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Title: Association Between Various Sedentary Behaviors and Academic Performance Among Students in Primary and Junior-high Schools: A Cross-sectional Study

Authors:

Takafumi Abe[1,*], Jun Kitayuguchi[2], Msamitsu Kamada[3], Shinpei Okada[4], Noritoshi Fukushima[5], Tetsuhiro Kidokoro[6], Ryo Miyazaki[7], and Chiaki Tanaka[8]

Affiliations:

[1] Center for Community-Based Healthcare Research and Education (CoHRE), Head Office for Research and Academic Information, Shimane University, 223-8 Enya-cho, Izumo city, Shimane 693-8501, Japan

[2] Physical Education and Medicine Research Center UNNAN, 328 Uji, Kamo-cho, Unnan-shi, Shimane 699-1105, Japan

[3] Department of Health Education and Health Sociology, School of Public Health, Graduate School of Medicine, The University of Tokyo, 7-3-1 Hongo, Bunkyo-Ku, Tokyo 113-0033, Japan

[4] Physical Education and Medicine Research Foundation, 6-1 Nunoshita, Tomi city,

Nagano 389-0402, Japan

[5] Department of Preventive Medicine and Public Health, Tokyo Medical University, 6-1-1 Shinjuku, Shinjuku-ku, Tokyo 160-8402, Japan

[6] Faculty of Sport Science, Nippon Sport Science University, 7-1-1 Fukazawa, Setagaya-ku, Tokyo 158-8508, Japan

[7] Faculty of Human Sciences, Shimane University, 1060 Nishikawatsu-cho, Matsue-shi, Shimane 690-8504, Japan

[8] Department of Human Nutrition, Tokyo Kasei Gakuin University, 22 Sanbancho, Chiyoda-ku, Tokyo 102-8341, Japan

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Running title: Sedentary Behaviors on Academic Performance

***Corresponding author's**

e-mail address:t-abe@med.shimane-u.ac.jp

Abstract

In Japan, research on how specific types of sedentary behavior are associated with academic performance among school-aged children remains limited. This cross-sectional study investigated the relationship between various sedentary behaviors and academic performance among Japanese children and adolescents. Data were collected in 2023 from 342 primary and 456 junior high school students in Unnan City, Shimane Prefecture. Academic performance was categorized as high or low based on median scores in Japanese and mathematics. Sedentary behaviors were assessed using a questionnaire—including time spent on reading books and newspapers and total recreational screen time, which was calculated from the time spent playing TV games, watching videos or using social networking services (SNS), and using educational tablets at home. Multiple linear regression analyses were conducted, adjusting for factors, such as gender, grade, breakfast habits, sleep duration, sports club participation, and cram school attendance. Spending < 2 hours on TV, games, watching videos, or SNS use was significantly associated with higher academic performance across school levels. Conversely, spending < 2 hours on total recreational screen time and using educational tablets at home was linked to higher scores among primary students. Reading books was positively associated with Japanese language scores in both groups.

Thus, the type of sedentary activity plays a crucial role in the academic outcomes. A shorter duration of recreational screen time and educational and literacy-related behaviors were associated with higher academic performance. This study highlights the need for further longitudinal research considering household socioeconomic factors to better understand these associations.

Keywords: sedentary, academic achievement, GIGA school initiative, social networking

日本語タイトル

児童・生徒における座って過ごす活動タイプと学力の関連：横断研究

著者名

安部孝文[1,*], 北湯口純[2]、鎌田真光[3]、岡田真光[4]、福島教照[5]、城所哲宏[6]、宮崎亮[7]、田中千晶[8]

所属

[1]島根大学研究学術情報本部地域包括ケア教育研究センター

[2]身体教育医学研究所うんなん

[3]東京大学大学院医学系研究科公共健康医学専攻健康教育・社会学分野

[4]公益財団法人身体教育医学研究所

[5]東京医科大学公衆衛生学分野

[6]日本体育大学体育学部

[7]島根大学人間科学部

[8]東京家政学院大学 人間栄養学部

日本語概要

本横断研究は、日本の児童・生徒を対象に、様々な座位行動と学業成績との関連を調査した。データは 2023 年に島根県雲南市の小学生 342 名および中学生 456 名を対象に収集された。学業成績は、国語と算数・数学のテストを学年別に偏差値を算出した。座位行動は質問紙を用いて評価した。テレビゲーム使用時間、動画視聴・SNS 利用時間、および、この 2 項目を組み合わせた余暇スクリーンタイム、また家庭での学習用タブレットの使用、読書、新聞閲読の有無を調査した。性別、学年、朝食摂取習慣、睡眠時間、運動部活動への参加、学習塾の利用の有無を調整因子として、重回帰分析を行った。その結果、テレビゲーム、動画視聴・SNS 利用に 2 時間未満費やすことは、小中学生ともに高い学業成績と有意に関連していた。その一方で、2 時間未満の余暇スクリーンタイムと家庭での学習用タブレットの使用は小学生の学業成績の高さと関連していた。読書は、小中学生両方で国語の成績と正の関連が見られた。これらの知見は、座位行動の種類が学業成績において重要な役割を果たすことを示唆している。娯楽的なスクリーンタイムの短さは高い学業成績と関連があった。また、教育的および識字関連の座位行動はより高い成績と関連していた。本研究は、これらの関連をより深く理解するために、世帯の社会経済的要因を考慮したさらなる縦断的研究の必要性を強調するものである。

Introduction

Sedentary behavior, particularly recreational screen time, has become a global public health concern [1]. The World Health Organization (WHO) recommends limiting such behavior in children and adolescents to promote physical and mental health [2]. Although many countries have adopted specific numerical targets—recommending < 2 hours of recreational screen time per day [3-5]—Japan's "2023 Physical Activity and Exercise Guidelines for Health Promotion" do not provide such quantitative benchmarks. Instead, they recommend minimizing sedentary time, particularly screen-based behaviors [6], in line with the WHO recommendations [2]. Further evidence is required to establish specific numerical targets [7].

