Neighborhood-level socioeconomic factors moderate the mitigating role of physical activity in the relative age effect: A cross-sectional survey study of early adolescents in widespread areas of Japan

Takaaki Mori
Doshisha University
Takumi Aoki
Miyagi Gakuin Women's University
Kan Oishi
Doshisha University
Tetsuo Harada
Kochi University
Chiaki Tanaka
Tokyo Kasei Gakuin University
Shigeho Tanaka
Kagawa Nutrition University
Hideki Tanaka
Hiroshima International University
Kazuhiko Fukuda
Edogawa University
Yasuko Kamikawa
University of Toyama
Nobuhiro Tsuji
Shiga University
Keisuke Komura
Meijo University
Shohei Kokudo
Chukyo University
Noriteru Morita
Hokkaido University of Education
Kazuhiro Suzuki
Miyagi Gakuin Women's University

Masashi Watanabe
Ibaraki University
Ryoji Kasanami
Nara University of Education
Taketaka Hara
Shimane University
Ryo Miyazaki
Shimane University
Takafumi Abe
Shimane University
Koji Yamatsu
Saga University
Daisuke Kume
Osaka Institute Technology
Hedenori Asai
Ehime University
Naofumi Yamamoto
Ehime University
Taishi Tsuji
University of Tsukuba
Tomoki Nakaya
Tohoku University
Kojiro Ishii (kishii@mail.doshisha.ac.jp)
Doshisha University

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Abstract

Background: Relative age effect is defined as a phenomenon where children born early generally perform better than children born later in the same cohort. Physical activity is an important factor that mitigates the relative age effect. Socioeconomic factors (e.g., parent's income, education level) are also associated with the adolescent's physical activity. However, no existing study has examined whether socioeconomic factors moderate the relative age effect on the adolescent's physical activity. This study aims to clarify how birth month and socioeconomic factors moderate sports and physical activity among adolescents in Japan.

Methods: We conducted a questionnaire survey targeting 21491 adolescents who live in a widespread neighborhood. We included 7138 adolescents (3701 males and 3437 females: mean age 13.06±1.44) in the analysis. Based on the participants' birth month, we divided them into four groups (April-June, July-September, October-December, January-March). We asked participants to report their organized sports participation. Using the International Physical Activity Questionnaire for Japanese Early Adolescents, we identified their levels of sports activity and moderate to vigorous physical activity (MVPA). Neighborhood-level socioeconomic factors (areal deprivation, average annual income, education level) were analyzed based on national surveys, such as the population census. We performed multilevel logistic and linear regression analysis for organized sports participation and MVPA, respectively. Moreover, a simple slope analysis was implemented if the interaction between birth month and socioeconomic factor was significant in the multilevel linear regression analysis.

Results: Among relatively younger adolescents (adolescents who were born later in the same grade), females were less likely to participate in organized sports activities (OR=0.91, 95% CI 0.85-0.98, $p<0.01$), while both males and females engaged in less MVPA ($b=-4.08$, $b=-2.50$, $p<0.01$, respectively). We observed an interaction between birth month and socioeconomic factors. Only low-income participants, females from more deprived neighborhoods, and relatively younger adolescents engaged in less MVPA.

Conclusions: Socioeconomic factors moderate the relative age effect on adolescents' physical activity. The relative age effect on adolescents' physical activity might be more likely to appear among adolescents from socioeconomically disadvantaged neighborhoods.

Background

In Japan, children enroll in school in April; the school year begins on April 2 and ends on April 1 of the following year. Thus, children born between January 1 and April 1 are younger by almost a year than those born at the beginning of the school year. Relative age effect is defined as gaps caused due to chronological age differences among students of the same grade [1]. This phenomenon presupposes that children born early in a cohort generally perform better than those born later in the same cohort. This may occur as children born between January 1 and April 1 may exhibit poorer physique and physical fitness. Many previous studies showed that those who were born later are likely to have poor scholastic

ability and poor socio-emotional development [2, 3]. Ultimately, the relative age effect remains until adulthood. For example, individuals born later were found to be less likely to go to university at the age of 18 years [2]. Other previous studies have shown that the distribution of the birth month of athletes across different sports was unbalanced, indicating a higher proportion of athletes born earlier in the academic year than those born later [1, 4, 5]. Therefore, it is essential to understand the relative age effect and to strive to mitigate the disadvantages caused by the relative age effect from childhood.

A Japanese study reported that the relative age effect of physical fitness exists among general Japanese primary school students regardless of sex and age; thus, birth month and level of sports activity can be considered as factors that explain the inequality in physical fitness [6]. In contrast, another study showed that relatively younger adolescents, with better physical fitness than relatively older adolescents, are likely to participate more in physical activities. This indicates that physical activity might be an important factor that mitigates the relative age effect [7].

