responses (91.4%) were usable for the current analysis.

Exposures

We identified two exposures of interest relating to the straight-line distance of a child's home to their nearest railway station. For the first of these, termed 'distance to any station' we ascertained the straight-line distance to the nearest of any of the 86 rail stations in or just outside the three Tokyo districts in which the cohort is located (for a map of the area, see Figure 1). For the second, termed 'distance to heavy rail stations' we excluded stations served only by the one light rail line in the cohort area (i.e. a low capacity rail service, similar to a tramway) thereby ascertaining the distance to the nearest of the 77 conventional or "heavy rail" stations within or close to the three Tokyo districts in which the cohort is based.

Distance to nearest railway station

To protect personally identifiable information, all data was anonymized and processed on an off-line computer (Bader et al., 2016). In order to 'geocode' participants' home addresses (i.e. obtain geographic co-ordinates), we first obtained the co-ordinates for all known residential addresses in the three Tokyo districts from open-source data. We then employed the 'generate near table' function in ArcGIS (ESRI 2011) to calculate distances from each address to the nearest railway station (all stations and then heavy rail stations only, with the location co-ordinates for the 86 railway stations described above being obtained from the website www.latlong.net). We then matched participants' addresses to their co-ordinates and the associated distances to stations on an off-line computer. Although the great majority of addresses (around 96%) of participants in the cohort could be matched to the co-ordinates and distances to the nearest station in this way, a small number could not be matched by the computer usually due to issues with the format of the recorded address. For these the distance from home addresses, where identifiable, to the nearest station and nearest heavy rail station were measured by hand using a detailed map of the area.

Outcomes

The Strengths and Difficulties Questionnaire is composed of 5 subscales: hyperactivity/inattention, emotional symptoms, conduct problems, peer problems and prosocial behaviour. Each subscale contains 5 items. The SDQ is a validated instrument to assess mental health in children and adolescents (Goodman, 2001), it has three different versions; for self-administration (for children between 11 and 16 years of age), or for completion by parents or teachers. We used the Japanese version of the SDQ (Matsuishi et al., 2008) with the parent as informant, which has been validated for the Japanese population (Moriwaki & Kamio, 2014). We selected three subscales: hyperactivity/inattention, emotional difficulties, and prosocial behaviour. The SDQ gives good dimensional estimates at the population level (Goodman & Goodman, 2009).

Covariates

We chose two covariates to further characterize the features of the nearest railway station and its immediate surroundings; trains per hour and Walk Score® (www.walkscore.com). 'Trains per hour' (TPH) was defined as the number of trains heading towards central Tokyo per hour, calculated by examining the morning railway timetables for specific one hour periods taking an average of a weekday rush hour and a holiday schedule. Pairs of adjacent stations on different lines were considered to constitute a single station for the purpose of calculating TPH, with the trains per hour on each line being added together. This covariate is related to station connectivity and its usefulness as a node in the transit system. Note that TPH was calculated separately for the two main exposures discussed above, i.e. a) trains per hour on all rail lines and b) trains per hour on 'heavy' rail lines only excluding the one light rail line. Walk Score is a well-researched indicator of walkability of the built environment. It is measured on a scale from 0 - 100 based on accessibility of destinations such as grocery stores, schools, parks, restaurants, and retail by walking (https://www.walkscore.com/professional/research.php) taking into account their distance and the 'pedestrian friendliness' and is therefore linked to the likelihood of undertaking basic errands on foot. Children in our sample were well under the age at which driving is permitted and therefore walkability of their neighbourhood is of high relevance. Walk Scores have been used to address the relationship between neighbourhoods and crime, to grade rail transit areas and have been used to assess geographical characteristics related to children's health (Duncan et al., 2011).

