Original Article

# A Longitudinal Analysis on the Prevalence of Overweight and Underweight Students in Aomori Prefecture in Relation to Gender, Birth Year and District

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[Received December 7, 2018 ; Accepted July 14, 2019]

**Background**: It has been reported that there is a pattern of onset of overweight and underweight in children and students. The prevalence of overweight children and students in Aomori Prefecture is higher than the national average for all grades, but a large-scale longitudinal analysis of overweight and underweight among children and students has not been conducted. Therefore, it has not been clarified whether there is a particular pattern in the onset of overweight or underweight. Thus, in Aomori Prefecture, large-scale longitudinal analysis on overweight and underweight of children and students is required. As the harmful effects of childhood obesity have become widely known and enlightenment activities have been carried out, overweight prevalence of children and students has been decreasing in recent years. Further reduction of overweight and underweight prevalence requires a high-risk approach, for which longitudinal data on overweight and underweight transitions is strongly required.

**Objective**: We aim to clarify whether there is a particular pattern in the prevalence of overweight and underweight children and students in Aomori Prefecture.

**Methods**: We constructed a pseudo-cohort using data from the *Aomori Prefecture children and Student's Health and Physical Fitness Survey Report* from fiscal year (FY) 2007 to FY2018 (full survey) and the *Annual Report of School Health Statistics Researches* by the Ministry of Education, Culture, Sports, Science and Technology (sample survey). Classification of overweight and underweight was based on standard weight. We longitudinally compared the prevalence of overweight and underweight by gender and age between Japan and Aomori Prefecture for children born between FY2000 and FY2006, until FY2018. Furthermore, dividing Aomori Prefecture into six districts, we analyzed overweight and underweight prevalence of children and students born between FY2000 and FY2006 by age (6-17) and gender longitudinally.

**Results**: The prevalence of overweight children and students increased from age 6 in both boys and girls, reaching a maximum at age 9. This was one year earlier than the national average, and the same tendency was observed in each region. The prevalence of children with a tendency to be underweight was highest at age 11 and increased from age 6. Additionally, in some districts we found that both overweight and underweight prevalence increased.

**Conclusion**: The maximum prevalence age of overweight children and students in Aomori Prefecture was shown to be one year earlier than the national average and was similar by birth year and by district in this prefecture. This implies that intervention is needed earlier than usually thought.

**Keywords:** overweight prevalence, underweight prevalence, high-risk approach, regional difference, longitudinal

**[School Health Vol.15, 54-68, 2019]**

## I. Introduction

It has been pointed out that lifestyle-related diseases are associated with being overweight[1]. In contrast, it has also been reported that underweight affects the risk of malnutrition, menstruation, and osteoporosis during the adolescent life cycle[2]. Overweight and underweight in childhood are important public health issues.

In Japan, the Ministry of Education, Culture, Sports, Science and Technology (hereinafter referred to as MEXT) conducts a survey of growth and health status of school children under the School Health and Safety Act once a year, and publishes the results in the *Annual Report of School Health Statistics Researches* (sample survey). According to their reports, the national average of the overweight prevalence tends to decrease, and the underweight prevalence tends to increase slightly, regardless of gender[3]. There are regional differences in overweight prevalence and underweight prevalence. The overweight prevalence is high in the Tohoku region, and the underweight prevalence is high in the Chubu region and the Kinki region[4]. The overweight prevalence increased from 6 to 11 years old for boys and from 6 to 12 years old for girls[5][6]. The underweight prevalence increased from 7 to 10 years old for boys and from 7 to 12 years old for girls[6]. For example, Aomori Prefecture has long been pointed out that children have high overweight prevalence. At almost all ages between 5 and 17 years old, overweight prevalence is above the national average[7], and overweight prevalence in adults is also a problem.

As overweight prevalence of children and students is decreasing slightly nationwide, it is considered that the population approach of awareness raising activities regarding the risk of overweight of children and students has been successful. Therefore, it will be necessary to promote a high-risk approach. It is especially important to implement a high-risk approach in Aomori Prefecture as soon as possible because overweight prevalence exceeds the national average. In order to effectively and efficiently implement a high-risk approach, it is necessary to narrow down the target and the intervention time. In order to do this, longitudinal data by gender, age and residence area is needed.

Although the Aomori Prefecture average of the underweight prevalence of children and students is lower than the national average, there are some districts in the education administration districts that exceed the national average depending on the age[8]. However, these reports on overweight and underweight prevalence are the results of cross-sectional comparisons by one year, and there are no reports of follow-up on the same population over time. Therefore, it is unclear whether such prevalence patterns are universal or unique to the group.

In addition, since regional differences exist in the physical constitution of children even within the same prefecture[4][9][10], it is difficult to grasp the characteristics of the district by prefecture average alone. According to the table of "Prefectural disease and abnormal disease prevalence" in the Annual Report of School Health Statistics Researches, the obesity prevalence averages of primary school children and junior high school students in Aomori Prefecture was less than the national average in fiscal year (FY) 1973, but has been among the worst in the country since FY2006. While it is clear that the overweight prevalence in Aomori Prefecture is higher than the national average, it has not been understood in which areas it is serious. Since FY2006, Aomori Prefecture has independently published overweight and underweight prevalence by district, but there are no reports with regard to a longitudinal transition of these values. We have already stated that regionality is important in epidemiological research, but the influence of the birth year should also be taken into consideration as social environment changes with time. Therefore, in order to examine effective and efficient intervention time in school health activities, longitudinal examination by region and by birth year is necessary.

