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Original Article

Trends in childhood obesity in Japan: A nationwide observational study from 2012 to 2021

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List of Abbreviations

WHO	World Health Organization
COVID-19	Coronavirus disease 2019
BMI	body mass index
POW	percentage of overweight
MEXT	Japanese Ministry of Education, Culture, Sports, Science, and Technology
JE	junior elementary school age
SE	senior elementary school age
JH	junior high school age
APC	annual percent change
CI	confidence interval
AAPC	average annual percentage change

What is already known about this subject

- Childhood obesity is a worldwide issue, yet Japan have been slowly decreasing since the 2000s due to increased awareness and efforts.
- Follow-up research on childhood obesity in Japan in this decade are scarce.
- The COVID-19 pandemic increased childhood obesity globally.

What this study adds

- Re-increasing trends in childhood obesity in Japan were observed.
- It highlights declining physical activity and increasing screen time as potential contributors to childhood obesity, emphasizing the need for school policies promoting healthy habits.

55   ●   The COVID-19 pandemic may have accelerated the re-emergence of childhood obesity

56   in Japan.

57

Abstract

Background:

The persistent ascension of childhood obesity on a global scale constitutes a significant quandary. The prevalence of childhood obesity in Japan peaked in the early 2000s and has been reported to have declined since then, but recent data and its trend including the novel coronavirus disease 2019 pandemic era are not available. Moreover, there is a dearth of studies examining the correlation between the trend in childhood obesity and exercise habits over the past decade. This study aims to examine the changes in the prevalence of obesity, physical fitness and exercise habits over the past 10 years in Japanese children.

Methods:

We investigated the prevalence of childhood obesity in Japan, using the School Health Statistics Survey data from 2012 to 2021. The dataset has a sample size representative of children nationwide and includes variables for obesity, such as height, weight, and age. Data were classified into groups by sex and age (6–8, 9–11, and 12–14-year age). Children weighing 20% or more of the standard body weight are classified as obese. The annual percentage changes and average annual percentage changes were estimated using the joinpint regression model. We also examined the trends in the physical fitness test score and exercise time.

Results:

Average annual percentage changes of boys increased, especially in the 6–8-year age group (3.4–4.6%). For girls, ~~AAPCs~~ average annual percentage changes had increased in 6–8-year (2.5–4.0%) and 9–11-year (0.9–2.2%) age groups. Since the late 2010s, significantly increasing annual percentage changes were observed in 12–14-year age boys (6.7-8.9%) and girls of many age groups (2.6-8.6%). The physical fitness test score and exercise time showed decreasing trends since the late 2010s.

Conclusion:

83   Childhood obesity <mark>may have</mark> generally risen in Japan, in the last decade. Encouraging healthy

84   eating and physical activity through school policies and curricula is necessary.

85

Introduction

Childhood obesity is a serious global health concern. Obesity in adults causes health problems such as hypertension, sleep apnea syndrome, type 2 diabetes, non-alcoholic fatty liver disease, dyslipidemia, and hyperuricemia.[1] Childhood-onset obesity often persists into adulthood and is associated with an increased risk of future morbidity.[2] The World Health Organization (WHO) estimated that the prevalence of overweight or obesity in children aged 5–19 years had increased considerably from 4% in 1975 to over 18% in 2016, equivalent to 340 million children worldwide.[3] Although the prevalence of childhood obesity possibly varies according to racial, ethnic, and socio-economic factors,[1] increasing trends have been observed in many developed and developing countries.[4]

In contrast to other developed and developing countries, Japan has historically had a low prevalence of childhood obesity.[5] A previous study reported that the prevalence of childhood obesity in Japan had increased from 1974 to 2000; however, the prevalence of childhood obesity has gradually decreased since the early 2000s.[6] Although the cause of the decline is unknown, the enactment of the Shokuiku Basic Act in 2005, which provided children with food and nutrition education, as well as the publication of diagnostic criteria for metabolic syndrome in children in 2007, might have played a certain role in fostering awareness of life-threatening health complications of obesity and underscoring the importance of dietary intervention in obesity prevention.[7]