Demographic variables were included. Relating directly to the children were the child's age in completed months and IQ measured using two subsets (Information and Picture Completion) from the Weschler Intelligence Scale for Children (WISC-III). Relating to children via the parents were family annual income and education of the parent stated to be the main carer by self-report, hereafter referred to as the 'main parent'. The options for educational level were; elementary school, junior high school, senior high school, professional school, junior college (3 years), university (4 years) and postgraduate school and/or university (6 years). Family income was assessed by parental self-report and was dichotomized using a cut-off of 4 million Japanese yen per year (USD 37366, EUR 31200 at the time of analysis) as this was the closest figure to the national median household income for 2013 of 4.15 million Japanese Yen per year from the

Ministry of Health, Labour and Welfare National Livelihood Survey 2014. For a description of the sample's demographic characteristics see Table 1.

Stratification

We performed analyses a) unstratified and b) stratified by child gender only. There were no statistically significant interactions between gender and "distance to any station" with respect to the outcome variables. However, we believe both that there may be gender differences in how children are allowed to relate to their neighbourhoods in urban Japan, and that scores on some of the SDQ subscales differ markedly between boys and girls - notably for hyperactivity where scores across the cohort's population were significantly higher in boys. We therefore conducted analyses both of the whole sample (boys and girls) followed by separate analyses for boys and girls, in accordance with the recommendations of SAGER guidelines (Heidari et al., 2016), which mandate that associations should be reported separately by gender.

Statistical Analyses

We used STATA v.13 (StataCorp. 2013) to run linear regression models with 'distance to nearest station' in kilometres as exposure and measures of emotional symptoms, hyperactivity and prosocial behaviour derived from the Strengths and Difficulties Questionnaire as outcomes.

As described above, we generated models for all children, followed by separate models for boys and girls. We initially ran unadjusted models and then corrected for a) urban factors (Walk Score of nearest station and its connectivity measured by TPH), b) child factors (age at time of data acquisition, IQ and c) parental factors (family income and education level of the 'main parent') so that our final model was adjusted for all three of these sets of covariates.

Sensitivity analysis

As a sensitivity analysis, we repeated the above analysis with the second exposure measure of distance from the home address to the nearest 'heavy rail' station, thereby excluding stations served only by the single 'light-rail' line.

Missing data analysis

Multiple Imputation with Chained Equations (MICE) was used. Scores on the Child behaviour Checklist (Itani et al., 2001) depression/anxiety and attention problems subscales were used as auxiliary variables and 30 sets were calculated which were deemed sufficient given the low Fraction of Missing Information (FMI) in the sample (largest FMI = 0.013).

Results

Of the 4,092 children studied living in the three Tokyo districts where the cohort is based at the age of 10 years, for whom data was available, 3887 (95.0%) were matched by their address to our list of geocodes. A further 165 (4.0%) had addresses which were complete but could not be matched by the computer, and therefore proximity to nearest station was established by hand measurement on a conventional map. In total, addresses and distance to stations was ascertained for 4052 of 4092 participants, 99.0% of the sample. The mean distance from home to the nearest railway station was 864.8 metres (± 518.5 m) and the mean distance to the nearest 'heavy rail' station was 894.8 metres (± 504.9 m). There were 70 different railway stations which were the nearest to the home of at least one participating child, and of these 61 were heavy rail stations.

Among the 4052 analyzable participants, 3,779 (93.3%) had complete data for outcome (SDQ) variables and for covariates. There were 2018 boys (53.4%) and 1761 girls (46.6%). By a large majority, most children (91.1%) were from families categorized as 'higher income' (4 million yen or more per year)– with only 8.9% categorized as being from 'lower income' families (table 1). Gender differences in covariates in the sample were examined, there were no differences in children's age, family income, 'main parent' education or urban characteristics. However, girls had significantly lower scores in total IQ (difference = -2.527, 95%CI -3.43 to -1.62, $p < 0.001$).

Association of distance to nearest railway station with mental health outcome measures

The distance from home to the nearest railway station was associated with the SDQ hyperactivity/inattention score in all children in the unadjusted analysis (β-coefficient = 0.144, 95% C.I. 0.013 to 0.276, $p = 0.031$) (table 2). After adjustment for urban, child and parental factors there was no longer any association (β-coefficient = 0.093, 95% C.I. -0.037 to 0.224, $p = 0.162$). However, in boys (table 3A) there was an association both in the unadjusted model (β-coefficient = 0.226, 95% C.I. 0.036 to 0.416, $p = 0.020$) and after all levels of adjustment, including after adjustment for urban, child and parental factors (β-coefficient = 0.198, 95% C.I. 0.009 to 0.386, $p = 0.040$). In contrast there was no association in girls (unadjusted analysis: β-coefficient = 0.079, 95% C.I. -0.091 to 0.251, $p = 0.360$; adjusted analysis: β-coefficient = 0.007, 95% C.I. -0.164 to 0.177, $p = 0.940$).