Socioeconomic status (SES), such as parents' income and education level, is one of the factors that influences adolescents' physical activity [8–10]. Adolescents with low SES are more likely to engage in less physical activity than adolescents with high SES. In addition, neighborhood socioeconomic factors are associated with healthy behavior. Since socioeconomically disadvantaged neighborhoods tend to have insufficient recreational facilities and few opportunities for individuals to participate in sports activities [11–13], adolescents might be more influenced by birth month in socioeconomically disadvantaged neighborhoods, where the relative age effect can be seen more clearly. However, no study has examined how birth month and socioeconomic factors influence adolescents' sports and physical activities. There are few race/ethnic minorities in Japan, while economic disparity has widened with the increase in poverty [14]. Therefore, this study's purpose was to clarify whether birth month and socioeconomic factors are related to the sports activity and physical activity of adolescents who live in widespread areas of Japan.

Methods

Target area and sample

Japan mainly consists of eight regions (Hokkaido, Tohoku, Kanto, Chubu, Kinki, Chugoku, Shikoku, and Kyushu). The Ministry of Internal Affairs and Communications of Japan determined city scale based on city population and classified cities as follows: large city (population of more than 500 thousand), core city (population of 200–500 thousand or prefectural capital), medium city (population of 100–200 thousand), small city (population of 10–100 thousand), and town and village (population of less than 10 thousand) [15].

Our research team comprised 18 researchers from 15 research institutions. We conducted a questionnaire survey of 11- to 18-year-old adolescents from 76 schools in Japan between 2017 and 2019 from the eight regions of Japan [16]. We obtained 21491 questionnaire responses. We excluded 3598 national primary

school and secondary school students and 9473 high school students from this study because it was difficult to specify the school district clearly. We also excluded 1282 adolescents due to missing data. As a result, 7138 adolescents (3701 males and 3437 females from 48 schools) were included in the analysis (Fig. 1).

Individual-level characteristics

We obtained information regarding participants' sex, birth year, birth month, height, body weight, and recreational activity as basic information. We divided birth month into four groups: Q1 (April to June), Q2 (July to September), Q3 (October to December), and Q4 (January to March). We calculated the body mass index percentile by sex and age from the height and body weight. Those with a body mass index above 85 percentile or more were categorized as being overweight [17]. We asked participants to report their organized sports participation. Those who participated in least one organized sports activity were categorized (e.g., school sports club activity, neighborhood sports group activity, private sports lesson) as "Active," and those who did not participate in any sports activities were categorized as "Inactive."

We used the International Physical Activity Questionnaire for Japanese Early Adolescents to assess students' level of physical activity. We also asked students, "How often and how long do you spend engaging in moderate physical activity and vigorous physical activity per week?" [18]. We computed individual physical activity per day by multiplying each participant's frequency of physical activity with the duration of physical activity per week. Moderate to vigorous physical activity (MVPA) was defined as the sum of moderate physical activity and vigorous physical activity per day [19].

Neighborhood-level characteristics

Each board of education in Japan determines the school district based on geographical conditions (e.g., streets and rivers), neighborhood traditions, and residents' preferences [20]. We defined a school district as a neighborhood unit because the size of the school district corresponded to the daily living area [21, 22]. Public school students in Japan must especially go to their designated school as per their residential address, and they are instructed not to go out of their school district without their guardians [23].

To apply the results of the national study data collected by the municipalities or by the block (*cho-cho-aza*), we conducted weighting interpolation with a geographic information system (Fig. 2). First, we overlapped a block-level neighborhood factor and school district polygon data. Then, we computed scores by the ratio of the size of the overlapped area per size of each school district. We calculated the mean of the overlapped area in the school district as the school district level score.

In Japanese culture, asking someone's academic background or income is frowned upon. A previous study in Japan also reported that only a few participants reported their academic background and income [24]. Thus, we substituted three neighborhood socioeconomic factors: areal deprivation, neighborhood education level, and average annual income. Areal deprivation is an index that reflects the relative size of poor household ratio. We used the Areal Deprivation Index (ADI), a weighted index wherein the following eight variables were associated with poverty from the Population Census in 2010:

proportion of elderly single households, elderly couple households, single mother households, rental housing households, sales and service workers, agricultural workers, blue-collar workers, and unemployed persons [25–27]. We overlapped block-level ADI and school district data and calculated the mean of each block that was composed in a school district as neighborhood ADI. To avoid instability of ADI in neighborhoods where very few households exist, we weighted neighborhood ADI with the number of general households based on normalized ADI. In addition, we obtained data regarding income and estimated the average annual income from the Housing and Land Survey in 2013 and the Population Census in 2015 [28, 29]. The division of the population according to income consisted of six classes: less than 3 million yen, 3–5 million yen, 5–7 million yen, 7–10 million yen, 10–15 million yen, and more than 15 million yen. We multiplied the class value by the number of households in each income class, summed up the product, and divided it by the number of general households in the school districts. We estimated block-level income data by overlapping the municipality-level income data obtained from the Housing and Land Survey in 2013 and block-level population data from the Population Census in 2015. Then, we overlapped block-level income data and school district data and calculated neighborhood-level income data. Furthermore, we calculated the proportion of people who graduated from university or graduate school as a neighborhood education level from the Population Census in 2015. Finally, we referred to population data from the Population Census in 2015 [28] and calculated the population density of school districts.