The novel coronavirus caused the coronavirus disease 2019 (COVID-19) on a global scale in December 2019, and the WHO declared COVID-19 a worldwide pandemic in January 2020.[8] Previous reports have revealed a significant increase in childhood obesity due to lifestyle changes caused by the COVID-19 pandemic. For instance, a meta-analysis in Taiwan revealed

significant increases in weight and body mass index (BMI) among Taiwanese children aged 2-18 during the lockdown period.[9]

Understanding recent trends in childhood obesity are essential for appropriate policymaking, especially in light of the dynamic changes in society due to COVID-19. However, little is known about recent trends in childhood obesity prevalence, and no study has analyzed trends in the prevalence of childhood obesity in Japan over the past decade. This study aimed to examine the trends in the prevalence of childhood obesity over the past 10 years, from 2012 to 2021 in Japan, covering the COVID-19 pandemic. We also investigated the changes in physical fitness and exercise habits of children as factors that may be associated with obesity.

Methods

Definition of obesity

Although definitions of childhood obesity are different from country-to-country, BMI percentile values or BMI-standard deviation score are widely used.[3] On the other hand, in Japan, childhood obesity is defined according to the "the percentage of overweight (POW)" obtained using the following formula:

$$The\ percentage\ of\ overweight\ (\%) = \frac{Measured\ weight\ (kg) - Standard\ weight\ (kg)}{Standard\ weight\ (kg)} \times 100$$

Children with a POW of 20% or higher are defined as obese.[10] In addition, obese children were classified as mildly obese if their POW was less than 30%, moderately obese if their POW was between 30% and 50%, and severely obese if their POW was 50% or higher. The standard weight was defined by sex, age, and height according to the designated formula, using data from the School Health Statistics Survey in 2000. The process of creating the formula involved the following steps: plotting the height and weight data by age and sex, with the height in

centimeters on the horizontal axis and the weight in 0.1 kg on the vertical axis. The regression

equation obtained using the least squares method for the plotted distribution ellipse was used

to calculate the standard weight by age and sex (the details are in Table S1).[11] The BMI

percentile value is widely used worldwide for evaluating childhood obesity. However, during

puberty, children undergo significant changes in body shape, thereby leading to varying body

shapes among individuals with similar BMI percentiles. This variation makes it challenging to

accurately assess the body fat. In contrast, the POW takes age and sex into account for the

calculation of standard weight and further refines this assessment by incorporating height.

Therefore, it provides a more precise assessment of body fat and aligning with the original

definition of obesity. In fact, when comparing the POW among Japanese children, BMI

percentile values tend to overestimate obesity in taller adolescents and underestimate it in

shorter adolescents.[12] Obtaining comprehensive and reliable data on height and weight is

crucial for accurately assessing obesity using the POW. In Japan, the School Health and Safety

Act mandates annual height and weight measurements, which enables the collection of

extensive and dependable data.[12] Furthermore, Japan benefits from having a highly ethnically

homogeneous population, which further enhances the reliability of standard weight

calculations.[12] Therefore, childhood obesity in Japan should be assessed using the POW.[7,13]

The POW also provides an intuitive understanding the patient's body size by percentile values.

Data source

Height and weight measurements of Japanese children have been continuously conducted by

the Japanese Ministry of Education, Culture, Sports, Science, and Technology (MEXT) since

1900, via the School Health Statistics Survey since 1960.[14] The survey contains data on height,

weight, and prevalence of obesity defined by the POW. We examined the School Health

Statistics Survey data from 2012 to 2021 to determine the prevalence of obesity.[15] Japanese

161   students attend elementary school for 6 years (6–11 years) and junior high school for 3 years

162   (12–14 years) as compulsory education. Each school year in Japan begins in April. The