Distance from home to the nearest railway station was not associated with the SDQ prosocial behaviour score either in all children (unadjusted analysis; β-coefficient= -0.048, 95% C.I. -0.174 to 0.078, $p = 0.452$; adjusted analysis: β-coefficient = -0.054, 95% C.I. -0.181 to 0.073, $p = 0.405$), in boys (unadjusted analysis; β-coefficient = -0.126, 95% C.I. -0.298 to 0.047, $p = 0.154$; adjusted analysis: β-coefficient= -0.144, 95% C.I. -0.318 to 0.030, $p = 0.105$), or in girls (unadjusted analysis; β-coefficient = 0.015, 95% C.I. -0.164 to 0.193, $p = 0.873$; adjusted analysis: β-coefficient = 0.027, 95% C.I. -0.154 to 0.207, $p = 0.772$).

Similarly, there was no robust association between distance from home to nearest station and the SDQ emotional symptoms score. The unadjusted analysis conducted in all children had a β-coefficient of 0.095 (95% C.I. -0.009 to 0.199, $p = 0.073$) and after full adjustment this weakened further (β-coefficient = 0.073, 95% C.I. -0.031 to 0.177, $p = 0.167$). There were no associations either in boys (unadjusted analysis; β-coefficient = 0.089, 95% C.I. -0.056 to 0.233, $p = 0.229$; adjusted analysis: β-coefficient = 0.080, 95% C.I. -0.065 to 0.224, $p = 0.280$), or in girls (unadjusted analysis; β-coefficient = 0.100, 95% C.I. -0.051 to 0.251, $p = 0.193$; adjusted analysis: β-coefficient = 0.059, 95% C.I. -0.091 to 0.210, $p = 0.439$).

Association of distance to nearest 'heavy rail' station with mental health outcome measures

The above analyses were repeated excluding stations served only by the lone low-capacity 'light rail' line, the exposure variable therefore being the distance from home to the nearest station served by a 'heavy rail' line. All of the results were similar to those obtained when all stations were included. Once again there was an association with proximity of the nearest 'heavy rail' station with SDQ hyperactivity scores in boys (β-coefficient = 0.201, 95% C.I. 0.005 to 0.396, $p = 0.044$) but not in girls. In general, the strength of the associations was slightly weaker than for the analysis that included all stations (analyses available on request).

Missing data analysis

Attrition analyses showed that 93% of the original sample, had complete data for exposures, outcomes and covariates. The most frequently missing variable was family income, missing in 5% of the sample and the SDQ scale which was missing in 2%. After imputation of missing data, there were no substantial changes to the reported associations of 'distance to any station' for any of the outcomes either in all children (table 2) or specifically in boys and girls (tables 3A, 3B).

Discussion

Our results suggest associations between distance from home to the nearest railway station and SDQ-derived hyperactivity/inattention scores in the unadjusted analysis across all children and in fully adjusted analyses in boys but not in girls. Increasing distance of home to railways stations was associated with higher hyperactivity/inattention scores in boys before and after correction for urban factors (trains per hour and Walk Score at nearest station), child factors (age and IQ) and parental factors (annual income and 'main parent' education).

However, the associations seen for the hyperactivity/inattention scores were not found with the other SDQ subscale outcomes. Neither the emotional symptoms subscale scores, nor the prosocial behaviour subscale scores were associated with distance from home to the nearest station. This suggests that any association we have found is specific to mental health symptoms congruent with ADHD only, rather than being related to mental health symptoms and behaviour in general.