MEXT has revised the judgment criteria for overweight and underweight children in the *Annual Report of School Health Statistics Researches* since FY2006. Aomori Prefecture also conducts physical condition, physical fitness and lifestyle surveys for all subjects from 6-17-year-old enrolled in elementary, middle, and high school using the same judgment criteria and publishes the results annually. The definition of overweight prevalence and underweight prevalence changed in FY2006, so it was not possible to examine the long-term transition across FY2006, but more than 10 years have passed since the revision and it has become possible to analyze the trend of these indicators longitudinally.

In this analysis, based on the *Health and Physical Fitness Survey Report* (full survey) for children and Students which published the results of a full survey of elementary, middle and high school students in Aomori Prefecture, we examined longitudinally their overweight and underweight prevalence by birth year and district.

Furthermore, we aimed to show effective and efficient timing for intervention, prevention or improvement of overweight and underweight in each area for school health activities.

## II. Methods

### 1. Overview of Survey Area

Aomori Prefecture is located at the northernmost tip of Honshu, Japan. It is surrounded by the sea on three

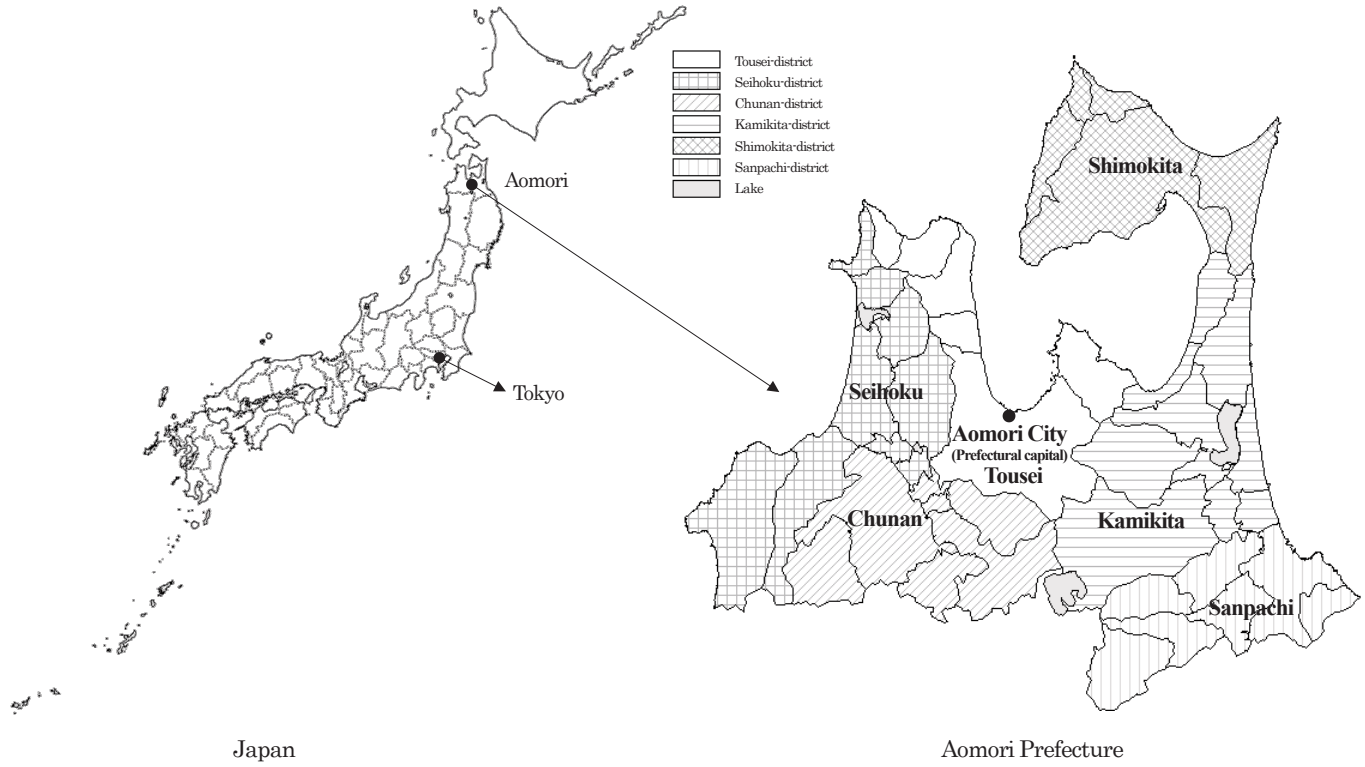


**Figure 1** Subjects of survey area classification

**Tousei-district**: Aomori city, Hiranai town, Imabetsu town, Yomogita village, Sotogahama town, **Seihoku-district**: Goshogawara city, Tsugaru city, Ajigasawa town, Hukaura town, Itayanagi town, Tsuruta town, Nakadomari Village, **Chunan-district**: Hirosaki city, Kuroishi city, Hirakawa city, Nishimeya village, Fujisaki town, Ohwani town, Inakadate village, **Kamikita-district**: Towada city, Misawa city, Yokohama city, Rokkasho village, Noheji town, Tohoku town, Shichinohe town, Oirase town, Rokunohe town, **Shimokita-district**: Mutsu city, Ooma town, Higashidori village, Kazamaura village, Sai village, **Sanpachi-district**: Hachinohe city, Sannohe town, Gonohe town, Takko town, Nanbu town, Hashikami town, Shingo village

sides and divided into Tsugaru area on the Japan Sea side and Nanbu area on the east side by the Pacific Ocean and Shimokita area on the north side. The prefectural office location is Aomori city, the average temperature is 10.7 °C[11], and the average snowfall for the last 20 years is 656 cm[12]. The Tsugaru area has a large amount of snowfall, while the Nanbu area has a small amount of snowfall, but summer is a cold climate by the effect of the *Yamase* wind. Aomori Prefecture has an estimated population of 1,277,086 (male 599,949, female 677,137), with 513,975 households[13]. The major sector of economy is the primary industry. However, wholesalers and retailers in the tertiary industry are the largest employer of workers 15 years old and over[14]. Aomori Prefecture has the shortest life expectancy in Japan, has a high mortality rate from cancer and cerebrovascular disease, and has a high prevalence of overweight, hypertension, and diabetes[15].