Recent studies have explored the association between different types of sedentary behavior and academic performance among children and adolescents, particularly screen-based behaviors such as video games, online videos, and social networking services (SNS) [8-12]. While some forms of screen use may displace learning time and negatively affect academic performance, others—such as educational tablet use—may have beneficial effects. However, findings have been varied and inconclusive, as highlighted in a recent umbrella review [12], underscoring the need for more nuanced investigations. In Japan, the Ministry of Education, Culture, Sports,

Science and Technology has launched the GIGA School Initiative [13], providing each student with a personal tablet device. This initiative aims to provide personalized learning opportunities, foster creativity, improve educational quality, and reduce disparities through the digitalization of education. This initiative prompts important questions about screen use for educational purposes, its impact on academic outcomes, and its effectiveness in supporting education. In Unnan city of the Shimane prefecture, the study area, a one-to-one digital device environment was established for students in 2021, along with the necessary infrastructure for their use. Therefore, determining the effects of these devices on academic performance is crucial for informing future educational policies. Western countries have begun to thoroughly investigate this issue [11, 14-17]; international recommendations regarding school-related sedentary behavior have also been proposed to maximize health and educational benefits [18]. However, few studies in Japan have systematically examined how specific types of sedentary behavior—particularly the distinction between recreational and educational sedentary behaviors—are associated with academic performance among school-aged children. Thus, research focusing on the qualitative aspects of screen use remains limited.

Therefore, we aimed to clarify the associations between different types of sedentary behavior and academic performance among primary and junior high school

(JHS) students in Japan.

Materials and Methods

Participants

The study was conducted in Unnan city, a rural region (area = 553.4 km^2; population = 35,738) in the Shimane Prefecture, Western Japan. Data were obtained from surveys investigating students' academic performance and lifestyle habits, conducted by the Unnan City Board of Education in November and December 2023. A letter explaining the ethical considerations and requesting voluntary participation was sent to parents/guardians. They were free to ask questions or refuse participation. Subsequently, the researchers received anonymized data for analysis. This process was handled entirely by the Unnan City Board of Education, without researcher involvement. We disclosed study information on the Shimane University website for the participants. The study protocol was approved by the Medical Research Ethics Committee, Shimane University Faculty of Medicine (#20240322-1).

Fig. 1 shows a flowchart of the study. In April 2023, 577 students from 15 public primary schools (PSs) aged 10–12 years (grades 5 and 6) and 576 students from 6 JHSs aged 12–14 years (grades 1 and 2) resided in this city. Based on the data obtained by the

Unnan City Board of Education from the academic performance and lifestyle habits survey, the participants included 342 students from 13 PSs and 456 students from 6 JHSs.

Academic performance

In this study, data from the Shimane Prefecture Academic Achievement Survey in Japanese language and mathematics were used. This survey was conducted on December 5–6, 2023. The survey was independently conducted by the Shimane Prefectural Board of Education. The survey overview is provided in Supplemental Method 1 and published on the official website of the Shimane Prefectural Board of Education (in Japanese) [19]. Due to grade-level differences in the test scores, standardized T-scores were calculated. Descriptive statistics for both raw and T-scores are presented in Supplemental Tables 1 and 2. No ceiling or floor effects were observed in these tests.

Types of sedentary behaviors

Information on activity type was collected from the questionnaire, including time spent on total recreational screen time, TV games, videos/SNS, educational tablets, reading

books, and reading newspapers. The TV game usage was assessed with the question, "On school days, how much time do you spend playing TV games (including computers, tablets, and smartphones) per day?" The responses were "None, < 1 hour, 1–2 hours, 2–3 hours, 3–4 hours, ≥ 4 hours." Next, watching videos/SNS use on smartphones and similar devices was assessed with the question, "On school days, how much time do you spend watching video sites or using social networking services (excluding those related to learning) on smartphones or tablets per day?" The responses were "None, < 30 minutes, 30 minutes–1 hour, 1–2 hours, 2–3 hours, 3–4 hours, ≥ 4 hours." These two questions were categorized into two groups (< 2 hours and ≥ 2 hours) according to a previous study [8]. This study created a "total recreational screen time" variable by combining the responses to two questions regarding playing TV games and watching videos/SNS and then categorized it into two groups: "<2 hours" or "≥2 hours." Next, the use of educational tablets at home was assessed with the question, "How often do you use tablets for learning at home?" The responses were "frequently, moderately, rarely, never." Responses of “frequently” and “moderately” were categorized as usage, whereas “rarely” and “never” were categorized as non-usage. For reading books, the question was "Do you read books (excluding manga and magazines)?" The responses were "strongly agree, somewhat agree, somewhat disagree, and strongly disagree." For

reading newspapers, the question was "Do you read newspaper articles?" with the response options of "strongly agree, somewhat agree, somewhat disagree, and strongly disagree." These three items were categorized into two groups based on the midpoint of the four-point scale (i.e., positive or negative responses). The Japanese version of this questionnaire is provided in the Supplemental Method 1.

Other variables

School grade (fifth or sixth grade at PS and first or second grade at JHS) and gender (boy or girl) were obtained using self-report questionnaire. Breakfast was assessed using a 5-point Likert scale (every day, 5–6 days, 3–4 days, 1–2 days, or never) and categorized as regular consumption or skipping meals. Sleep duration was classified as follows: < 6 hours, 6–7 hours, 7–8 hours, 8–9 hours, 9–10 hours, and ≥10 hours. Adequate sleep duration was considered as ≥ 9 hours (with the maximum of 10 hours) for PS students, and 8–10 hours for JHS students [20, 21]. Participation in sports clubs was assessed with the question "Are you a member of a sports club?" with responses being "yes" or "no." Additionally, attendance at a cram school was assessed with the question "Do you study at a cram school?" with responses being "attendance or non-attendance."

Statistical analysis

Descriptive statistics were generated to summarize participant characteristics by school level (PS and JHS). Further, descriptive statistics of academic performance were conducted for each type of sedentary behavior among students in both groups. Subsequently, we conducted a multiple linear regression analysis to estimate the unstandardized coefficients (B) and 95% confidence intervals (CIs) for academic performance of the PS and JHS groups. The types of sedentary behaviors derived from questionnaire data included weekday total recreational screen time (≥ 2 hours as reference), TV game usage (≥ 2 hours as reference), weekday videos/SNS usage (≥ 2 hours as reference), use of tablets for learning at home (non-usage as reference), reading books (disagree as reference), and reading newspapers (disagree as reference). Each type of sedentary activity was individually analyzed using gender, grade, breakfast, sleep duration, participation in sports clubs, and attendance of cram schools as covariates. P-values were calculated, and the significance threshold was adjusted for multiple comparisons using the Bonferroni method. Two-sided P value < 0.05 were considered statistically significant. To examine whether the relationship between types of sedentary activity and academic performance differed by gender, an interaction term between gender and each type of sedentary activity was included in the model. All the

statistical analyses were carried out using IBM SPSS Statistics 29.0 for Windows (IBM Corp., Armonk, NY, USA).