There are various plausible explanations as to why proximity to a railway station might be associated with better outcomes with respect to mental health symptoms of hyperactivity and inattention. These include proximity to stations being associated with; 1) Improved quality of life in terms of better accessibility to other parts of Tokyo and destinations beyond, 2) Improved quality of life through access to the hub of social activity that stations represent, which as noted earlier is described by some authors as 'third place' (Jeffres et al., 2009; Oldenburg, 1999), 3) Access to the aggregation of higher IQ parents/families in locations closer to railways stations leading to more intellectual stimulation and the possibility to have more positive and stimulating peer-interaction, and 4) Parents who live close to stations spending less time on daily commute, more time interacting with children. All these social mechanisms could lead to consequent benefits of reducing the risk of children developing hyperactivity/inattention symptoms or indeed ADHD. There is some evidence that children with ADHD that engage in stimulating activities express fewer ADHD symptoms, proximity to a station can increase and facilitate the amount of activities the child is exposed to thereby reducing symptoms of hyperactivity or inattention (Amoly et al., 2014; Peralta et al., 2018). This effect may not be relevant to other psychiatric symptomatology such as depressive symptoms where motivation and not just availability of stimulus is also at play.

There has only been limited work on proximity to urban features and child mental health, and no previous studies of proximity to stations and hyperactivity and inattention symptoms. Duncan and colleagues (Duncan et al., 2013) examined these relationships in adolescents in an urban setting in the United States and reported that increased density of subway stations within 400 metres of home may be associated with increased depressive symptoms in one of the ethnic groups studied. However, Tokyo differs markedly from large cities in the USA in many ways. Firstly, there is much less heterogeneity of ethnicity. Secondly, in the United States and many other countries, but not in Japan, urban transit hubs may be especially associated with elevated risk of crime, a factor which opposes potential benefits of living close to good quality transit which we have described here. Thirdly, on the national level, Japan has substantially less inequality of family income distribution than the United States (e.g. as evidenced by a GINI index of 37.9, against 45.0 in the USA (C.I.A. 2018). Fourthly and of particular relevance in this study is Tokyo's lower prevalence of car ownership (18 cars per 100 residents) than comparable western cities (e.g. 31 per 100 residents in London and 56 per 100 residents in both Melbourne and Sydney) (Pan 2013). In some urban environments, many of the benefits of proximity to frequent and reliable rail transit that we have discussed might be delivered, irrespective of the location of the family home, by access to a motor vehicle, subject to the availability of an adult. The advantages of access to a private car must be considered against the negative health associations of car dependence (Kjellstrom & Hinde, 2006). In suburban Tokyo, the relatively low rates of car ownership are explained not only by the very high urban density and lack of space for car-parking, but also by the unusually high intensity and utility of its commuter railway network, with the 0.96 rail journeys per person per day undertaken in Tokyo greatly outnumbering journeys undertaken by bus (0.06 per person per day) and being a higher figure than that in any other major metropolis (e.g. New York 0.54, London 0.44 and Chicago 0.18 per person per day) (Pan 2013).

Results were similar in the sensitivity analysis where we considered only proximity to 'heavy rail' stations, thereby eliminating stations served only by the area's one light rail line. This suggests that benefits for children associated with proximity of their home to rail transit apply irrespective of the type of rail-based transit offered.

It is notable that the statistically significant association between distance of home to the nearest railway station and children's hyperactivity/inattention symptoms in the unadjusted analyses was attenuated after full adjustment for urban, child and parental factors, in the sample of all children but persisted in boys but not in girls. This finding may relate both to the SDQ instrument capturing significantly lower hyperactivity/inattention symptoms in girls compared with boys, and to the possibility that there are gender-related differences in exposure to a child's surrounding environment and/or its impact on mental health and behaviour that are particular to the context of family life in Japan.

Strengths of the study include 1) the use of a population-based sample of eligible children, 2) approximately 99% of participants' addresses were usable for the geographic analyses, 3) we confirmed the results using imputation for missing data for the 6.8% of individuals who lacked full ascertainment of outcome or covariate scores.