The survey area consists of six districts under the jurisdiction of the education administration: "Tosei district", "Seihoku district", "Chunan district", "Kamikita district", "Shimokita district", and "Sanpachi district". Data are summarized for each district (**Figure 1**). The relationship between the above three areas of Aomori Prefecture and the six districts under the jurisdiction of the educational administration is as follows; Tsugaru consists of Tosei district, Seihoku district and Chunan district, and Nanbu consists of Kamikita district and Sanpachi district. Shimokita consists of only Shimokita district. In addition, Aomori city where the prefectural office is located is in Tosei district.

## 2. Survey Target and Survey Items

In the analysis, we used the overweight and underweight prevalence in the *Aomori Prefecture Student Health and Physical Fitness Survey Report* (hereinafter referred to as "Report") from FY2007 to FY2018 of the children and students of Aomori Prefecture[16-27]. This survey has been implemented based on the School Health and Safety Act. The subjects of the survey in the Report are all students in elementary, middle, and high school (full-time and part-time courses) in Aomori

Prefecture. However, we excluded students in special needs schools, full-time high school students 18 years old and over, students whose age and grade do not match, and students belonging to correspondence upper secondary school. Since the number of persons surveyed is not described in the Report, we used the tabulated results for each municipality in Aomori Prefecture in the Basic Survey of School (**Table 1**)[28]. In addition, since the survey results in FY2006 of the report are samples by the stratified random sampling method, we examined the transition from the results in FY2007. The data is organized as follows: The school system in Japan is 6 years (ages 6 to 11) for elementary school, 3 years (ages 12 to 14) for junior high school, and 3 years (ages 15 to 17) for high school[29)30)]. First graders in FY2007 were born in FY2000 (April 2, 2000-April 1, 2001), becoming second graders in FY2008, third graders in FY2009, and finally becoming third grade high school students in FY2018. The data series connecting the results of each year's report in this way is called the 2000 cohort. We constructed the 2001-year cohort to 2006-year cohort in a similar manner. Since individual subjects are not followed up in these data, we cannot consider dropouts, transferences, etc. Therefore, they should be called pseudo-cohorts. We constituted six pseudo-cohorts from FY2000 to FY2006. We examined the transition of overweight and underweight prevalence from 6 till 17 years old for the FY2000 pseudo-cohort and from 6 till 11 years old for the FY2006 pseudo-cohort by entire Aomori Prefecture and district. The transference of children and students usually occurs with the transference of households. In epidemiological research, it is assumed that there is regionality even if there are household transfers. Therefore, it is considered possible to clarify region-specific patterns even in research using a pseudo-cohort like this research. We used the same report as used in the *Annual Report of School Health Statistics Researches* conducted by MEXT to define the degree of obesity (degree of overweight)[31)]. Furthermore, we have defined overweight-prone as being greater than 20% degree of overweight and underweight-prone as being less than -20% degree of overweight.

When comparing the overweight and the underweight prevalence with the national average, we used the results of the *Annual Report of School Health Statistics Researches* by MEXT. The result of the *Annual Report of School Health Statistics Researches* is based on the stratified two-stage random sampling method according to the number of students and schools in each prefecture[32)]. Therefore, the sample size of the *Annual Report of School Health Statistics Researches* is about 26,000 to about 45,000 people by gender in each grade[7)]. The standard error of the overweight prevalence is estimated to be around 0.0002, ie around 0.2% therefore, it affects the final digit of each numerical value shown in Results but does not affect Discussion and Conclusions.

Moreover, based on the data in the report, we examined the differences in annual growth of height and weight for children and students in Aomori Prefecture and the whole country according to gender and birth year[16-27)]. The annual growth rate is the height and weight of the previous year minus the measured value of the next year. The growth rate is not calculated at 6 years old because there were no previous year height and weight measurement results. If there was a discrepancy between two figures, we considered the figures for the next fiscal year to be transcription errors and adopted the figures for the previous year. Therefore, the previous year's height, weight, and growth figures in FY2012 and FY2013 reports differ from the figures presented in this analysis.

## 3. Statistical Analysis

In this research, since full data is used, methods of estimation statistics such as tests and estimation cannot be used.

# III. Results

## 1. Children and Students' physical characteristics and growth

Children and students' height, weight, and annual growth by age/grade (**Table 2**). Between the ages of 6-12 boys grew about 1 cm per year more than girls, so at 13 they were about 5-6 cm and at 14 about 10 cm taller. Both boys and girls in Aomori tended to be taller than the national average. Growth peaked at age 12 in boys and ages 10-11 in girls. Weight peaked at age 12 in boys and at age 11 in girls.