Statistical analysis

Since this study included both individual-level and neighborhood-level variables, we used multilevel modeling. First, we examined only the birth month (Model 1) to calculate the interclass correlation coefficient. Then, we added each socioeconomic factor to Model 1 (Model 2; Model 2a: Areal deprivation; Model 2b: Average annual income; Model 2c: neighborhood education level). Furthermore, we examined the cross-level interaction between birth month and each socioeconomic factor (Model 3). To prepare for multilevel regression analysis, we used the centering method for all independent variables and covariates.

We conducted multilevel logistic regression analysis to examine whether adolescent organized sports participation was associated with birth month and socioeconomic factors. We estimated a 95% confidence interval (95% CI) using the Wald test. We also ran multilevel linear regression analysis to clarify whether adolescent MVPA was related to birth month and socioeconomic factors. If statistical significance was observed, we conducted a simple effect analysis [30]. To express cross-level interaction, we estimated a single slope of the birth month at mean ± 1 standard deviation [31].

All models were conducted by sex, and we adjusted for the following covariates: age, body weight, and population density. Furthermore, we added sports activity to the multilevel linear regression model as a covariate. We conducted statistical analysis using EZR (Easy R) [32], and statistical significance was set at $p < 0.05$.

Results

Table 1 shows the individual-level characteristics of the study participants. The mean age was almost the same for males and females, and few adolescents were overweight. Regardless of sex, the distribution of age at birth was unbiased. Of the participants, 77.4% were males, and 52.5% were females. Average MVPA time was 78.9 ± 69.1 min/day for males and 55.4 ± 69.9 min/day for females. Table 2 shows the neighborhood-level characteristics of this research.

Table 1. The individual-level characteristics of current research participants

	Males (n=3701)		Females (n=3437)	
	Mean or %	SD	Mean or %	SD
Individual characteristics				
Age(years)	13.1	1.4	13.0	1.4
Height(cm)	154.5	12.0	151.0	7.9
Body mass index percentile	41.2	28.2	38.6	27.1
Weight status				
Overweight	10.0%		7.0%	
Non-Overweight	90.0%		93.0%	
Birth month				
Q1(April-June)	25.0%		24.7%	
Q2(July-September)	27.7%		27.0%	
Q3(Octorber-December)	22.9%		23.6%	
Q4(January-March)	24.5%		24.7%	
Organized sports participation				
Active	77.4%		52.5%	
Inactive	22.6%		47.5%	
MVPA time(min/day)	78.9	69.1	55.4	69.9

SD: standard deviation, MVPA: moderate-to-igorous physical activity

Table 2. The neighborhood-level characteristics of the participating schools in this study (48 schools)

	Mean	SD
Areal deprivation	42.4	25.8
Education level (%)	15.1	6.8
Average annual income ($\times 10^4$ yen)	548.1	50.6
Population density (/ha)	12.7	19.3

SD: standard deviation

Tables 3 and 4 show the results of multilevel logistic regression analysis: whether males' birth month was not associated with organized sports participation (Model 1, Table 3) and relatively younger females were less likely to participate in sports activities (Odds Ratio [OR] = 0.91, 95% CI 0.85–0.98, $p < 0.01$, Model 1, Table 4). Though there was an association between birth month and adolescent sports activity, none of the socioeconomic factors were associated with adolescent organized sports participation (Model 2).

Table 3. Estimates from multilevel logistic modeling for male adolescents' organized sports participation (n = 3701)

	Model 1 OR(95%CI)	Model 2a OR(95%CI)	Model 2b OR(95%CI)	Model2c OR(95%CI)
Fixed effects				
Intercept	2.88 (2.13–3.89) **	2.87 (2.11–3.89) **	2.88 (2.12–3.90) **	2.91 (2.15–3.94) **
Birth month	0.93 (0.85–1.00)	0.93 (0.85–1.00)	0.93 (0.85–1.00)	0.93 (0.86–1.00)
Socioeconomic factor				
Areal deprivation		1.00 (0.99–1.01)		
Average annual income			1.00 (0.99–1.01)	
Education level				1.01 (0.96–1.06)

OR: odds ratio, 95%CI: 95% confidence interval

Model 1: Only birth month was considered. No socioeconomic factor was added.

Model 2: Birth month and one Socioeconomic factor(Model2a: Areal deprivation, Model2b: Average annual income, Model2c: Education level)

All models were adjusted for age, body weight, population density.

** $p<0.01$, Interclass correlation coefficients=0.16, Design effect=12.87

Table 4. Estimates from multilevel logistic modeling for female adolescents' organized sports participation (n = 3437)

	Model 1 OR(95%CI)	Model 2a OR(95%CI)	Model 2b OR(95%CI)	Model 2c OR(95%CI)
Fixed effects				
Intercept	0.90 (0.71–1.15)	0.90 (0.70–1.15)	0.90 (0.70–1.15)	0.89 (0.70–1.14)
Birth month	0.91 (0.85–0.98) **	0.91 (0.85–0.98) **	0.91 (0.85–0.98) **	0.91 (0.85–0.98) **
Socioeconomic factor				
Areal deprivation		1.00 (0.99–1.01)		
Average annual income			1.00 (0.99–1.00)	
Education level				0.99 (0.95–1.03)

OR: odds ratio, 95%CI: 95% confidence interval

Model 1: Only birth month was considered. No socioeconomic factor was added.