Results

Table 1 presents the characteristics of participants. Among the 342 PS students, 151 were fifth graders (44.2%) and 177 were male (51.8%). Among the 456 JHS students, 216 were first graders (47.4%) and 203 were male students (44.5%). The proportions of sedentary behaviors among PS students were as follows: total recreational screen time (<2 hours) was 24.3%, playing TV games (<2 hours) was 52.6%, watching TV games (<2 hours) was 70.5%, using educational tablets at home was 37.4%, reading books (agree) was 51.2%, and reading newspapers (agree) was 19.6%. Among JHS students, total recreational screen time (<2 hours) was 18.9%, playing TV games (<2 hours) was 58.8%, watching TV games (<2 hours) was 53.5%, using educational tablets at home was 20.2%, reading books (agree) was 54.8%, and reading newspapers (agree) was 15.6%.

[Insert Table 1]

Table 2 presents the descriptive statistics of academic performance by types of sedentary behavior for PS and JHS students. Supplemental Table 1 reports the descriptive statistics for Japanese language and mathematics scores and T-scores by grade in PS and JHS.

[Insert Table 2]

Table 3 and 4 show associations between types of sedentary behavior and academic performance among students in the PS and JHS. Regarding Japanese language performance, students in PS with a total recreational screen time of < 2 hours/day had significantly higher scores compared with those with 2 or more hours/day (B=4.14, 95% CI: 1.66–6.63, P<0.01). Similarly, playing TV games for < 2 hours/day (B=3.51, 95% CI: 1.38–5.64, P<0.01) and watching video/SNS for < 2 hours/day (B=5.36, 95% CI: 3.04–7.68, P<0.001) were significantly associated with better performance. Furthermore, using educational tablets at home (B=3.61, 95% CI: 1.40–5.82, P<0.01) and agreeing to reading books (B=2.92, 95% CI: 0.81–5.03, P=0.04) were both significantly associated with higher scores compared to their respective reference groups of non-usage and disagreement. In terms of mathematics performance, students

with < 2 hours of total recreational screen time per day scored significantly higher (B=3.92, 95% CI: 1.46–6.38, P<0.01) than those with 2 or more hours/day. Playing TV games for 2 hours/day (B=3.90, 95% CI: 1.81–5.99, P<0.01) and watching video/SNS for < 2 hours/day (B=3.86, 95% CI: 1.53–6.18, P<0.01) were also significantly associated with higher scores. Additionally, using educational tablets at home was significantly associated with higher mathematics scores compared to non-usage (B=3.75, 95% CI: 1.57–5.93, P<0.01). Supplemental Table 3 shows that no significant interaction was observed between gender and each type of sedentary behavior for academic performance in either Japanese language or mathematics (P>0.05 for all) among PS students.

[Insert Table 3]

Regarding Japanese language performance in JHS, playing TV games for < 2 hours/day was significantly associated with higher scores compared to 2 or more hours (B=3.82, 95% CI: 1.93–5.71, P<0.001). Similarly, watching video/SNS for < 2 hours/day was significantly associated with better performance compared to those with 2 or more hours/day (B=3.00, 95% CI: 1.20–4.79, P<0.01). Additionally, agreeing to

reading books was significantly associated with higher Japanese language scores compared to those who disagreed (B=3.76, 95% CI: 1.96–5.56, P<0.001). Regarding mathematics performance, playing TV games for < 2 hours/day was significantly associated with higher scores compared to 2 or more hours/day (B=4.47, 95% CI: 2.57–6.37, P<0.001). Furthermore, watching video/SNS for < 2 hours/day was also significantly associated with higher mathematics scores compared to those with 2 or more hours/day (B=3.39, 95% CI: 1.57–5.20, P<0.01). Supplemental Table 3 shows that no significant interaction was observed between gender and each type of sedentary behavior for academic performance in either Japanese language or mathematics (P>0.05 for all) among JHS students.

[Insert Table 4]

Discussion

We examined the associations between various types of sedentary behavior and academic performance among PS and JHS students. The findings revealed that a shorter duration of recreational screen-based behaviors—particularly playing TV games and watching videos or using SNS for < 2 hours/day—was consistently associated with

higher academic performance in Japanese language and mathematics across school levels. In contrast, educationally oriented sedentary behaviors, such as using educational tablets at home and reading books, were positively associated with academic outcomes, particularly among PS students. A positive association between reading books and Japanese language scores was observed in JHS students. Although this study was conducted using data obtained from surveys investigating the academic performance and lifestyle habits of students, these findings provide evidence for educators, parents, and policymakers aiming to develop balanced guidelines that promote better learning environments at home and in school. However, as this was a cross-sectional study, causal relationships cannot be inferred. Therefore, caution should be applied when interpreting the results by considering the possibility of reverse causation, such as lower academic performance leading to longer leisure screen time.

In Japan's 2024 National Achievement Test [22], 51.0% of sixth-grade PS students and 50.8% of third-year JHS students reported playing video games for < 2 hours/day on weekdays. For watching videos or SNS on weekdays, the percentages were 66.4% for elementary students and 43.4% for junior high students. While a simple comparison is not possible due to differences in the survey methods, the proportion of PS and JHS students with short screen time in our study was similar to or slightly higher

than that found in the national survey. Therefore, the participants in this study were similar to those in the national population.

Sedentary behaviors involving the use of screen-based behaviors for recreation and communication were negatively associated with academic performance; this is consistent with previous research. In Japan, we found two studies reporting recreational screen time [23, 24]. A cross-sectional study of elementary school students in Tokyo, investigated the association between leisure screen time and self-reported academic performance [23], suggesting that less screen time (< 3 hours) may be linked to higher academic performance. Another study examined the longitudinal associations of various combinations of physical activity and screen time with academic performance (mean scores across Japanese language, mathematics, social studies, and science) [24]. The findings revealed a significant association between < 2 hours of screen time and higher academic performance, irrespective of the level of physical activity. Romer et al. demonstrated television viewing to be negatively correlated with academic achievement in youths aged 14–29 years in the United States [14]. Similarly, a Canadian study involving 4,408 students in grades 9–12 reported negative associations between academic performance and screen-based behaviors, such as watching television programs or movies, streaming content, and engaging in communication [16]. Screen-

based and relaxation-related sedentary behaviors have been reported to be negatively associated with academic outcomes in a study involving 2,216 adolescents aged 11–16 years in Spain [17]. However, a study involving 13,960 high school students in the United States reported a cross-sectional positive association between video game use and performance in reading and mathematics; however, no longitudinal relationship was observed [15]. Similarly, Hunter et al. [16] demonstrated a positive correlation between television viewing and mathematics achievement in a Canadian study. These inconsistent findings regarding the impact of leisure screen time on learning outcomes suggest the need for further investigation into the qualitative aspects of screen use.