163   measurements are conducted between April 1 and June 30 of every year, and the study

164   participants were students who belong to schools selected by the MEXT. This survey was a

165   sample survey using a stratified two-stage random sampling method. In this method, the

166   number of schools to be surveyed is determined using the number of children and schools in

167   each prefecture and for each school type (kindergarten, elementary school, junior high school,

168   and high school). In each prefecture and for each school type, all schools are stratified by

169   several strata according to the number of students, with the same number of students in each

170   stratum. The surveyed schools were randomly selected within each stratum. As a result,

171   approximately 700,000 children, or 5% of all students in this country, were included in the

172   survey every year (the details are in Table S2).

173

174   The national survey on physical fitness, athletic ability, and exercise habits, which includes the

175   national physical fitness test and exercise habits questionnaire, has been conducted by the Japan

176   Sports Agency, a bureau of MEXT, and the results are disclosed to the public.[16] The survey has

177   been targeting 10- and 13-year-old children since 2008; however, this survey was not conducted

178   in 2020 due to the COVID-19 pandemic. The national physical fitness test consists of eight

179   exercise tests: grip strength test, sit-ups, anteflexion while sitting, side-to-side jump, long-

180   distance run or shuttle run, 50-meter run, standing broad jump, and softball throw or handball

181   throw. Test results are scored according to sex- and age-specific reference values, and athletic

182   performance is evaluated using the scores (the details are in Table S3). The exercise habits

183   survey was administered to students through a questionnaire that asked about exercises, such

184   as frequency and length of exercise time and exercise preferences. In the School Health

185   Statistics Survey and national survey on physical fitness, athletic ability, and exercise habits,

186 each age group is defined within a maximum width of one year. For example, the six-year-old

187 group students include children, aged 6.0–6.99 years. In our study, we adopted the age group

188 definition as it is.

189

190

191 We examined the trends of the prevalence of childhood obesity by sex and age (6–14 years of

192 age) based on the School Health Statistics Survey data of one decade from 2012 to 2021.

193 Surveyed data were classified into six groups according to sex and age: boys and girls of junior

194 elementary school age (JE: aged 6–8 years), senior elementary school age (SE: aged 9–11

195 years), and junior high school age (JH: aged 12–14 years). We also examined the trends of the

196 total score of the national physical fitness test and length of exercise time per week, excluding

197 physical education time in school, using the national data. The results of the length of exercise

198 time per week in 2012 were excluded from the analysis because a different form was used in

199 2012 from earlier years. Moreover, the national survey on physical fitness, athletic ability, and

200 exercise habits was not conducted due to the COVID-19 pandemic, resulting in a lack of data

201 for 2020.

202

203 **Statistical analyses and data processing**

204 A joinpoint regression model was applied using the Joinpoint Regression Program, version

205 4.9.1.0, April 2022 (Statistical Research and Applications Branch, National Cancer Institute,

206 USA) to estimate the trends in the prevalence of childhood obesity, total score of the physical

207 fitness and motor ability survey, and length of exercise time per week. The Joinpoint

208 Regression Program is a statistical software employed for trend analysis through joinpoint

209 models, wherein various lines converge at inflection points or "joinpoints." Joinpoint

210 regression analysis is valuable for examining data predominantly focused on identifying trend

211 changes, points of incidence, mortality, and prevalence of target diseases. The fundamental

212 structure of the joinpoint regression model comprises continuous linear segments

213 interconnected at the joinpoints. In our investigation, we utilized the grid search method in

214 conjunction with the log-linear model. The grid search method involves fabricating a "grid"

215 that encompasses all potential joinpoint locations determined by the settings, followed by

216 computing the sum of squared residuals at each location to discern the optimal model and detect

217 the joinpoints within the trends. One method for describing trends in the rate of obesity over

218 time is through the use of annual percent change (APC) between joinpoints. With this approach,

219 the prevalence of obesity is assumed to change at a constant percentage between each joinpoint.