Model 2: Birth month and one Socioeconomic factor(Model2a: Areal deprivation, Model2b: Average annual income, Model2c: Education level)

All models were adjusted for age, body weight, population density.

** $p<0.01$, Interclass correlation coefficients=0.10, Design effect=7.99

Tables 5 and 6 show the estimated adolescent MVPA from multilevel linear modeling. Relatively younger adolescents reported negative associations with MVPA for both males (b = -4.08, p < 0.01) and females (b = -2.50, p < 0.01). No association was found between socioeconomic factors and adolescent MVPA. Furthermore, we used cross-level interaction modeling in order to examine whether neighborhood-level socioeconomic factors moderated the association between birth month and adolescent MVPA. We observed significant cross-level interaction between birth month and areal deprivation for only females (b = -0.07, p < 0.01, Table 6). Only relatively younger females in more deprived areas were likely to spend less MVPA (b = -4.21, p < 0.01, Fig. 3); no significant association was observed in less deprived areas. Further, there was a significant interaction between birth month and average annual income among both males (b = 0.03, p < 0.05, Table 5) and females (b = 0.02, p < 0.05, Table 6). Relatively younger adolescents in low-income neighborhoods reported associations with less MVPA time (males: b = -4.68, p < 0.01, females: b = -3.99, p < 0.01, Fig. 4), compared to those in high-income neighborhoods. No interaction was found between birth month and education level for MVPA among both males and females.

Table 5. Estimates from multilevel linear modeling for male adolescents' Moderate-to-Vigorous Physical Activity (MVPA) (n = 3701)

	Model 1 b(SE)	Model2a b(SE)	Model 2b b(SE)	Model 2c b(SE)	Model 3a b(SE)	Model 3b b(SE)	Model3c b(SE)
Fixed effects							
Intercept	72.68 (4.24) **	73.07 (4.38) **	72.81 (4.30) **	73.75 (4.37) **	73.05 (4.38) **	72.81 (4.30) **	73.75 (4.37) **
Birth month	-4.08 (0.95) **	-4.03 (0.95) **	-4.05 (0.95) **	-4.02 (0.95) **	-4.02 (0.95) **	-4.03 (0.95) **	-4.02 (0.95) **
Socioeconomic factor							
Areal deprivation		-0.13 (0.11)			-0.12 (0.08)		
Average annual income			0.03 (0.06)			0.03 (0.06)	
Education level				1.07 (0.55)			1.07 (0.55)
Cross-level interaction							
Birth month*Areal Deprivation					-0.04 (0.03)		
Birth month*Average annual income						0.03 (0.01) *	
Birth month*Education Level							0.01 (0.17)

SE: Standard error

Model 1: Only Birth month was considered. No Socioeconomic factor was added.

Model 2: Birth month and one Socioeconomic factor(Model2a: Areal deprivation, Model2b: Average annual income, Model2c: Education level)

Model 3: Birth month, one Socioeconomic factor and one Cross-level interaction (Model3a: Birth month*Areal deprivation, Model3b: Birth month* Average annual income, Model3c: Birth month*Education level)

All models were adjusted for age, body weight, organized sports participation, population density.

** p<0.01, * p<0.05, Interclass correlation coefficients=0.10, Design effect=8.41

Table 6. Estimates from multilevel linear modeling for female adolescents' Moderate-to-Vigorous Physical Activity (MVPA) (n = 3437)

	Model1 b(SE)	Model 2a b(SE)	Model 2b b(SE)	Model 2c b(SE)	Model3a b(SE)	Model3b b(SE)	Model 3c b(SE)
Fixed effects							
Intercept	48.47 (3.61) **	48.50 (3.65) **	48.45 (3.61) **	48.69 (3.66) **	48.5 (3.64) **	48.46 (3.61) **	48.46 (3.66) **
Birth month	-2.50 (0.80) **	-2.50 (0.80) **	-2.50 (0.80) **	-2.5 (0.80) **	-2.5 (0.80) **	-2.48 (0.80) **	-2.47 (0.80) **
Socioeconomic factor							
Areal deprivation		-0.01 (0.08)			-0.01 (0.08)		
Average annual income			-0.01 (0.04)			-0.01 (0.04)	
Education level				0.18 (0.38)			0.16 (0.38)
Cross-level interaction							
Birth month*Areal Deprivation					-0.07 (0.03) **		
Birth month*Average annual income						0.02 (0.01) *	
Birth month*Education level							0.23 (0.14)

SE: Standard error

Model 1: Only Birth month was considered. No Socioeconomic factor was added.