## 2. Trends in overweight prevalence

For every birth cohort at every age the prevalence of overweight was higher among both boys and girls in Aomori than the national average (**Figure 2**). An increase in the prevalence for both boys and girls was seen between the ages of 6-9, peaking earlier than the national average. After peaking, both the Aomori and national rates either gradually declined or leveled off. Overweight

**Table 1** The number of the subjects by birth year / district

| Fiscal Year | Sex | District | Elementary school | | | | | | Junior high school | | | High school | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1st | 2nd | 3rd | 4th | 5th | 6th | 1st | 2nd | 3rd | 1st | 2nd | 3rd |
| | | | 6 years | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 2000 | Boys | Tousei | 1,496 | 1,497 | 1,483 | 1,485 | 1,487 | 1,481 | 1,492 | 1,496 | 1,502 | | | |
| | | Seihoku | 700 | 705 | 709 | 705 | 708 | 705 | 697 | 698 | 697 | | | |
| | | Chunan | 1,266 | 1,266 | 1,251 | 1,254 | 1,250 | 1,257 | 1,248 | 1,244 | 1,245 | | | |
| | | Kamikita | 1,090 | 1,075 | 1,057 | 1,054 | 1,050 | 1,053 | 1,039 | 1,036 | 1,034 | | | |
| | | Shimokita | 363 | 365 | 362 | 362 | 361 | 359 | 352 | 351 | 350 | | | |
| | | Sanpachi | 1,514 | 1,507 | 1,513 | 1,490 | 1,486 | 1,487 | 1,489 | 1,496 | 1,501 | | | |
| | | Subtotal | 6,429 | 6,415 | 6,375 | 6,350 | 6,342 | 6,342 | 6,317 | 6,321 | 6,329 | | | |
| | Girls | Tousei | 1,460 | 1,463 | 1,456 | 1,441 | 1,435 | 1,428 | 1,410 | 1,409 | 1,407 | | | |
| | | Seihoku | 676 | 673 | 669 | 662 | 667 | 666 | 656 | 654 | 653 | | | |
| | | Chunan | 1,268 | 1,279 | 1,284 | 1,286 | 1,293 | 1,294 | 1,312 | 1,314 | 1,315 | | | |
| | | Kamikita | 1,008 | 1,011 | 1,010 | 1,003 | 1,006 | 998 | 968 | 965 | 959 | | | |
| | | Shimokita | 360 | 365 | 367 | 370 | 361 | 356 | 352 | 351 | 350 | | | |
| | | Sanpachi | 1,478 | 1,464 | 1,452 | 1,451 | 1,449 | 1,464 | 1,461 | 1,454 | 1,456 | | | |
| | | Subtotal | 6,250 | 6,255 | 6,238 | 6,213 | 6,211 | 6,206 | 6,159 | 6,147 | 6,140 | | | |
| | Total | | 12,679 | 12,670 | 12,613 | 12,563 | 12,553 | 12,548 | 12,476 | 12,468 | 12,469 | 12,044 | 11,761 | 11,450 |
| 2001 | Boys | Tousei | 1,512 | 1,514 | 1,528 | 1,530 | 1,528 | 1,534 | 1,530 | 1,521 | 1,523 | | | |
| | | Seihoku | 694 | 690 | 687 | 685 | 682 | 674 | 661 | 663 | 660 | | | |
| | | Chunan | 1,289 | 1,299 | 1,293 | 1,302 | 1,303 | 1,303 | 1,314 | 1,317 | 1,319 | | | |
| | | Kamikita | 1,068 | 1,052 | 1,038 | 1,039 | 1,043 | 1,035 | 1,016 | 1,013 | 1,015 | | | |
| | | Shimokita | 363 | 361 | 361 | 358 | 355 | 351 | 336 | 336 | 335 | | | |
| | | Sanpachi | 1,487 | 1,486 | 1,494 | 1,491 | 1,497 | 1,507 | 1,505 | 1,499 | 1,492 | | | |
| | | Subtotal | 6,413 | 6,402 | 6,401 | 6,405 | 6,408 | 6,404 | 6,362 | 6,349 | 6,344 | | | |
| | Girls | Tousei | 1,434 | 1,437 | 1,432 | 1,445 | 1,425 | 1,425 | 1,395 | 1,396 | 1,405 | | | |
| | | Seihoku | 712 | 711 | 706 | 701 | 697 | 700 | 698 | 701 | 702 | | | |
| | | Chunan | 1,237 | 1,240 | 1,241 | 1,247 | 1,244 | 1,244 | 1,240 | 1,237 | 1,236 | | | |
| | | Kamikita | 990 | 985 | 985 | 984 | 982 | 971 | 952 | 949 | 946 | | | |
| | | Shimokita | 385 | 377 | 377 | 381 | 372 | 369 | 365 | 363 | 357 | | | |