220 The prevalence of obesity, which changes at a constant percentage every year, changes linearly

221 on a log scale.[17]

222 The APCs between joinpoints were determined using 95% confidence intervals (CIs). We

223 estimated the average annual percentage change (AAPC) for the entire period to observe the

224 progress of the trend over a decade. A p value <0.05 was defined as the level at which the slope

225 was significantly different from zero.

226

Ethics approval

228 This study used publicly available data published by the Japan Ministry of Education, Culture,

229 Sports, Science, and Technology. Since this study was a retrospective examination of routinely

230 gathered data, informed consent was not required.

231

Results

Trends in the prevalence of childhood and adolescent obesity

234 The prevalence of obesity in 2021 compared to that in 2012 increased in all groups. In boys,

235 the highest increase was observed in the 9-year-old group, from 9.2–12.0%. The increase was

236 lower in girls than in boys, but the highest increase was seen in the 8-year-old group, from 6.1–

237 8.3%. In 2020, when the COVID-19 pandemic occurred, the prevalence of obesity increased

238 in all groups, with most age groups experiencing the highest obesity rates observed in the

239 decade. Especially SE boys showed significant increases: 10.6–13.6% (+3.0%) in the 9-year-

240 old group, 10.6–14.2% (+3.6%) in the 10-year-old group, and 11.1–13.3% (+2.2%) in the 11-

241 year-old group. However, in 2021, the prevalence of obesity decreased among all groups

242 compared to that in 2020, except for the 11- and 12-year-old girl groups. Detailed numerical

243 values for the percentage of obesity according to age and sex are shown in Table S4.

244

245 The trends in the prevalence of childhood obesity by sex and age groups are shown in **Figure**

246 **1** and the results of the joinpoint regression analysis are shown in **Table 1**. In the 10-year trend

247 for boys, almost all groups showed a statistically significant increase in AAPCs. Boys in the

248 JE group showed an increase in the AAPCs of 3.4–4.6%. JE and SE boys showed

249 monotonically increasing APCs (2.8–4.6%), while JH boys showed significant increases in the

250 late 2010s, with APCs of 6.7–8.9%. For girls, significant increases in the AAPCs were observed

251 in JE (2.5–4.0%) and SE (0.9–2.2%) groups, while no rise was observed in JH girls. Elevations

252 in the APC trends were also observed among girls after the late-2010s, at APCs of 2.6–8.6%.

253 **Trends in physical fitness test results and exercise time**

254 Trends in the total scores of the national physical fitness test and length of the exercise time

255 per week are shown in **Figure 2**, and the results of the joinpoint regression analysis are in **Table**

256 **2**. The AAPC of the total score of the national physical fitness test decreased in 10-year-old

257 boys (-0.3%). Particularly, the APCs of 10-year-old boys and 10-year and 13-year-old girls

258 showed significantly decreasing trends after 2018.

259

260 The length of exercise time per week, excluding physical educational time, in 2021 compared

261 to that in 2013, decreased in all groups except 10-year-old girls. Of note, 13-year-old boys were

262 found to have a markedly reduced exercise time in 2021 (192 min, accounting for a 21%

263 decrease). In the trend analysis, the AAPCs showed decreasing trends, except for 10-year-old

264 girls. Since 2017, obvious declines in APCs have been occurring in all groups: -3.9% in 10-

265 year-old boys, -6.9% in 13-year-old boys, -2.4% in 10-year-old girls (not significant), and -

266 7.5% in 13-year-old girls.

267

268

269 **Discussion**

270 Our study found the following key results:1) the prevalence of childhood obesity increased in

271 all age groups from 2012 to 2021, 2) the prevalence of childhood obesity was the worst in 2020

272 amidst the COVID-19 pandemic, 3) 10-year trend analysis of the prevalence of childhood

273 obesity revealed an upward trend in boys in almost all ages and elementary school girls, 4) JH

274 boys and girls generally showed increasing APCs in the prevalence of obesity in the late 2010s,

275 and 5) trends in the physical fitness test and exercise time showed downward trends since the

276 mid-2010's.