Limitations of the study are as follows: 1) We used 'Straight line' distance rather than actual walking distance between participants' home and their nearest station. However, the Tokyo suburban street network is dense with very short block lengths and access to stations in the area studied is not impeded by major natural obstacles such as large rivers, lakes or mountains, and very rarely by man-made obstacles. For example, express highways which cannot be crossed on foot are usually elevated in the neighbourhoods studied allowing pedestrians to cross underneath. Therefore, we believe that this limitation was likely to have had little impact on the results. 2) As we have discussed in contrasting our results to those of Duncan et al., (2013), the transferability of the findings to other cities can be questioned, since Tokyo has high use of public transit (especially trains) relative to car use, low ethnic heterogeneity, and lower inequality of family income and lower rates of crime at least compared with many urban settings in the Americas where crime rates are pervasively higher. Note also that the mean distance to the nearest station was only 874 metres, or just over half a mile, which illustrates the unusually high density of the suburban railway network in this part of the Tokyo metropolitan area. 3) We controlled for parental IQ since it is associated with shorter distances from home to the nearest station, but the possibility of residual confounding remains. We also controlled for income. This variable is not co-linear with distance to the nearest railway station, since property values in suburban Tokyo are linked not only to the proximity to stations, but also to plot or unit size, which tend to be larger at greater distance from stations, and to distance from the centre of the Tokyo Metropolitan area, with inner suburbs generally commanding higher prices than similarly sized units in more distant areas. In our sample while children in lower income families lived on average slightly further (difference = 41.1 metres) from the nearest station than those in higher income families, this difference was not statistically significant ($p = 0.168$), illustrating the lack of association between income and proximity to railway stations. 4) Families recorded as being of lower income comprised only 8.9% of the child/parent pairs for whom data was available at 10 years. This reflects the issue that not only is the Tokyo Metropolitan area economically more prosperous than many other regions of Japan, but additionally the Tokyo Early Adolescence Survey is based in three relatively wealthy districts of the metropolis, where the average family earns well over the median national annual income. In addition, many cohort studies see lower participation rates and greater attrition rates over time in participants or families who are economically less prosperous (Howe et al., 2013). 5) While the relationships we have described suggest evidence of an association the design of the present study does not permit causality to be inferred, and it remains possible that the associations could be explained by reverse causality (i.e. families who have children with hyperactivity/inattention symptoms being more likely to live further from a railway station). However, the Tokyo Early Adolescence Survey and the related Tokyo Teen Cohort is a longitudinal study which will be collecting data at several time-points as the participants grow into adolescence and adulthood and it should be possible to examine these relationships longitudinally in future studies.

Conclusions

In children aged around 10 years we report associations between the distance from home to the nearest railway station and the mental health related outcome of hyperactivity/inattention symptoms ascertained using the Strengths and Difficulties Questionnaire. Associations were found for the whole sample in the unadjusted analysis, and after full adjustment for urban, child and parental factors, in boys but not in girls. There were no associations with other mental health-related outcomes (emotional symptoms and prosocial behaviour). While the characteristics of the urban setting studied is unique to Japan, these findings deserve further study in other urban environments. If replicated, these associations suggest that access to environments featuring the availability of high-quality transit may be associated with improved hyperactivity/inattention outcomes in children, and the intriguing possibility that an additional benefit of transit-oriented developments in urban settings may be a positive impact on this important aspect of children's mental health.

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Table 1: Demographic, Parental and Urban characteristics of participating children stratified by gender. Table includes the 3779 participants who had complete data for SDQ subscales and all child and parental covariates (age, IQ, family income and parental education).