| | | Sanpachi | 1,392 | 1,380 | 1,383 | 1,373 | 1,368 | 1,376 | 1,383 | 1,385 | 1,378 | | | |
| | | Subtotal | 6,150 | 6,130 | 6,124 | 6,131 | 6,088 | 6,085 | 6,033 | 6,031 | 6,024 | | | |
| | Total | | 12,563 | 12,532 | 12,525 | 12,536 | 12,496 | 12,489 | 12,395 | 12,380 | 12,368 | 11,903 | 11,606 | |
| 2002 | Boys | Tousei | 1,484 | 1,486 | 1,480 | 1,475 | 1,475 | 1,456 | 1,490 | 1,487 | 1,427 | | | |
| | | Seihoku | 670 | 659 | 659 | 655 | 663 | 659 | 648 | 648 | 646 | | | |
| | | Chunan | 1,234 | 1,247 | 1,257 | 1,247 | 1,250 | 1,255 | 1,253 | 1,252 | 1,159 | | | |
| | | Kamikita | 1,009 | 994 | 991 | 993 | 992 | 990 | 963 | 957 | 915 | | | |
| | | Shimokita | 377 | 382 | 381 | 368 | 359 | 361 | 353 | 353 | 351 | | | |
| | | Sanpachi | 1,449 | 1,441 | 1,442 | 1,442 | 1,439 | 1,444 | 1,434 | 1,434 | 1,414 | | | |
| | | Subtotal | 6,223 | 6,209 | 6,210 | 6,180 | 6,178 | 6,165 | 6,141 | 6,131 | 6,133 | | | |
| | Girls | Tousei | 1,364 | 1,364 | 1,372 | 1,375 | 1,369 | 1,368 | 1,347 | 1,343 | 1,318 | | | |
| | | Seihoku | 653 | 646 | 651 | 651 | 646 | 641 | 640 | 641 | 639 | | | |
| | | Chunan | 1,093 | 1,099 | 1,104 | 1,104 | 1,102 | 1,109 | 1,110 | 1,106 | 1,020 | | | |
| | | Kamikita | 968 | 970 | 965 | 966 | 962 | 954 | 936 | 934 | 899 | | | |
| | | Shimokita | 375 | 371 | 372 | 375 | 361 | 357 | 347 | 349 | 345 | | | |
| | | Sanpachi | 1,359 | 1,357 | 1,355 | 1,348 | 1,343 | 1,346 | 1,349 | 1,341 | 1,313 | | | |
| | | Subtotal | 5,812 | 5,807 | 5,819 | 5,819 | 5,783 | 5,775 | 5,729 | 5,714 | 5,703 | | | |
| | Total | | 12,035 | 12,016 | 12,029 | 11,999 | 11,961 | 11,940 | 11,870 | 11,845 | 11,836 | 11,300 | | |
| 2003 | Boys | Tousei | 1,372 | 1,388 | 1,365 | 1,354 | 1,345 | 1,341 | 1,384 | 1,386 | 1,318 | | | |
| | | Seihoku | 542 | 538 | 542 | 536 | 536 | 537 | 536 | 540 | 541 | | | |
| | | Chunan | 1,250 | 1,260 | 1,256 | 1,253 | 1,244 | 1,244 | 1,221 | 1,221 | 1,121 | | | |
| | | Kamikita | 973 | 964 | 961 | 946 | 947 | 939 | 918 | 914 | 881 | | | |
| | | Shimokita | 369 | 364 | 352 | 351 | 353 | 353 | 343 | 337 | 336 | | | |
| | | Sanpachi | 1,372 | 1,366 | 1,373 | 1,367 | 1,377 | 1,371 | 1,367 | 1,365 | 1,353 | | | |
| | | Subtotal | 5,878 | 5,880 | 5,849 | 5,807 | 5,802 | 5,785 | 5,769 | 5,763 | 5,748 | | | |
| | Girls | Tousei | 1,293 | 1,292 | 1,297 | 1,274 | 1,272 | 1,271 | 1,266 | 1,270 | 1,244 | | | |
| | | Seihoku | 552 | 554 | 549 | 552 | 554 | 550 | 543 | 541 | 540 | | | |
| | | Chunan | 1,132 | 1,132 | 1,128 | 1,133 | 1,130 | 1,127 | 1,119 | 1,124 | 1,034 | | | |
| | | Kamikita | 929 | 933 | 926 | 913 | 918 | 913 | 895 | 891 | 835 | | | |
| | | Shimokita | 351 | 356 | 345 | 342 | 335 | 329 | 326 | 324 | 324 | | | |
| | | Sanpachi | 1,354 | 1,352 | 1,356 | 1,365 | 1,367 | 1,372 | 1,374 | 1,368 | 1,345 | | | |
| | | Subtotal | 5,611 | 5,619 | 5,601 | 5,579 | 5,576 | 5,562 | 5,523 | 5,518 | 5,512 | | | |
| | Total | | 11,489 | 11,499 | 11,450 | 11,386 | 11,378 | 11,347 | 11,292 | 11,281 | 11,260 | | | |
| 2004 | Boys | Tousei | 1,376 | 1,371 | 1,368 | 1,372 | 1,366 | 1,364 | 1,386 | 1,301 | | | | |
| | | Seihoku | 627 | 624 | 615 | 612 | 614 | 615 | 609 | 610 | | | | |
| | | Chunan | 1,098 | 1,094 | 1,090 | 1,094 | 1,092 | 1,087 | 1,079 | 993 | | | | |