Model 2: Birth month and one Socioeconomic factor(Model2a: Areal deprivation, Model2b:Average annual income , Model2c: Education level)

Model 3: Birth month, one Socioeconomic factor and one Cross-level interaction (Model3a: Birth month*Areal deprivation, Model3b: Birth month* Average annual income, Model3c: Birth month*Education level)

All models were adjusted for age, body weight, organized sports participation, population density.

** $p<0.01$, * $p<0.05$, Interclass correlation coefficients=0.10, Design effect=6.43

Discussion

This study showed that among relatively younger adolescents, females were less likely to participate in sports activities, although both males and females spent less time on MVPA. These results mostly support previous studies indicating that relatively younger adolescents have less time to play sports [24]. Other previous studies have showed that relatively younger adolescents are likely to have poorer physical fitness [6, 7, 33] and noncognitive skills (e.g., self-efficacy, ability belief) [2, 3]. Considering these previous studies, relatively younger adolescents might be more likely to be reluctant to play sports. Although this study did not investigate adolescent sports skills and subjective perception about sports, the capability and interest caused by relative age might have an influence on adolescent sports activity. In addition, we found a relative age effect of organized sports participation only among females. Although the reason for this is not clear, there are some possible explanations. First, since females are likely to have secondary sexual characteristics [34, 35], fewer females might participate in sports activities than males. For example, a female's physical performance (e.g., running, jumping) reaches its peak at the age of 13, while a male's physical performance shows a linear improvement [34]. Second, while many males are likely to naturally participate in organized sports activities, enjoying some sports activities may be an important factor for females in engaging in sufficient physical activity [9]. Since relatively younger females might have fewer opportunities to play active roles in sports, they might be less likely to participate in sports activities.

We also observed a significant interaction between MVPA and average annual income for both males and females. Relatively younger adolescents were significantly associated with spending less MVPA time only in low-income neighborhoods. This result indicates that the relative age effect of physical activity might be more likely to emerge in socioeconomically disadvantaged neighborhoods. Although no study has

examined how socioeconomic factors moderate the association between birth month and adolescent physical activity, there are some possible explanations. High-income families may afford to spend on recreational activities. Socioeconomically disadvantaged neighborhoods are less likely to have parks [12, 13] or sports facilities [36–38], thus offering limited opportunities to participate in sports activities. Relatively younger adolescents in socioeconomically disadvantaged neighborhoods might have few opportunities to transfer to other sports activities, while relatively younger adolescents who live in affluent neighborhoods might be able to transfer to other sports activities more easily.

Thus, as mentioned above, physical activity is an important factor that mitigates relative age effect [7]. However, since relatively younger adolescents might have undergone fewer successful experiences of sports than their relatively older counterparts, they might likely become inactive. Therefore, teachers and coaches should encourage relatively younger adolescents to engage in physical activity. For example, teachers and coaches must formulate sports rules to enable equal active roles among adolescents. In addition, it is essential for schools and sports facilities to provide later-born adolescents with adequate opportunities to engage in physical activity and to play active roles in sports by participating in various sports. In this study, we observed a relative age effect of physical activity in both male and female adolescents from socioeconomically disadvantaged areas. Socioeconomically disadvantaged adolescents are less likely to engage in physical activity owing to their financial instability. Thus, schools and public sports facilities should support socioeconomically disadvantaged adolescents to engage in sports at minimum financial costs.

This study was the first to examine how socioeconomic factors moderate the association between birth month and adolescent physical activity. In addition, we defined school districts as units of neighborhood, and we applied municipality-level and block-level data for neighborhood-level data. Furthermore, we showed the relative age effect of adolescent organized sports participation and physical activity by adjusting various individual and neighborhood characteristics. Nevertheless, this study has some limitations. First, this was a cross-sectional study; therefore, we could not address causal relations. Second, while some previous studies examined physical fitness as a relative age effect outcome [6, 7, 33], we did not research participants' physical fitness. However, previous studies have reported that high-level physical fitness is related to more MVPA time [7]. Thus, those who spent more time on MVPA seemed to have a higher level of physical fitness in this study. Third, since we could not ask participants about their SES, we could not address how high the SES of the household is. In Japan, cultural norms make it difficult to directly ask for parents' SES. Therefore, we substituted neighborhood-level socioeconomic factors based on demographics, such as census data. Previous studies have reported that individual-level socioeconomic factors are more strongly related to adolescent physical activity than neighborhood-level factors [9, 10]. We might observe a clearer association between socioeconomic factors and adolescent physical activity upon utilizing individual-level socioeconomic factors.

Conclusion

We showed the association of relative age effect and adolescents' organized sports participation and physical activity for both male and female adolescents in widespread areas of Japan. We also observed a significant interaction between birth month and socioeconomic factors; the relative age effect of physical activity was seen only for adolescents who lived in a socioeconomically disadvantaged neighborhood. Since few studies have examined the relationship between the relative age effect and neighborhood type, further studies are required to address neighborhood characteristics where the relative age effect is likely to appear.