	Boys (N = 2018, 53.4%)		Girls (N = 1761, 46.6%)		P-value for comparison	All participants (N = 3779, 100.0%)	
	Mean ± SD or N	Range or (%)	Mean ± SD or N	Range or (%)		Mean ± SD or N	Range or (%)
Demographic Characteristics							
Age (completed months)	122.27 ± 3.38	115-132	122.13 ± 3.27	115-131	$p = 0.195$	122.20 ± 3.33	115-132
IQ scores	108.82 ± 14.60	54.2-146.3	106.30 ± 13.69	50.9-144.3	$p < 0.001$	107.65 ± 14.19	50.9-146.3
Parental Characteristics							
Family income (¥/year)					$p = 0.226$		
<3,990,000	190	(9.4)	146	(8.3)		336	(8.9)
>=4,000,000	1828	(90.6)	1615	(91.7)		3443	(91.1)
Main parent† education level					$p = 0.072$		
Elementary school	12	(0.6)	11	(0.6)		23	(0.6)
Junior high school	14	(0.7)	18	(1.0)		32	(0.8)
Senior high school	323	(16.0)	257	(14.6)		580	(15.3)
Professional school	517	(25.6)	429	(24.3)		946	(25.0)
Junior college	366	(18.1)	303	(17.2)		669	(17.7)
University	728	(36.1)	672	(38.1)		1400	(37.0)
Postgraduate school	58	(2.9)	71	(4.0)		129	(3.4)
Urban Characteristics							
Distance to nearest station (km)	0.8606 ± 0.5151	0.0549- 2.8040	0.8754 ± 0.5302	0.0138- 2.7700	$p = 0.383$	0.8675 ± 0.5222	0.0138-2.8040
Walk Score of nearest station	90.65 ± 7.06	54-99	90.78 ± 6.97	54-99	$p = 0.570$	90.71 ± 7.02	54-99
Trains per hour (TPH) at nearest station	11.43 ± 6.03	5-38.5	11.67 ± 6.43	5-38.5	$p = 0.240$	11.55 ± 6.22	5-38.5

† 'Main parent' refers to the parent who is reported to be the child's main carer and is not necessarily the parent with the higher education level.

Table 2. β-coefficients and 95% confidence intervals for the association between distance to nearest railway station and mental health in the full sample (with no stratification). Mental health scores measured as a continuous variable of the hyperactivity/inattention, prosocial behaviour and emotional symptoms subscales of the Strengths and Difficulties Questionnaire (SDQ), distance to nearest station measured in kilometres.

Variables	Unadjusted	(1) Adjusted for urban factors	(2) Adjusted for (1) and child factors	(3) Adjusted for (1), (2) and parental factors	Fully Adjusted Imputed Sample
Observations	3779	3779	3779	3779	4052
Hyperactivity/inattention					
Distance to nearest station (km)	0.144	0.151	0.117	0.093	0.100
Confidence interval	0.013 to 0.276	0.019 to 0.283	-0.014 to 0.248	-0.037 to 0.224	-0.025 to 0.226
R-squared	0.0012	0.0025	0.016	0.0265	0.0669
p	0.031	0.024	0.081	0.162	0.117
Prosocial behaviour					
Distance to nearest station (km)	-0.048	-0.062	-0.064	-0.054	-0.064
Confidence interval	-0.174 to 0.078	-0.189 to 0.064	-0.191 to 0.063	-0.181 to 0.073	-0.186 to 0.059
R-squared	0.0002	0.0021	0.0028	0.0045	0.0337
p	0.452	0.336	0.326	0.405	0.308
Emotional symptoms					
Distance to nearest station (km)	0.095	0.099	0.085	0.073	0.058
Confidence interval	-0.009 to 0.199	-0.006 to 0.203	-0.019 to 0.190	-0.031 to 0.177	-0.043 to 0.160
R-squared	0.0009	0.0016	0.0096	0.0193	0.0207
p	0.073	0.064	0.109	0.167	0.261