| | | Kamikita | 895 | 903 | 900 | 899 | 889 | 882 | 854 | 249 | | | | |
| | | Shimokita | 331 | 311 | 309 | 305 | 302 | 299 | 295 | 821 | | | | |
| | | Sanpachi | 1,282 | 1,274 | 1,268 | 1,265 | 1,264 | 1,276 | 1,259 | 1,252 | | | | |
| | | Subtotal | 5,609 | 5,577 | 5,550 | 5,547 | 5,527 | 5,523 | 5,482 | 5,442 | | | | |
| | Girls | Tousei | 1,257 | 1,261 | 1,254 | 1,259 | 1,259 | 1,256 | 1,274 | 1,251 | | | | |
| | | Seihoku | 587 | 583 | 579 | 578 | 579 | 578 | 576 | 571 | | | | |
| | | Chunan | 1,106 | 1,111 | 1,113 | 1,113 | 1,108 | 1,101 | 1,093 | 999 | | | | |
| | | Kamikita | 896 | 888 | 884 | 883 | 878 | 871 | 849 | 799 | | | | |
| | | Shimokita | 322 | 311 | 308 | 298 | 291 | 287 | 275 | 277 | | | | |
| | | Sanpachi | 1,247 | 1,237 | 1,240 | 1,244 | 1,251 | 1,260 | 1,255 | 1,229 | | | | |
| | | Subtotal | 5,415 | 5,391 | 5,378 | 5,375 | 5,366 | 5,353 | 5,322 | 5,312 | | | | |
| | Total | | 11,024 | 10,968 | 10,928 | 10,922 | 10,893 | 10,876 | 10,804 | 10,754 | | | | |
| 2005 | Boys | Tousei | 1,213 | 1,204 | 1,211 | 1,202 | 1,197 | 1,200 | 1,169 | | | | | |
| | | Seihoku | 542 | 537 | 532 | 535 | 531 | 528 | 519 | | | | | |
| | | Chunan | 1,034 | 1,040 | 1,030 | 1,021 | 1,022 | 1,030 | 936 | | | | | |
| | | Kamikita | 854 | 836 | 826 | 828 | 819 | 812 | 764 | | | | | |
| | | Shimokita | 329 | 319 | 308 | 307 | 305 | 303 | 296 | | | | | |
| | | Sanpachi | 1,248 | 1,252 | 1,257 | 1,259 | 1,250 | 1,239 | 1,226 | | | | | |
| | | Subtotal | 5,220 | 5,188 | 5,164 | 5,152 | 5,124 | 5,112 | 5,119 | | | | | |
| | Girls | Tousei | 1,225 | 1,215 | 1,200 | 1,204 | 1,195 | 1,206 | 1,181 | | | | | |
| | | Seihoku | 530 | 531 | 526 | 523 | 523 | 519 | 514 | | | | | |
| | | Chunan | 1,030 | 1,031 | 1,035 | 1,039 | 1,036 | 1,029 | 931 | | | | | |
| | | Kamikita | 882 | 871 | 866 | 856 | 850 | 846 | 784 | | | | | |
| | | Shimokita | 299 | 300 | 300 | 294 | 296 | 297 | 286 | | | | | |
| | | Sanpachi | 1,112 | 1,119 | 1,118 | 1,114 | 1,108 | 1,099 | 1,071 | | | | | |
| | | Subtotal | 5,078 | 5,067 | 5,045 | 5,030 | 5,008 | 4,996 | 4,970 | | | | | |
| | Total | | 10,298 | 10,255 | 10,209 | 10,182 | 10,132 | 10,108 | 10,089 | | | | | |
| 2006 | Boys | Tousei | 1,231 | 1,216 | 1,218 | 1,212 | 1,218 | 1,218 | | | | | | |
| | | Seihoku | 524 | 521 | 517 | 516 | 514 | 515 | | | | | | |
| | | Chunan | 1,046 | 1,054 | 1,060 | 1,058 | 1,060 | 1,058 | | | | | | |
| | | Kamikita | 819 | 817 | 812 | 808 | 799 | 802 | | | | | | |
| | | Shimokita | 325 | 319 | 316 | 309 | 304 | 300 | | | | | | |
| | | Sanpachi | 1,244 | 1,245 | 1,249 | 1,243 | 1,240 | 1,235 | | | | | | |
| | | Subtotal | 5,189 | 5,172 | 5,172 | 5,146 | 5,135 | 5,128 | | | | | | |
| | Girls | Tousei | 1,273 | 1,274 | 1,279 | 1,272 | 1,270 | 1,269 | | | | | | |
| | | Seihoku | 499 | 498 | 495 | 493 | 487 | 487 | | | | | | |
| | | Chunan | 1,054 | 1,062 | 1,064 | 1,066 | 1,067 | 1,071 | | | | | | |
| | | Kamikita | 827 | 829 | 826 | 821 | 811 | 807 | | | | | | |
| | | Shimokita | 316 | 314 | 306 | 302 | 297 | 295 | | | | | | |
| | | Sanpachi | 1,207 | 1,204 | 1,214 | 1,208 | 1,206 | 1,209 | | | | | | |
| | | Subtotal | 5,176 | 5,181 | 5,184 | 5,162 | 5,138 | 5,138 | | | | | | |
| | Total | | 10,365 | 10,353 | 10,356 | 10,308 | 10,273 | 10,266 | | | | | | |