Abbreviations

SES: socioeconomic status

MVPA: moderate to vigorous physical activity

ADI: Areal Deprivation Index

Declarations

Ethics approval and consent to participate

The purpose, method, benefits, and risks of this study were explained to the principals of the schools. We also explained to the participants that their private information would be protected and that answers to the questionnaires were not related to their school records. Participants provided consent before answering the questionnaire. All methods were performed in accordance with relevant guidelines and regulations. We obtained approval from the Ethics Committee of Doshisha University (approval number: 17095).

Consent for publication

Not applicable.

Availability of data and materials

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

TM and KI conceptualized and designed this study. TA and KI acquired funding. TA, TH, CT, ST, HT, KF, YK, NT, KK, SK, NM, KS, MW, RK, TH, RM, TA, KY, DK, HA, NY, TT and KI conducted the survey. TA, KO, and KI sorted out the data. TN created the dataset and provided technical information about the Areal Deprivation Index. TM performed statistical analysis and drafted the manuscript. TM and KI reviewed and edited the manuscript. All authors read and approved the final manuscript.

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Figures

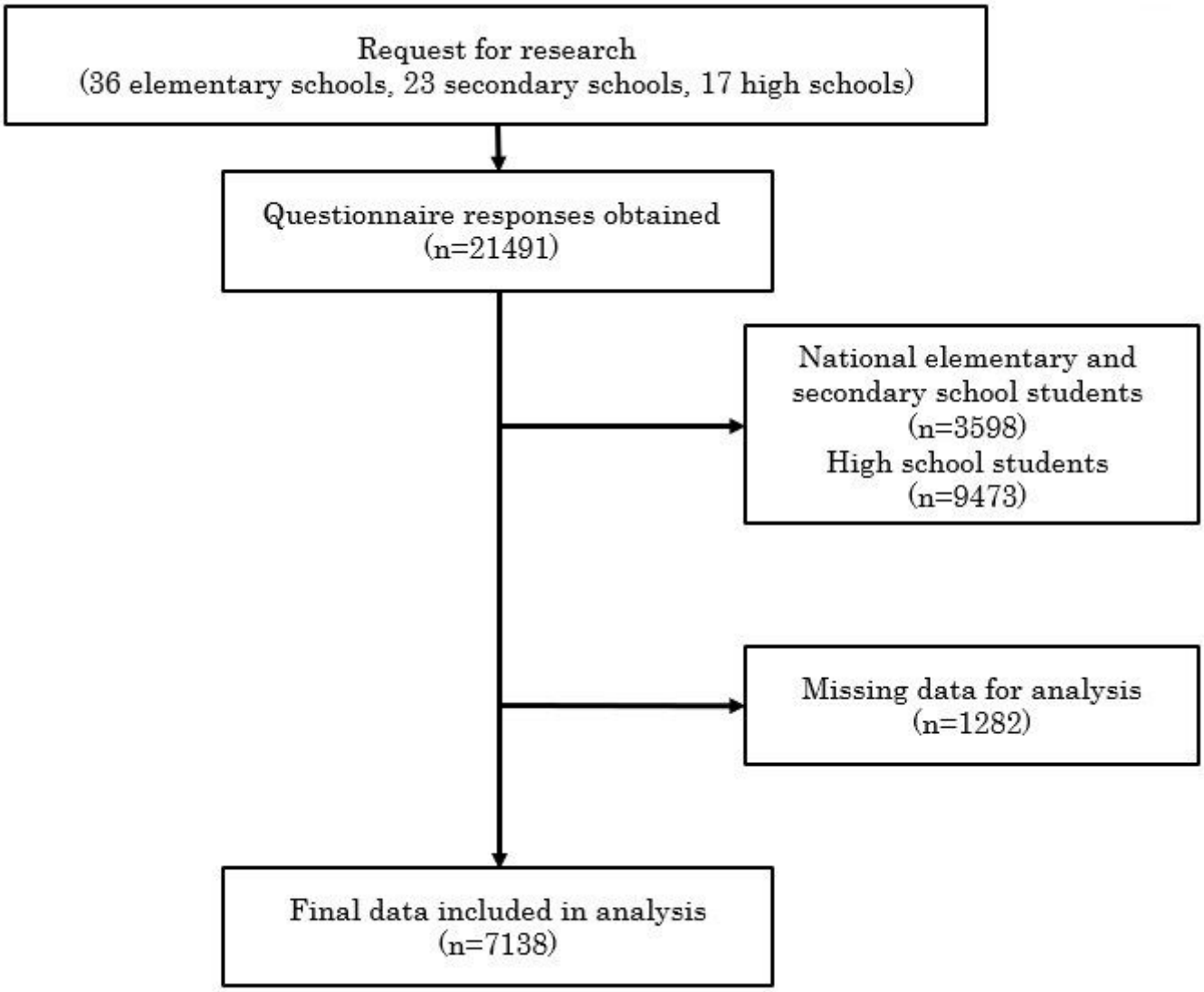

Figure 1

Protocol for recruiting research participants for analysis

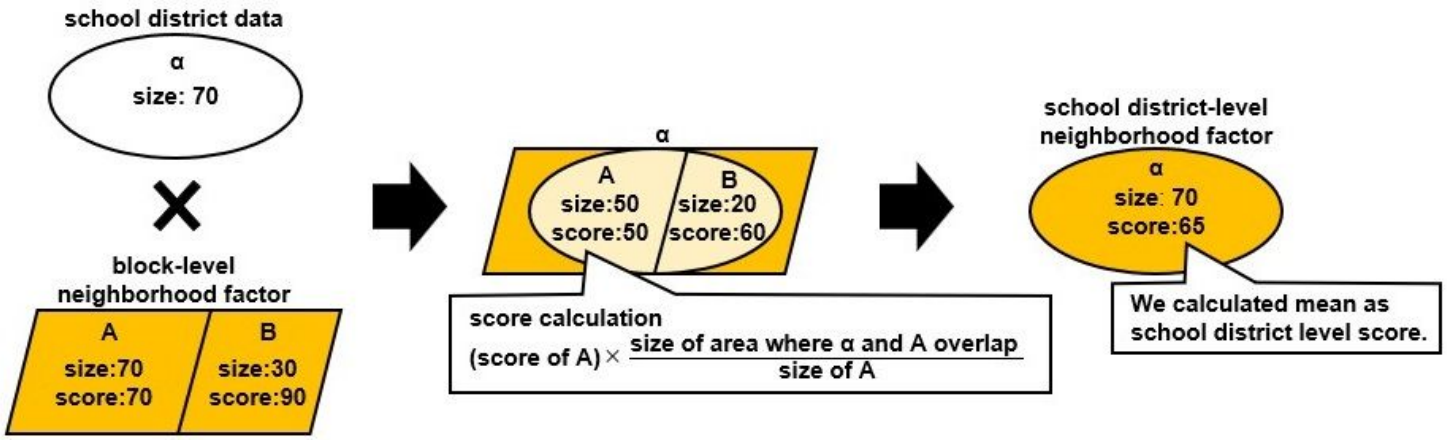

Figure 2

The procedure of areal weighting interpolation in this study

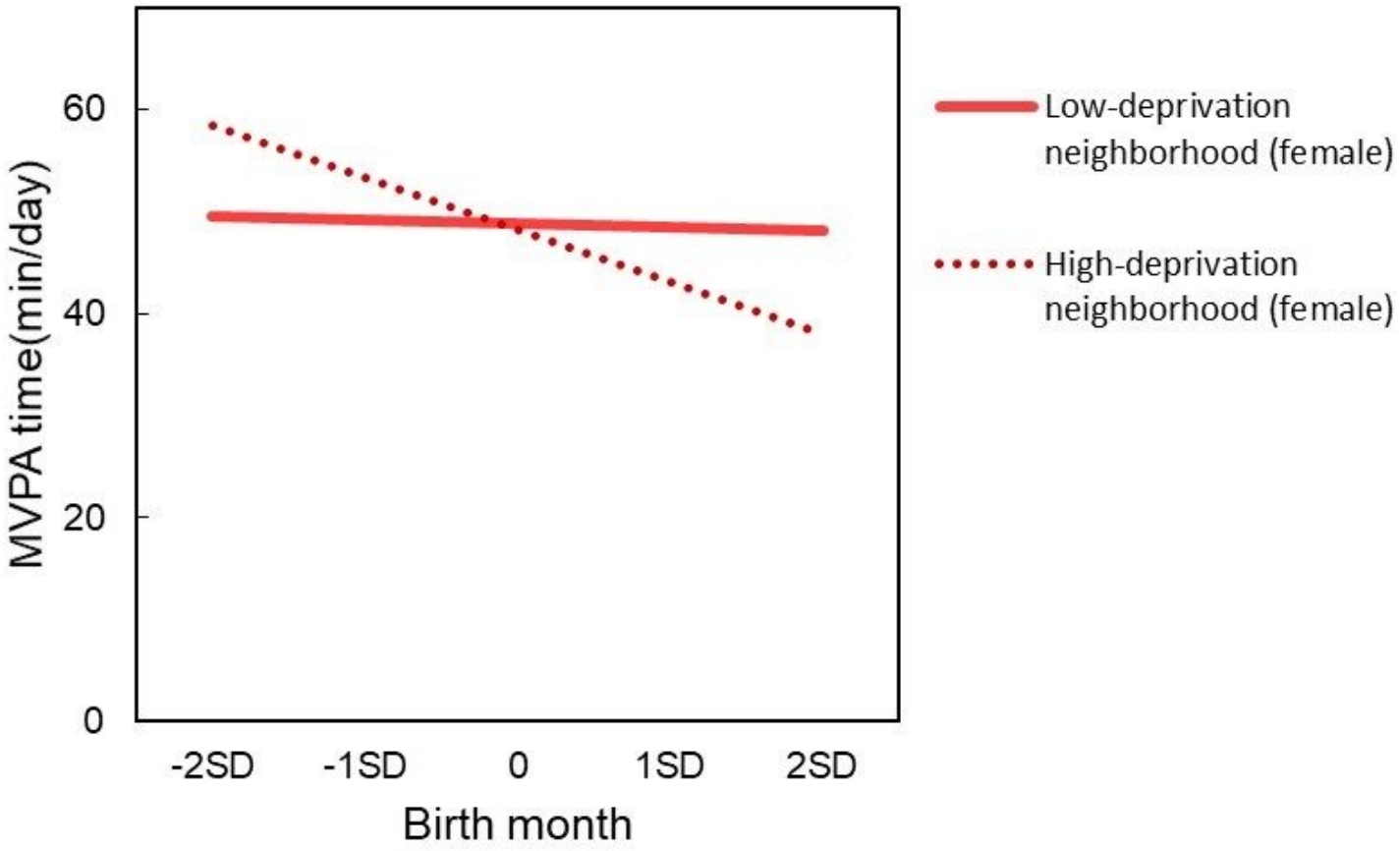

Figure 3

Simple slope of relative age effect by areal deprivation

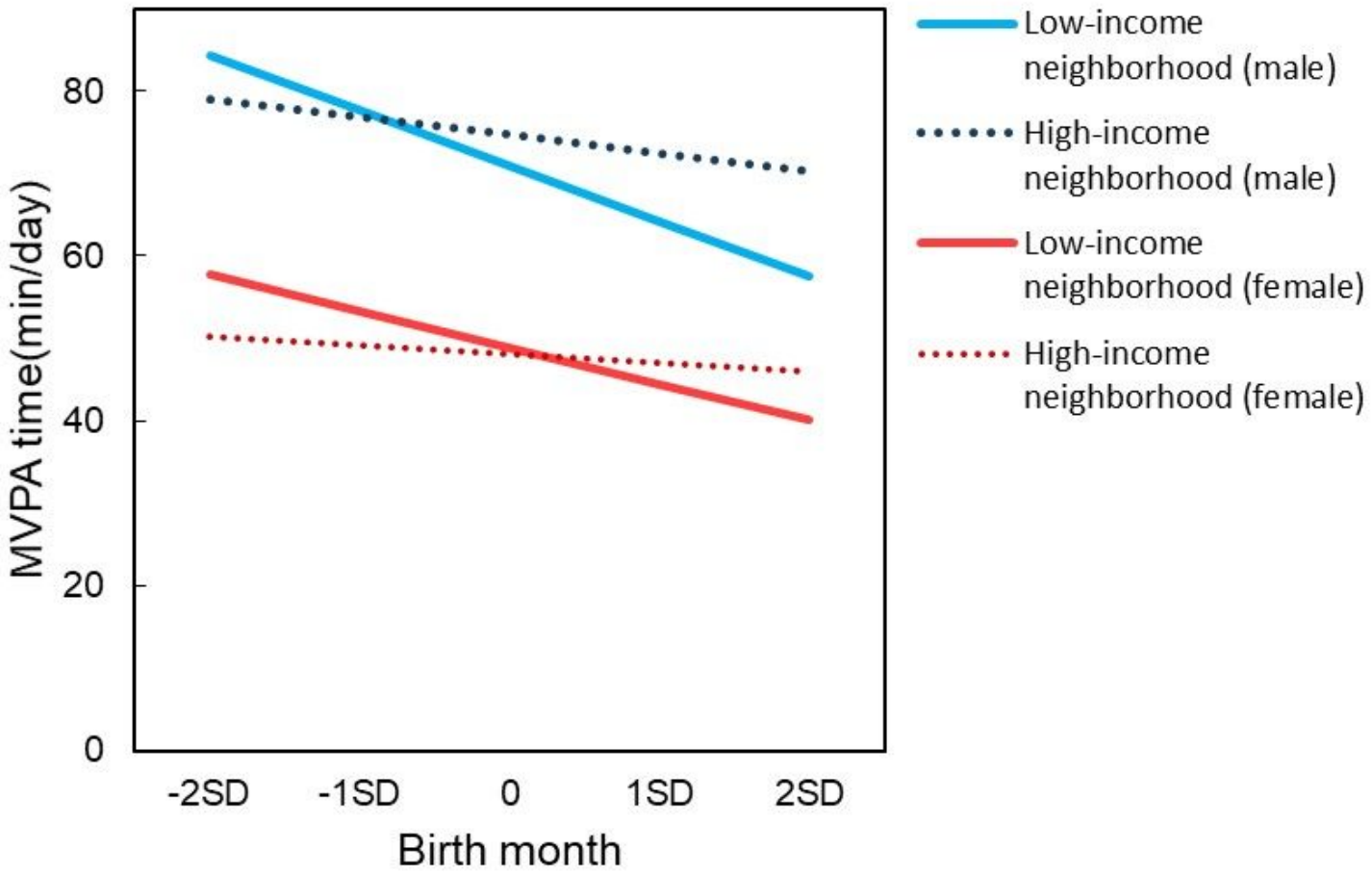

Figure 4

Simple slope of relative age effect by average annual income