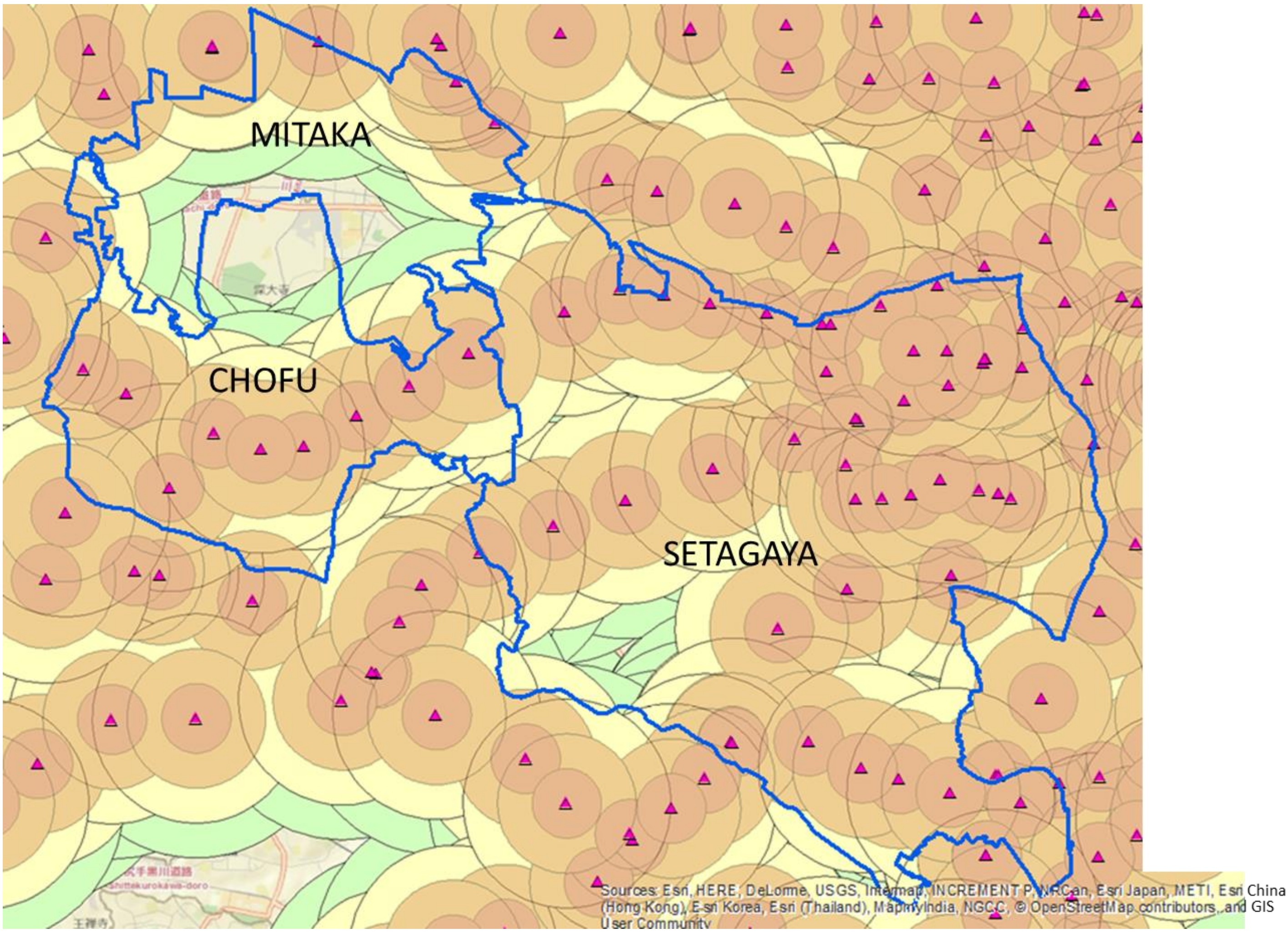
Table 3A. β-coefficients and 95% confidence intervals for the association between distance to nearest railway station and mental health in BOYS. Mental health scores measured as a continuous variable of the hyperactivity/inattention, prosocial behaviour and emotional symptoms subscales of the Strengths and Difficulties Questionnaire (SDQ), distance to nearest station measured in kilometres.