277

278 In 2020, the COVID-19 pandemic occurred, and cities were locked down globally. Previous

279 studies have shown an increase in childhood obesity due to lifestyle changes during the

280 pandemic.[18] A retrospective study conducted in South Korea reported that the percentage of

281 children who had overweight or obese increased from 24.5% to 38.1% during the COVID-19

282 pandemic lockdown within 1 year.[19] Similarly, in Australia, the percentage of overweight or

283 obese children aged 7–10 years increased from 20.7% in September 2019 to 26.2% in March

284 2021.[20] In China, the percentage of obese children increased from 13.3% in 2019 to 15.3% in

285 2020.[21] These studies suggest that dietary changes and decreased exercise time during the

286 COVID-19 pandemic and lockdown period have contributed to the increase in obesity.

287 Although direct comparisons are difficult between each report, owing to the different

288 definitions of obesity, it is clear that childhood obesity in Japan also increased during the

289 COVID-19 pandemic. In Japan, the government issued a state of emergency and implemented

290 "social distancing" and "stay at home" measures in April 2020, which may have contributed to

291 the rise in childhood obesity.[22] The high obesity prevalence in the first year of the pandemic

292 (2020) would be one of the major factors that influenced the trends of the AAPCs over the 10-

293 year period. Although the prevalence of obesity showed a decline in 2021 across various age

294 groups, it has not yet reached the levels observed before the pandemic. Onwards close

295 monitoring, immediate policy interventions, and modifications to the curriculum in schools,

296 aimed at promoting healthy eating habits and physical activity, may be necessary to facilitate

297 an improvement in this trend.

298

299 Our study found that over a 10-year period, obesity increased in boys in almost all age groups

300 and in elementary school girls. High AAPCs were observed in elementary school boys and

301 younger elementary school girls, indicating that obesity is increasing among these age groups.

302 A previous report comparing childhood BMI trends from 1975 to 2016 by country found a

303 global increase, with some high-income countries in northwestern Europe, English-speaking

304 countries, and the Asia–Pacific region plateauing at high levels since the 2000s.[23] In Japan,

305 childhood obesity increased from the 1970s to around 2000, similar to other countries, but it

306 peaked in the 2000s and started decreasing since then.[6] The recent increases in obesity among

307 elementary school boys and junior elementary school girls are a matter of concern and should

308 be addressed urgently.

309

The significant increases in obesity among JH boys and girls in many age groups since the late-2010s suggests that factors other than the COVID-19 pandemic may exist in that age groups. Our study also revealed significant declining trends in the total score of the national physical fitness test and exercise time per week during the same period. These declining trends in physical activity may have influenced the increase in obesity in each group, which may have contributed to the rising APCs. Previous studies have demonstrated the impact of diet and exercise on childhood obesity; children who maintain a healthy diet but are physically inactive, have a higher risk of being overweight compared to their counterparts who eat healthily and engage in physical activity.[24]

Although there is no known direct cause, the declining trends in physical activity may have been caused by an increase in screen time. A survey conducted by the Japan Sports Agency found that between 2017 and 2021, the percentage of children with more than two hours of screen time per day increased in all age and sex groups.[16] The survey also revealed a correlation between screen time and exercise time, with longer daily screen time resulting in shorter exercise time. Previous studies reported an association between increased screen time and physical inactivity,[25] as well as an increased risk of obesity in children with more than 2 hours of screen time per day.[26] These results suggest that the rise in screen time among Japanese children may have led to a decrease in exercise and an increase in obesity as a consequence.