In this study, playing TV games and watching videos or using SNS were associated with academic performance in PS and JHS students. However, the combined measure of recreational screen time was associated with academic performance in PS students but not in JHS students. For JHS students, it is possible that the threshold of screen time associated with academic performance differs from that of PS students. The proportion of JHS students with <2 hours of usage was smaller, which may suggest a different relationship. The small sample size of short-term users made it more difficult to detect a statistical association. Future research should therefore investigate various forms of recreational screen time in more detail.

In contrast, our finding that educational sedentary behaviors were positively associated with academic performance supports the results of previous studies, despite certain methodological differences. A longitudinal study conducted in Spain involving 466 children and 717 adolescents aged 8–18 years demonstrated that educational sedentary behaviors, such as doing homework and reading, were positively associated with academic performance in cross-sectional analyses [11]. Furthermore, longitudinal analyses revealed that transitions from screen-based to educational sedentary behavior profiles were positively associated with academic performance [11]. A longitudinal study in the United States also reported a positive association between reading and self-reported academic achievement [14]. A Canadian longitudinal study involving 4,408 students found that doing homework was associated with higher English grades [16]. Additionally, a study in Spain reported that learning-related sedentary behaviors positively correlated with academic performance [17].

Our findings revealed that the use of educational tablets at home was positively associated with academic performance in primary school students. In contrast, no association was observed among junior high school students. In Japan, the GIGA School initiative has provided one tablet per student as a learning aid [13]. However, research on how school-provided, take-home devices affect learning activities at home remains limited. A meta-

271 analysis examining the effects of K-12 one-to-one laptop programs reported a
272 significantly positive average effect size in English, writing, mathematics, and science,
273 with generally positive outcomes [25]. In contrast, a quasi-experimental study conducted in
274 Sweden [26] found no significant improvement in mathematics, native language, or English
275 following the distribution of tablets. In our study, the specific details of tablet usage are
276 unknown (e.g., quality of content [27]; teacher support [28]; device training from schools [29];
277 and digital capacity levels such as infrastructure digital competence of students, parents,
278 and teachers [30]. A previous meta-analysis reported that the educational use of tablets
279 shows a higher effect on learning achievement in primary school students than in junior
280 high school students [31], consistent with our finding where the benefits were more
281 pronounced in younger students. However, the specific reasons for these differences
282 remain unknown. We hypothesize that this may be due to the differences in learning
283 content. Primary school students' learning often involves foundational, repetitive tasks,
284 whereas junior high school students' learning is more complex and exploratory, requiring
285 higher-level thinking. A previous study has reported that children's reading
286 comprehension is better with printed materials than with tablets, and that this advantage
287 of print is more significant for children with lower reading comprehension [32]. This
288 suggests that tablet-based learning may be less effective for junior high school students,

289 whose advanced curricula demands strong reading comprehension skills. It is therefore
290 hypothesized that as students advance in grade level, a discrepancy in tablet-based reading
291 comprehension tends to arise, resulting in diminished learning effectiveness. In addition,
292 the proportion of students using tablets at home was approximately 17% higher in primary
293 school students than in junior high school students suggesting that primary school
294 students may have more established habits of using tablets for learning compared to junior
295 high school students. In Japan, the new curriculum guideline for junior high schools was
296 implemented one year later than for primary schools, beginning in April 2021. However,
297 the GIGA School initiative was accelerated from its initial start date to 2021 due to the
298 COVID-19 pandemic [13]. Based on a study of junior high school teachers [33], the new
299 curriculum guideline was implemented without adequate preparation, a factor that cannot
300 be discounted. These policy-related issues may therefore have contributed to the limited
301 effectiveness observed in junior high schools.
302 Potential mechanisms underlying the observed associations can be revealed
303 based on the findings of this study. Recreational screen-based behaviors, such as TV
304 gaming and video/SNS use, may displace time otherwise spent on cognitively enriching
305 tasks (e.g., homework, reading), and thus be negatively associated with academic
306 performance. This observation suggests that within the constraints of limited leisure

time, the time spent on learning behaviors may have been relatively reduced owing to distractions [34, 35]. Similarly, Kidokoro et al. [36] reported that prolonged use of social media was associated with depression among Japanese female JHS students. This suggests that the link between social problems experienced through social media and depression may be related to persistently low academic performance over time [37]. Furthermore, the use of educational tablets and reading materials (books, newspapers) provide structured, goal-oriented content that supports literacy and reasoning [38, 39], which may explain their positive associations with academic outcomes. Educational tablets, enhanced by advances in content development, can deliver tasks tailored to children's individual abilities and offer engaging incentives that encourage repeated learning [38]. Moreover, students who engage in educational screen use or reading may possess higher levels of self-regulation and intrinsic motivation, traits that are also conducive to academic success. However, although educational sedentary behaviors demonstrated a tendency toward higher academic performance, no significant associations were observed. For example, among JHS students, the use of educational tablets and reading newspapers were not significantly associated with better academic performance. Screen time may be recommended for specific purposes, such as learning, rather than without any clear objective [12]. Moreover, the impact of screen time on

learning outcomes may vary depending on how it is utilized [18]. Future research should carefully examine the purposes and methods of screen time usage. The higher academic performance of certain sedentary behaviors may depend on contextual factors (e.g., parental supervision, content of educational tablets, books, and newspapers), which were not captured in the current models.