Includes students from special needs classes. Includes national elementary schools and private junior high schools. High school values are not separated by sex and include full-time and part-time students from public schools and students from private schools.

**Table 2** Height and weight of subjects

| | Fiscal Year | Grade | Elementary school | | | | | | Junior high school | | | High school | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1st | 2nd | 3rd | 4th | 5th | 6th | 1st | 2nd | 3rd | 1st | 2nd | 3rd |
| | | Age | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| Height (cm) | 2000 | Boys | 117.2 | 123.3 | 128.9 | 134.6 | 139.8 | 146.8 | 153.9 | 161.0 | 166.2 | 169.3 | 170.4 | 171.0 |
| | | Growth | NA | 6.1 | 5.6 | 5.7 | 5.2 | 7.0 | 7.1 | 7.1 | 5.2 | 3.1 | 1.1 | 0.6 |
| | | Japan | 116.6 | 122.5 | 128.3 | 133.5 | 138.8 | 145.0 | 152.3 | 159.7 | 165.1 | 168.3 | 169.9 | 170.6 |
| | | Girls | 116.1 | 122.3 | 128.2 | 134.3 | 141.3 | 147.9 | 152.4 | 155.2 | 156.6 | 156.9 | 157.5 | 157.7 |
| | | Growth | NA | 6.2 | 5.9 | 6.1 | 7.0 | 6.6 | 4.5 | 2.8 | 1.4 | 0.3 | 0.6 | 0.2 |
| | | Japan | 115.8 | 121.7 | 127.5 | 133.5 | 140.2 | 146.7 | 151.8 | 154.8 | 156.5 | 157.1 | 157.6 | 157.8 |
| | 2001 | Boys | 117.1 | 123.1 | 128.9 | 134.3 | 140.3 | 146.2 | 153.8 | 161.0 | 166.1 | 168.8 | 170.3 | |
| | | Growth | NA | 6.0 | 5.8 | 5.4 | 6.0 | 5.9 | 7.6 | 7.2 | 5.1 | 2.7 | 1.5 | |
| | | Japan | 116.7 | 122.6 | 128.2 | 133.5 | 138.9 | 145.0 | 152.5 | 159.8 | 165.2 | 168.2 | 169.9 | |
| | | Girls | 116.5 | 122.5 | 128.7 | 134.9 | 141.5 | 148.2 | 152.8 | 155.5 | 156.9 | 157.3 | 157.8 | |
| | | Growth | NA | 6.0 | 6.2 | 6.2 | 6.6 | 6.7 | 4.6 | 2.7 | 1.4 | 0.4 | 0.5 | |
| | | Japan | 115.8 | 121.7 | 127.4 | 133.5 | 140.1 | 146.8 | 151.8 | 154.9 | 156.5 | 157.1 | 157.6 | |
| | 2002 | Boys | 117.2 | 123.1 | 129.0 | 134.8 | 140.0 | 146.4 | 154.1 | 161.5 | 166.5 | 168.7 | | |
| | | Growth | NA | 5.9 | 5.8 | 5.8 | 5.2 | 6.4 | 7.7 | 7.4 | 5.0 | 2.5 | | |
| | | Japan | 116.7 | 122.5 | 128.2 | 133.6 | 139.0 | 145.1 | 152.6 | 159.9 | 165.3 | 168.4 | | |
| | | Girls | 116.5 | 122.7 | 128.4 | 134.9 | 141.6 | 148.0 | 152.8 | 155.7 | 157.0 | 157.1 | | |
| | | Growth | NA | 6.3 | 5.7 | 6.5 | 6.7 | 6.4 | 4.8 | 2.9 | 1.3 | 0.1 | | |
| | | Japan | 115.8 | 121.7 | 127.4 | 133.4 | 140.1 | 146.8 | 151.8 | 154.8 | 156.5 | 157.1 | | |
| | 2003 | Boys | 117.2 | 123.3 | 129.0 | 134.5 | 140.1 | 147.2 | 154.2 | 161.5 | 166.4 | | | |
| | | Growth | NA | 6.1 | 5.7 | 5.5 | 5.6 | 7.1 | 7.0 | 7.3 | 4.9 | | | |
| | | Japan | 116.7 | 122.6 | 128.2 | 133.6 | 138.9 | 145.2 | 152.7 | 160.0 | 165.3 | | | |
| | | Girls | 116.3 | 122.5 | 129.1 | 134.8 | 141.6 | 148.0 | 152.7 | 155.5 | 156.8 | | | |
| | | Growth | NA | 6.2 | 6.6 | 5.7 | 6.8 | 6.4 | 4.7 | 2.8 | 1.3 | | | |
| | | Japan | 115.8 | 121.6 | 127.4 | 133.6 | 140.1 | 146.7 | 151.9 | 154.9 | 156.6 | | | |
| | 2004 | Boys | 117.2 | 123.4 | 128.9 | 134.4 | 140.7 | 146.4 | 154.1 | 161.3 | | | | |
| | | Growth | NA | 6.2 | 5.5 | 5.5 | 6.3 | 5.7 | 7.7 | 7.2 | | | | |
| | | Japan | 116.6 | 122.4 | 128.2 | 133.6 | 138.9 | 145.2 | 152.8 | 159.8 | | | | |
| | | Girls | 116.5 | 122.6 | 128.5 | 134.8 | 141.5 | 148.1 | 152.8 | 155.6 | | | | |
| | | Growth | NA | 6.0 | 5.9 | 6.3 | 6.7 | 6.6 | 4.7 | 2.8 | | | | |
| | | Japan | 115.6 | 121.6 | 127.3 | 133.4 | 140.1 | 146.8 | 151.8 | 154.9 | | | | |
| | 2005 | Boys | 116.9 | 123.1 | 128.8 | 134.5 | 139.9 | 146.3 | 154.0 | | | | | |