The present study is the first to analyze nationwide trends in the prevalence of childhood obesity in Japan. Our study provides age- and sex-specific characteristics and evidence of a re-increase in childhood obesity among most groups since the 2010s. Moreover, we analyzed the data of the total score of the physical fitness test and exercise time, which showed decreasing APCs in the late 2010s. Although a causal relationship cannot be proven owing to the nature

335   of the study, it is suggested that these declining trends in physical activity may have influenced

336   the increase in obesity in those groups. However, this study has several limitations. First, the

337   data collection period for the School Health Statistics Survey was longer in 2020 and 2021

338   (from April 1 to March 31 of the following year), which may have led to an overestimation or

339   underestimation of the prevalence of obesity. Second, data from the exercise habits survey in

340   2012 were excluded owing to the use of a different question format and the national physical

341   fitness test, and the data for 2020 were unavailable due to the COVID-19 pandemic. Third, the

342   study did not differentiate between rural and urban regions in terms of the prevalence of

343   childhood obesity in Japan. The analysis was not adjusted for various confounding factors such

344   as familial background, dietary environments, and the prevalence of secondary causes of

345   obesity such as endocrine disorders, genetic variants, and syndromic diseases. Additionally,

346   this study was a trend analysis using publicly available repeated cross-sectional data on the

347   prevalence of obesity in Japan. Although it is possible to observe changes in the prevalence

348   rates both before and after the COVID-19 pandemic, it is difficult to establish a causal link

349   between the pandemic and such changes. Despite these limitations, to our knowledge, this

350   study is the first to use national data from the School Health Statistics Research, physical fitness

351   test, athletic ability, and exercise habits survey to conduct a joinpoint regression analysis.

352

353   In conclusion, our research findings indicated that the prevalence of childhood obesity in Japan

354   had increased significantly, especially among elementary school boys and junior elementary

355   school girls, over the previous decade. Notably, junior high school boys and elementary and

356   junior high school girls showed a sharp increase in APCs starting from the late 2010s. Dietary

357   changes and decreased exercise time as well as lockdown amid the COVID-19 pandemic may

358   have contributed to the increase in the prevalence of obesity. Policy and curriculum

359   modifications promoting healthy eating and physical activity in schools are essential to combat

360 this unfavorable trend. Further research and ongoing monitoring of the trends of childhood

361 obesity are necessary to understand the current progression of the problem and its potential

362 long-term effects.

363

366 **Conflicts of interest**

367 The authors declare no conflicts of interest in association with the present study.

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372 **Author's contributions**

373 S.F. collected and analyzed the data and drafted the manuscript. K.Harada., H.H., T.K., and

374 K.Hasegawa. designed the study and critically reviewed the manuscript. H.T. and F.O.

375 supervised the study.

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459

460   **Table 1. Trends in childhood obesity rate in Japan by sex, 2012–2021**

461

Sex	Age (years)	Period 1 Years	Period 1 APC (%)		Period 2 Years	Period 2 APC (%)		Average APC (%) (95% CI)	
Boy	6	2012-2021	3.4	*				3.4 (1.3 to 5.6)	*
	7	2012-2021	4.6	*				4.6 (1.9 to 7.3)	*
	8	2012-2021	4.3	*				4.3 (1.2 to 7.4)	*
	9	2012-2021	4.0	*				4.0 (1.7 to 6.3)	*
	10	2012-2021	2.8	*				2.8 (0.3 to 5.5)	*
	11	2012-2017	-0.8		2017-2021	7.6	*	2.9 (0.2 to 5.6)	*
	12	2012-2017	-1.5		2017-2021	6.7	*	2.1 (0.2 to 4.0)	*
	13	2012-2017	-1.5		2017-2021	8.9	*	3.0 (-0.6 to 6.7)	
	14	2012-2017	-1.1		2017-2021	8.0	*	2.8 (0.2 to 5.6)	*
Girl	6	2012-2021	2.5	*				2.5 (0.9 to 4.2)	*
	7	2012-2017	-0.8		2017-2021	8.6	*	3.3 (0.0 to 6.7)	
	8	2012-2018	1.1		2018-2021	10.3		4.0 (0.6 to 7.6)	*
	9	2012-2021	2.0	*				2.0 (0.5 to 3.6)	*
	10	2012-2018	-0.1		2018-2021	7.0		2.2 (-0.4 to 4.9)	
	11	2012-2015	-2.5		2015-2021	2.6	*	0.9 (0.1 to 1.6)	*
	12	2012-2017	-0.9		2017-2021	2.8		0.7 (-0.8 to 2.3)	
	13	2012-2018	-1.1		2018-2021	5.0	*	0.9 (-0.3 to 2.1)	
	14	2012-2021	0.6					0.6 (-0.6 to 1.9)	