This study has some limitations. First, this study employed a cross-sectional design, which limits the ability to infer causal relationships between sedentary behavior patterns and academic performance. It is therefore plausible that academic performance may influence sedentary behavior [34]. Longitudinal or experimental studies such as randomized controlled trials are warranted to establish temporal and causal associations, for example, determining whether reducing TV game usage time improves academic performance. Second, sedentary behavior and other variables were assessed using self-reported questionnaires, which may be subject to recall and social desirability biases. In addition, self-reported sedentary behaviors and learning habits may be particularly susceptible to social desirability bias (e.g., under-reporting of recreational screen time or over-reporting of educational behaviors) and recall bias, potentially creating discrepancies between reported data and actual behaviors. Future research should consider methods to reduce these biases, such as the introduction of objective

343 measurements or data collection from multiple sources. Third, although the models
344 were adjusted for several covariates (e.g., sleep duration, breakfast consumption,
345 extracurricular activities), other potential confounders—such as parental involvement,
346 socioeconomic status, and home learning environment—were not included. For
347 example, these potential confounders might create a spurious association between
348 recreational screen time and academic performance, which can hinder causal inference.
349 It is particularly important to conduct a longitudinal study that accounts for household
350 socioeconomic factors, such as parental education and income, as these can strongly
351 influence the cause and effect. Fourth, the sample was drawn from a specific population
352 of PS and JHS students in Japan, which may limit the generalizability of the findings to
353 other cultural or educational contexts. Fifth, the sample size of this study was small,
354 potentially leading to low statistical power. The association might be underestimated.
355 Although we examined the interaction between gender and sedentary behavior, no
356 significant associations were found in this study. Post hoc power analyses indicated that
357 the statistical power to detect interaction effects was limited (e.g., power = 0.062 in
358 elementary school children [n = 342] and 0.107 in junior high school children [n =
359 456]). The other interaction tests yielded similarly low values. Thus, the absence of
360 statistically significant interactions should be interpreted with caution, and future

studies with larger sample sizes are warranted. Finally, screen-based behaviors were broadly classified (e.g., TV games, video/SNS, educational tablets) without capturing the specific content or purpose of use. Hallgren et al.[40] reported that it is necessary to consider the distinction between passive and mentally active sedentary behaviors. Furthermore, this study used a questionnaire that has not undergone formal validation. Although the items were developed based on input from the Boards of Education in the Shimane Prefecture and Unnan City, the psychometric properties of the instrument—such as its validity and reliability—remain unverified. The current study is limited by its coarse classification of screen time, which may have obscured certain associations. Future research should use more detailed data collection methods, such as gathering information on specific application types and content, to provide a more nuanced understanding of how different forms of digital engagement affect academic performance. This limitation may affect the credibility of the findings and interpretation of the results. Future randomized controlled trials should distinguish between passive and interactive forms of screen use, as well as between educational and entertainment content, using validated measurement instruments.

In conclusion, we investigated the associations between different types of sedentary behaviors and academic performance among PS and JHS students. Results

379 demonstrated that spending < 2 hours daily on recreational screen-based behaviors—
380 such as playing TV games or using videos/SNS—was consistently linked to higher
381 academic performance in both Japanese language and mathematics. In contrast, using
382 educational tablets was positively associated with academic outcomes, particularly
383 among PS students and reading books was positively associated with higher Japanese
384 language among PS and JHS students. Although this study was conducted using data
385 obtained from surveys investigating the academic performance and lifestyle habits of
386 students, these findings highlight the importance of distinguishing between types of
387 sedentary behavior when evaluating their academic performance. Further research is
388 warranted to clarify causal pathways, examine contextual influences, and rigorously
389 establish the effects of different sedentary behaviors on learning.

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Contributions

TA conceptualized the study design and protocol and determined the study institutions. TA and JK collected and assembled the data. TA carried out the analysis and interpretation of data. TA, JK, and MK drafted the manuscript. All authors have critically reviewed, revised, and approved the manuscript.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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Table 1. Characteristics of study participants

		Primary schools		Junior-high schools	
		n=342		n=456	
		n	%	n	%
School grade	Fifth	151	44.2		
	Sixth	191	55.8		
	First			216	47.4
	Second			240	52.6
Gender	Male	177	51.8	203	44.5
	Female	165	48.2	253	55.5
Sports club	Participation	244	71.3	306	67.1
	No participation	98	28.7	150	32.9
Breakfast consumption	Skipping	30	8.8	54	11.8
	Daily	312	91.2	402	88.2
Sleep duration	Non-achievement	265	77.5	312	68.4
	8–10 hours / ≥ 9 hours	77	22.5	144	31.6
Cram schools	Non-attendance	310	90.6	352	77.7
	Attendance	32	9.4	101	22.3
Total recreational screen time	< 2 hours	83	24.3	86	18.9
	≥ 2 hours	259	75.7	370	81.1
Playing TV game (weekday)	< 2 hours	180	52.6	268	58.8
	≥ 2 hours	162	47.4	188	41.2
	< 2 hours	241	70.5	244	53.5

Watching video or SNS (weekday)	≥ 2 hours	101	29.5	212	46.5
Using educational tablets at home	Usage	128	37.4	92	20.2
	Non-usage	214	62.6	364	79.8
Reading books	Agree	175	51.2	250	54.8
	Disagree	167	48.8	206	45.2
Reading newspapers	Agree	67	19.6	71	15.6
	Disagree	275	80.4	384	84.4

SNS: social networking service

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Table 2. Descriptive statistics of academic performance by types of sedentary behavior

				Total recreational screen time (weekday)		Playing TV game (weekday)		Watching video or SNS (weekday)		Using educational tablets at home		Reading books		Reading newspapers	
				≥ 2 hours	< 2 hours	≥ 2 hours	< 2 hours	≥ 2 hours	< 2 hours	Non-usage	Usage	Disagree	Agree	Disagree	Agree
Primary schools															
Japanese language	Fifth grade	Score	Mean (SD)	68.1 (16.2)	72.1 (15.5)	66.5 (17.0)	71.4 (15.0)	63.6 (14.8)	70.6 (16.1)	67.4 (16.5)	73.9 (14.1)	66.3 (15.5)	71.9 (16.2)	67.8 (16.2)	74.3 (14.8)
		T-score	Mean	49.3 (10.1)	51.8 (9.7)	48.3 (10.6)	51.4 (9.3)	46.5 (9.2)	50.9 (10.0)	48.9 (10.3)	52.9 (8.8)	48.2 (9.6)	51.7 (10.1)	49.1 (10.1)	53.2 (9.2)