Variables	Unadjusted	(1) Adjusted for urban factors	(2) Adjusted for (1) and child factors	(3) Adjusted for (1), (2) and parental factors	Fully Adjusted Imputed Sample
Observations	2018	2018	2018	2018	2162
Hyperactivity/inattention					
Distance to nearest station (km)	0.226	0.248	0.209	0.198	0.186
Confidence interval	0.036 to 0.416	0.057 to 0.438	0.020 to 0.399	0.009 to 0.386	0.001 to 0.372
R-squared	0.0027	0.0072	0.0309	0.0386	0.0359
p	0.020	0.011	0.030	0.040	0.049
Prosocial behaviour					
Distance to nearest station (km)	-0.126	-0.150	-0.148	-0.144	-0.141
Confidence interval	-0.298 to 0.047	-0.323 to 0.024	-0.321 to 0.264	-0.318 to 0.030	-0.311 to 0.029
R-squared	0.001	0.005	0.0053	0.0056	0.0054
p	0.154	0.091	0.096	0.105	0.105
Emotional symptoms					
Distance to nearest station (km)	0.089	0.089	0.081	0.080	0.075
Confidence interval	-0.056 to 0.233	-0.056 to 0.234	-0.063 to 0.227	-0.065 to 0.224	-0.065 to 0.215
R-squared	0.0007	0.001	0.0076	0.017	0.0161
p	0.229	0.227	0.271	0.280	0.295

Table 3B. β-coefficients and 95% confidence intervals for the association between distance to nearest railway station and mental health in GIRLS. Mental health scores measured as a continuous variable of the hyperactivity/inattention, prosocial behaviour and emotional symptoms subscales of the Strengths and Difficulties Questionnaire (SDQ), distance to nearest station measured in kilometres.

Variables	Unadjusted	(1) Adjusted for urban factors	(2) Adjusted for (1) and child factors	(3) Adjusted for (1), (2) and parental factors	Fully Adjusted Imputed Sample
Observations	1761	1761	1761	1761	1890
Hyperactivity/inattention					
Distance to nearest station (km)	0.079	0.073	0.038	0.007	0.020
Confidence interval	-0.091 to 0.251	-0.099 to 0.245	-0.133 to 0.209	-0.164 to 0177	-0.146 to 0.185
R-squared	0.0005	0.001	0.0136	0.0266	0.0272
p	0.360	0.405	0.666	0.940	0.817
Prosocial Behaviour					
Distance to nearest station (km)	0.015	0.012	0.014	0.027	0.014
Confidence interval	-0.164 to 0.193	-0.168 to 0.191	-0.166 to 0.194	-0.154 to 0.207	-0.162 to 0.190
R-squared	0	0.0005	0.0009	0.0038	0.0046
p	0.873	0.898	0.876	0.772	0.873
Emotional symptoms					
Distance to nearest station (km)	0.100	0.106	0.086	0.059	0.031
Confidence interval	-0.051 to 0.251	-0.046 to 0.257	-0.065 to 0.237	-0.091 to 0.210	-0.116 to 0.178
R-squared	0.001	0.0028	0.012	0.0267	0.0289
p	0.193	0.171	0.263	0.439	0.676

Figure: Map of the three Tokyo wards or cities where the Tokyo Early Adolescence Survey is based, showing locations of railway stations (red triangles) in and around these areas. Among the stations illustrated, locations of 86 stations in or just outside three districts were used to calculate proximity of participants home address to the nearest station. Colour shading indicates the straight-line distance to the nearest railway station; less than 500 metres (dark orange), 501-1000 metres (light orange), 1001-1500 metres (yellow), 1501-2000 metres (green) and >2000 metres (unshaded). Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors and GIS User Community.



Scale: 1000m = ◆——◆

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Acknowledgements

We thank Gerard Romme, University of Toronto for his support with using ArcGIS software. We are grateful to Professor Kwame McKenzie of the Wellesley Institute and University of Toronto, for his general support and discussions of factors relating to the impact of environment on mental health. This work was supported by a Grant-in-Aid for Scientific Research on Innovative Areas (23118002; Adolescent Mind & Self-Regulation) from the Ministry of Education, Culture, Sports, Science, and Technology of Japan; Japan Society for the Promotion of Science (JSPS) KAKENHI (grant numbers JP16H06395, 16H06398, 16H06399, 16K21720, 16K15566, 16H03745, 17H05931, JP19H04877, 20H03951, 20H03596, 20H01777, and 21H00451); the UTokyo Center for Integrative Science of Human Behavior (CiSHuB); and the International Research Center for Neurointelligence (WPI-IRCN) at the University of Tokyo Institutes for Advanced Study (UTIAS).

Declarations of Interest

None