462

463 **Table 2. Trends in the total score of national physical fitness test and exercise time per**

464 **week by sex, 2012–2021**

465

Sex	Age (years)	Period 1			Period 2			Average APC (%) (95% CI)	
		Years	APC (%)		Years	APC (%)			
Fitness score test									
Boy	10	2012-2018	0.1		2018-2021	-1.0	*	-0.3 (-0.4 to -0.1)	*
	13	2012-2018	0.1		2018-2021	-0.8		-0.2 (-0.5 to 0.1)	
Girl	10	2012-2018	0.4	*	2018-2021	-0.7	*	0.0 (-0.1 to 0.2)	
	13	2012-2018	0.7	*	2018-2021	-1.2	*	0.1 (-0.2 to 0.4)	
Exercise test									
Boy	10	2013-2017	0.3		2017-2021	-3.9	*	-1.9 (-2.4 to -1.3)	*
	13	2013-2017	1.6		2017-2021	-6.9	*	-2.8 (-3.7 to -1.8)	*
Girl	10	2013-2016	5.8		2016-2021	-2.4		0.6 (-1.3 to 2.4)	
	13	2013-2017	3.4	*	2017-2021	-7.5	*	-2.2 (-3.1 to -1.3)	*

466

467
468 **Table legends**

469 **Table 1. Trends in childhood obesity rates in Japan by sex, 2012–2021**

470 * Significantly different from zero (*p*<0.05).

471 APC, annual percentage change; CI, confidential.

472 The study period was separated into Periods 1 and 2 when the trend changes were statistically

473 detected in the joinpoint regression analysis during the study period.

474

475 **Table 2. Trends in the total score of national physical fitness test and exercise time per**

476 **week by sex, 2012–2021**

477 * Significantly different from zero (*p*<0.05).

478 APC, annual percentage change; CI, confidential

479 Physical fitness test data were covered from 2012 to 2021, whereas exercise time data were

480 available from 2013 to 2021.

481   The study period was separated into Periods 1 and 2 when the trend changes were statistically

482   detected in the joinpoint regression analysis during the study period.

483

484   **Figure legends**

485   **Figure 1. Trends in childhood obesity rates in Japan by sex, 2012–2021**

486   Regarding the 10-year trend for boys, almost all groups demonstrated statistical <mark>increases</mark> in

487   AAPCs. In the late 2010s, while JE and SE boys had monotonically increasing APCs (2.8–

488   4.3%), JH boys showed a significant increase, with APCs ranging from 6.7–8.9%. Significant

489   increases in AAPCs were observed in JE (2.5–4.0%) and SE (0.9–2.2%) girls, but not in JH

490   girls. In the late 2010s, <mark>increases</mark> in APC trends were also detected in girls, with APCs

491   ranging from 2.6–8.6%.

492

493   **Figure 2. Trends in the score of physical fitness test from 2012 to 2021, and the exercise**

494   **time per week from 2013 to 2021 in Japan by sex**

495   After 2018, the APCs of the total score on the national physical fitness test decreased

496   significantly among 10-year-old boys, 10-year-old girls, and 13-year-old girls. The length of

497   exercise time per week, excluding physical educational time, in 2021 compared to that in

498   2013 decreased in all groups except the 10-year-old girls. The AAPCs of exercise time

499   exhibited decreasing trends for all girls, except 10-year-old girls.

500