			(SD)											
	Sixth grade	Score	Mean (SD)	58.3 (18.2)	69.1 (13.5)	56.5 (18.2)	64.6 (16.6)	53.9 (18.0)	64.6 (16.5)	57.8 (17.5)	63.9 (17.8)	58.0 (16.8)	63.1 (18.5)	59.8 (17.9)	64.4 (17.2)
		T-score	Mean (SD)	48.7 (10.2)	54.8 (7.6)	47.7 (10.2)	52.2 (9.3)	46.2 (10.1)	52.2 (9.3)	48.4 (9.8)	51.9 (10.0)	48.5 (9.4)	51.4 (10.4)	49.5 (10.0)	52.1 (9.6)
Mathematics	Fifth grade	Score	Mean (SD)	55.3 (20.3)	61.1 (19.0)	52.6 (20.1)	60.5 (19.5)	50.5 (16.4)	58.5 (20.6)	53.5 (19.2)	66.0 (19.8)	54.2 (18.1)	59.5 (21.5)	54.6 (19.6)	65.2 (19.9)

		T-score	Mean (SD)	49.2 (10.1)	52.1 (9.5)	47.8 (10.0)	51.8 (9.7)	46.8 (8.2)	50.8 (10.3)	48.3 (9.6)	54.5 (9.9)	48.6 (9.0)	51.3 (10.7)	48.8 (9.8)	54.1 (9.9)
	Sixth grade	Score	Mean (SD)	67.3 (17.0)	76.8 (12.9)	65.3 (17.5)	73.3 (14.7)	65.0 (18.0)	71.9 (15.3)	67.6 (16.3)	71.5 (16.8)	66.9 (17.5)	71.8 (15.4)	69.2 (17.4)	69.9 (12.9)
		T-score	Mean (SD)	48.8 (10.2)	54.5 (7.8)	47.5 (10.5)	52.4 (8.9)	47.4 (10.8)	51.5 (9.2)	48.9 (9.8)	51.3 (10.1)	48.5 (10.5)	51.5 (9.3)	49.9 (10.4)	50.3 (7.8)
Junior-high schools															
Japanese language	First grade	Score	Mean	60.4 (18.5)	67.6 (17.5)	55.4 (19.1)	66.6 (16.6)	58.7 (19.2)	64.8 (17.4)	61.2 (18.7)	64.8 (17.4)	58.3 (18.7)	65.5 (17.5)	61.3 (18.0)	67.0 (18.8)

			(SD)											
		T-score	Mean (SD)	49.1 (10.0)	53.0 (9.5)	46.4 (10.3)	52.5 (9.0)	48.2 (10.4)	51.5 (9.4)	49.6 (10.1)	51.5 (9.4)	48.0 (10.1)	52.0 (9.5)	49.6 (9.8)	52.7 (10.2)
	Second grade	Score	Mean (SD)	63.3 (19.1)	68.9 (18.9)	59.7 (19.8)	67.3 (18.1)	61.3 (19.5)	66.7 (18.5)	64.7 (19.2)	61.8 (19.2)	59.0 (19.0)	67.7 (18.5)	63.1 (19.3)	69.9 (17.6)
		T-score	Mean (SD)	49.6 (10.0)	52.5 (9.9)	47.7 (10.3)	51.6 (9.5)	48.5 (10.2)	51.3 (9.7)	50.3 (10.0)	48.7 (10.0)	47.3 (9.9)	51.9 (9.7)	49.4 (10.1)	53.0 (9.2)

Mathematics	First grade	Score	Mean (SD)	50.4 (20.7)	56.3 (18.4)	44.4 (22.1)	56.9 (17.2)	46.9 (21.6)	55.8 (18.2)	51.6 (20.8)	52.4 (18.2)	48.4 (20.5)	55.1 (19.5)	51.0 (19.8)	56.8 (22.3)
		T-score	Mean (SD)	49.3 (10.2)	52.2 (9.1)	46.4 (10.9)	52.5 (8.5)	47.6 (10.7)	52.0 (9.0)	49.9 (10.3)	50.3 (9.0)	48.3 (10.1)	51.7 (9.6)	49.6 (9.7)	52.5 (11.0)
	Second grade	Score	Mean (SD)	44.1 (20.1)	49.5 (24.0)	40.7 (19.3)	47.9 (21.4)	42.2 (20.7)	47.4 (20.7)	45.4 (20.8)	42.9 (21.2)	43.7 (19.7)	45.8 (21.6)	44.5 (20.8)	47.3 (21.3)
		T-score	Mean	49.6 (9.7)	52.2 (11.5)	48.0 (9.3)	51.4 (10.3)	48.7(10.0)	51.2 (9.9)	50.2 (10.0)	49.0 (10.2)	49.4 (9.4)	50.4 (10.4)	49.8 (10.0)	51.1 (10.2)

			(SD)												

SD: standard deviation

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Table 3. Associations between types of sedentary behavior and academic performance among students in primary schools (n=342)

		Japanese language					Mathematics				
		R^2	B	(95% CI)	P value[a]	VIF[b]	R^2	B	(95% CI)	P value[a]	VIF[b]
Total screen time (weekday)	< 2 hours	0.06	4.14	(1.66, 6.63)	<0.01	1.07	0.08	3.92	(1.46, 6.38)	0.01	1.07
Playing TV game (weekday)	< 2 hours	0.06	3.51	(1.38, 5.64)	<0.01	1.07	0.09	3.90	(1.81, 5.99)	<0.01	1.07
Watching video or SNS (weekday)	< 2 hours	0.09	5.36	(3.04, 7.68)	<0.001	1.09	0.08	3.86	(1.53, 6.18)	<0.01	1.09
Using educational tablets at home	Usage	0.06	3.61	(1.40, 5.82)	<0.01	1.10	0.09	3.75	(1.57, 5.93)	<0.01	1.10
Reading books	Agree	0.05	2.92	(0.81, 5.03)	0.04	1.08	0.07	2.53	(0.44, 4.62)	0.11	1.08
Reading newspapers	Agree	0.05	3.15	(0.48, 5.82)	0.13	1.07	0.07	2.48	(-0.17, 5.12)	0.40	1.07

Each sedentary behavior was analyzed separately using multiple linear regression, with adjustments made for gender, age, breakfast consumption, sleep duration, participation in sports clubs, and attendance at cram schools.

[a] Bonferroni-corrected p-values are shown.

[b] The VIF shows the highest value among the variables in the model.

R2: R-squared, B: Unstandardized coefficient, CI: confidence intervals, SNS: social networking service, VIF: Variance Inflation Factor

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Table 4. Associations between types of sedentary behavior and academic performance among students in junior-high schools (n=456)

		Japanese language					Mathematics				
		R^2	B	(95% CI)	P value[a]	VIF[b]	R^2	B	(95% CI)	P value[a]	VIF[b]
Total screen time (weekday)	< 2 hours	0.08	2.87	(0.53, 5.21)	0.10	1.126	0.06	2.59	(0.22, 4.96)	0.20	1.126
Playing TV game (weekday)	< 2 hours	0.10	3.82	(1.93, 5.71)	<0.001	1.185	0.09	4.47	(2.57, 6.37)	<0.001	1.185
Watching video or SNS (weekday)	< 2 hours	0.09	3.00	(1.20, 4.79)	<0.01	1.107	0.08	3.39	(1.57, 5.20)	<0.01	1.107
Using educational tablets at home	Usage	0.07	0.76	(-1.50, 3.03)	1.00	1.133	0.05	-0.06	(-2.35, 2.23)	1.00	1.133
Reading books	Agree	0.10	3.76	(1.96, 5.56)	<0.001	1.124	0.06	1.84	(-0.004, 3.69)	0.30	1.124
Reading newspapers	Agree	0.08	3.09	(0.62, 5.56)	0.09	1.119	0.06	1.84	(-0.68, 4.36)	0.91	1.119

Each sedentary behavior was analyzed separately using multiple linear regression, with adjustments made for gender, age, breakfast consumption, sleep duration, participation in sports clubs, and attendance at cram schools. Bold indicates $p<0.05$.

[a] Bonferroni-corrected p-values are shown.

[b] The VIF shows the highest value among the variables in the model.

R^2: R-squared, B: Unstandardized coefficient, CI: confidence intervals, SNS: social networking service, VIF: Variance Inflation Factor

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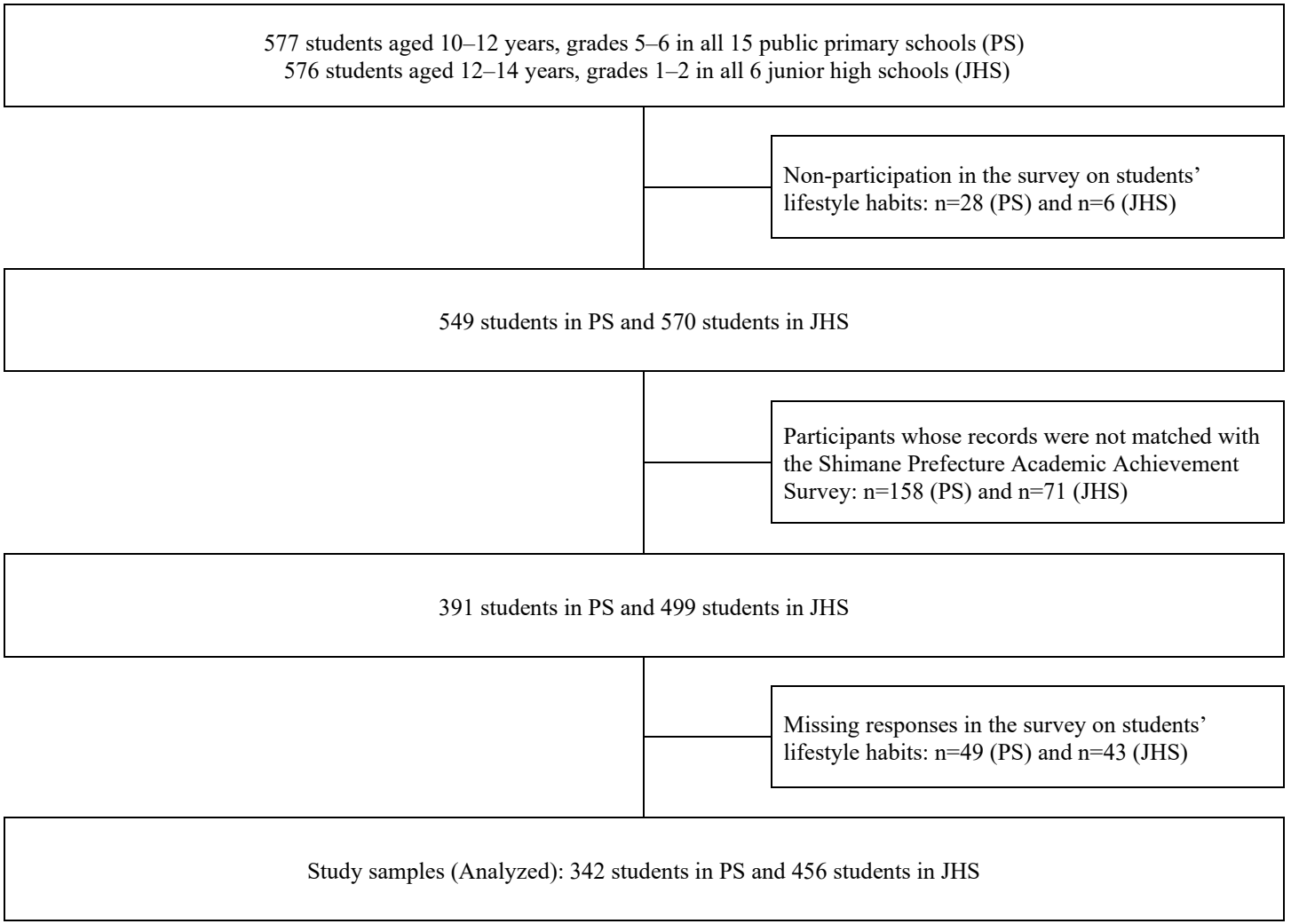

Fig 1. Flowchart of the study.

Supplemental file

Supplemental Method 1. Overview of the Shimane Prefecture Academic Achievement Survey

The Japanese language and mathematics tests used in this study were developed by Tokyo Shoseki Co., Ltd., commissioned by the Shimane Prefectural Board of Education, as part of the Shimane Prefecture Academic Achievement Survey. The purpose of this survey is "To objectively assess students' learning status in relation to the goals and content of each subject as outlined in the national Course of Study, as well as their attitudes and actual conditions regarding learning and daily life. This assessment aims to provide necessary guidance and support to students, evaluate the progress made in addressing instructional challenges identified through the National Assessment of Academic Ability and other surveys, and contribute to further enhancement and enrichment of school instruction and educational policies". Approximately 10,600 students from 197 public primary schools and about 9,800 students from 97 public junior-high schools within Shimane Prefecture participated in the survey. The same Japanese language and mathematics tests used in this study were also administered nationwide in the same year (the number of participating schools is not publicly disclosed). The average scores for the Japanese language and mathematics tests for both

Shimane Prefecture and the entire nation have been published in Japanese[19]. Tokyo Shoseki Co., Ltd. is an educational publisher that produces textbooks for primary and junior high schools nationwide.

Supplemental Method 2. Questionnaire about sedentary behaviors

Playing TV games

1. On school days, how much time do you spend playing TV games (including computers, tablets, and smartphones) per day?

   学校がある日（平日）に、1 日あたりどれくらいの時間、テレビゲーム（コンピューターゲーム、タブレット、スマートフォンを含む）をしますか？

   None, < 1 hour, 1–2 hours, 2–3 hours, 3–4 hours, ≥ 4 hours

   全くない・1 時間未満・1 時間以上 2 時間未満・2 時間以上 3 時間未満・3 時間以上 4 時間未満・4 時間以上

Watching videos or SNS use

2. On school days, how much time do you spend watching video sites or using social networking services (excluding those related to learning) on smartphones or tablets per day?

   学校がある日（平日）に、1 日あたりどれくらいの時間、スマートフォン

やタブレットで動画サイトや SNS を見ますか？（学習のための動画やゲームの時間は含めない）

None, < 30 minutes, 30 minutes–1 hour, 1–2 hours, 2–3 hours, 3–4 hours, ≥ 4 hours

全くない・３０分未満・30 分以上 1 時間未満・1 時間未満・1 時間以上 2 時間未満・2 時間以上 3 時間未満・3 時間以上 4 時間未満・4 時間以上

Using educational tablets at home

3. How often do you use tablets for learning at home?

学習用タブレットを、家でどのくらいつかいますか？

frequently, moderately, rarely, never

よく使う・まあまあ使う・あまり使わない・全く使わない

Reading books

4. Do you read books (excluding manga and magazines)?

本（マンガや雑誌を含まない）を読んでいる

strongly agree, somewhat agree, somewhat disagree, strongly disagree

あてはまる・まあまああてはまる・あまりあてはまらない・まったくあてはまらない

Reading newspapers

5. Do you read newspaper articles?

新聞の記事を読んでいる

strongly agree, somewhat agree, somewhat disagree, strongly disagree

あてはまる・まあまああてはまる・あまりあてはまらない・まったくあてはまらない

Supplemental Table 1. Statistical characteristics of Japanese language and mathematics test scores among students in primary schools

		Primary schools							
		Fifth grade				Sixth grade			
		Japanese language		Mathematics		Japanese language		Mathematics	
		Score	T-score	Score	T-score	Score	T-score	Score	T-score
Mean		69.19	50.00	56.92	50.00	60.59	50.00	69.36	50.00
Standard deviation		16.06	10.00	20.08	10.00	17.83	10.00	16.62	10.00
Percentile	25^{th}	57.69	42.84	41.94	42.53	50.00	44.06	59.38	44.00
	50^{th}	69.23	50.02	54.84	48.96	61.54	50.53	71.88	51.52
	75^{th}	80.77	57.21	74.19	58.60	73.08	57.00	81.25	57.16
Minimum		19.23	18.89	0.00	21.65	7.69	20.33	15.63	17.68
Maximum		100.00	69.18	100.00	71.46	96.15	69.94	100.00	68.44
Skewness		-0.60	-0.60	-0.10	-0.10	-0.58	-0.58	-0.45	-0.45
Standard error of skewness		0.20	0.20	0.20	0.20	0.18	0.18	0.18	0.18

Kurtosis	0.19	0.19	-0.50	-0.50	0.12	0.12	-0.02	-0.02
Standard error of kurtosis	0.39	0.39	0.39	0.39	0.35	0.35	0.35	0.35
Potential ceiling effects[a]	85.25	60.00	77.00	60.00	78.42	60.00	85.98	60.00
Potential floor effects[b]	53.13	40.00	36.85	40.00	42.76	40.00	52.73	40.00

[a]An indicator of potential ceiling effects: Mean + 1 * standard deviation.

[b]An indicator of potential floor effects: Mean -1 * standard deviation.

Supplemental Table 2. Statistical characteristics of Japanese language and mathematics test scores among students in junior-high schools

	Junior-high schools							
	First grade				Second grade			
	Japanese language		Mathematics		Japanese language		Mathematics	
	Score	T-score	Score	T-score	Score	T-score	Score	T-score
Mean	62.00	50.00	51.74	50.00	64.15	50.00	44.95	50.00

Standard deviation		18.47	10.00	20.28	10.00	19.16	10.00	20.82	10.00
Percentile	25th	50.00	43.50	37.50	42.98	51.85	43.58	28.13	41.92
	50th	65.38	51.83	53.13	50.68	66.67	51.31	40.63	47.92
	75th	75.96	57.56	68.18	58.11	77.78	57.11	62.50	58.43
Minimum		3.85	18.51	0.00	24.49	22.22	28.12	9.38	32.91
Maximum		96.15	68.49	93.75	70.71	100.00	68.71	93.75	73.44
Skewness		-0.52	-0.52	-0.14	-0.14	-0.25	-0.25	0.37	0.37
Standard error of skewness		0.17	0.17	0.17	0.17	0.16	0.16	0.16	0.16
Kurtosis		-0.13	-0.13	-0.73	-0.73	-0.60	-0.60	-0.81	-0.81
Standard error of kurtosis		0.33	0.33	0.33	0.33	0.31	0.31	0.31	0.31
Potential ceiling effects[a]		80.47	60.00	72.02	60.00	83.31	60.00	65.77	60.00
Potential floor effects[b]		43.53	40.00	31.46	40.00	44.99	40.00	24.13	40.00

[a]An indicator of potential ceiling effects: Mean + 1 * standard deviation.

[b]An indicator of potential floor effects: Mean -1 * standard deviation.

Supplemental Table 3. P-values for interaction between gender and each type of sedentary behaviors for academic performance

	Students in primary schools（n=342）		Students in junior-high schools (n=456)	
	Japanese language	Mathematics	Japanese language	Mathematics
	P value for interaction	P value for interaction	P value for interaction	P value for interaction
Total recreational screen time (weekday)	0.53	0.91	0.09	0.26
Playing TV games (weekday)	0.70	0.55	0.20	0.44
Watching videos or SNS use (weekday)	0.69	0.60	0.97	0.25
Using educational tablets at home	0.84	0.56	0.91	0.56
Reading books	0.24	0.23	0.72	0.61
Reading newspapers	0.98	0.90	0.80	0.41

An interaction term between gender and sedentary behavior type was included.