| | | Growth | NA | 6.2 | 5.7 | 5.7 | 5.4 | 6.4 | 7.7 | | | | | |
| | | Japan | 116.5 | 122.4 | 128.0 | 133.5 | 138.8 | 145.0 | 152.7 | | | | | |
| | | Girls | 116.4 | 122.4 | 128.4 | 134.7 | 141.5 | 148.1 | 152.7 | | | | | |
| | | Growth | NA | 6.0 | 6.0 | 6.3 | 6.8 | 6.6 | 4.6 | | | | | |
| | | Japan | 115.6 | 121.6 | 127.4 | 133.4 | 140.2 | 146.7 | 151.9 | | | | | |
| | 2006 | Boys | 117.1 | 123.2 | 128.7 | 134.3 | 139.9 | 146.3 | | | | | | |
| | | Growth | NA | 6.1 | 5.5 | 5.6 | 5.6 | 6.4 | | | | | | |
| | | Japan | 116.6 | 122.4 | 128.1 | 133.6 | 139.0 | 145.2 | | | | | | |
| | | Girls | 116.5 | 122.6 | 128.5 | 134.8 | 141.7 | 148.2 | | | | | | |
| | | Growth | NA | 6.1 | 5.9 | 6.3 | 6.9 | 6.5 | | | | | | |
| | | Japan | 115.6 | 121.5 | 127.3 | 133.4 | 140.1 | 146.8 | | | | | | |
| Weight (kg) | 2000 | Boys | 22.3 | 25.2 | 28.6 | 31.7 | 35.8 | 40.5 | 46.4 | 51.3 | 56.1 | 61.2 | 62.8 | 64.8 |
| | | Growth | NA | 2.9 | 3.4 | 3.1 | 4.1 | 4.7 | 5.9 | 4.9 | 4.8 | 5.1 | 1.6 | 2.0 |
| | | Japan | 21.5 | 24.2 | 27.2 | 30.0 | 33.8 | 38.2 | 43.9 | 48.8 | 53.9 | 58.7 | 60.6 | 62.4 |
| | | Girls | 21.7 | 24.5 | 27.8 | 31.7 | 35.6 | 40.9 | 45.5 | 48.9 | 51.4 | 53.0 | 53.6 | 53.9 |
| | | Growth | NA | 2.9 | 3.3 | 3.9 | 3.9 | 5.3 | 4.6 | 3.4 | 2.5 | 1.6 | 0.6 | 0.3 |
| | | Japan | 21.0 | 23.6 | 26.5 | 30.0 | 34.0 | 38.9 | 43.7 | 47.2 | 49.9 | 51.7 | 52.6 | 52.9 |
| | 2001 | Boys | 22.2 | 25.0 | 28.0 | 32.1 | 36.1 | 40.5 | 46.3 | 51.3 | 56.2 | 61.3 | 62.9 | |
| | | Growth | NA | 2.8 | 3.0 | 4.1 | 4.0 | 4.4 | 5.8 | 5.0 | 4.9 | 5.1 | 1.6 | |
| | | Japan | 21.5 | 24.1 | 26.5 | 30.3 | 34.0 | 38.3 | 44.0 | 48.8 | 53.9 | 58.9 | 60.6 | |
| | | Girls | 21.9 | 24.5 | 28.0 | 31.6 | 35.7 | 41.1 | 45.8 | 49.2 | 51.8 | 53.1 | 53.9 | |
| | | Growth | NA | 2.6 | 3.5 | 3.6 | 4.1 | 5.4 | 4.7 | 3.4 | 2.6 | 1.3 | 0.8 | |
| | | Japan | 21.0 | 23.5 | 26.5 | 29.8 | 34.0 | 39.0 | 43.6 | 47.3 | 50.0 | 51.6 | 52.5 | |
| | 2002 | Boys | 22.2 | 25.3 | 28.5 | 32.1 | 36.0 | 40.5 | 46.4 | 51.5 | 56.3 | 61.2 | | |
| | | Growth | NA | 3.2 | 3.2 | 3.6 | 3.9 | 4.5 | 5.9 | 5.1 | 4.8 | 4.9 | | |
| | | Japan | 21.5 | 24.0 | 27.0 | 30.5 | 34.3 | 38.4 | 43.9 | 48.8 | 53.9 | 58.6 | | |
| | | Girls | 21.7 | 24.9 | 27.7 | 31.7 | 35.9 | 40.8 | 45.6 | 49.2 | 51.7 | 53.1 | | |
| | | Growth | NA | 3.2 | 2.8 | 4.1 | 4.2 | 4.9 | 4.8 | 3.6 | 2.5 | 1.4 | | |
| | | Japan | 21.0 | 23.5 | 26.4 | 29.9 | 34.0 | 39.0 | 43.6 | 47.2 | 50.0 | 51.6 | | |
| | 2003 | Boys | 22.5 | 25.0 | 28.2 | 32.3 | 36.0 | 40.5 | 46.4 | 51.4 | 56.3 | | | |
| | | Growth | NA | 2.5 | 3.2 | 4.1 | 3.7 | 4.5 | 5.9 | 5.0 | 4.9 | | | |
| | | Japan | 21.4 | 24.0 | 27.1 | 30.4 | 34.0 | 38.2 | 44.0 | 49.0 | 54.0 | | | |
| | | Girls | 21.9 | 24.3 | 27.7 | 31.4 | 35.7 | 40.7 | 45.6 | 49.0 | 51.5 | | | |
| | | Growth | NA | 2.4 | 3.4 | 3.7 | 4.3 | 5.0 | 4.9 | 3.4 | 2.5 | | | |
| | | Japan | 21.0 | 23.4 | 26.3 | 30.0 | 34.0 | 38.8 | 43.7 | 47.2 | 49.9 | | | |
| | 2004 | Boys | 22.1 | 25.0 | 28.6 | 32.3 | 35.9 | 40.7 | 46.6 | 51.5 | | | | |
| | | Growth | NA | 2.9 | 3.5 | 3.7 | 3.6 | 4.8 | 5.9 | 4.9 | | | | |
| | | Japan | 21.3 | 24.0 | 27.1 | 30.4 | 34.0 | 38.4 | 44.0 | 48.8 | | | | |
| | | Girls | 21.6 | 24.4 | 27.8 | 31.5 | 35.7 | 41.0 | 45.8 | 49.2 | | | | |
| | | Growth | NA | 3.2 | 3.3 | 3.7 | 4.2 | 5.3 | 4.8 | 3.4 | | | | |
| | | Japan | 20.8 | 23.5 | 26.4 | 29.8 | 33.9 | 39.0 | 43.6 | 47.2 | | | | |
| | 2005 | Boys | 22.0 | 25.0 | 28.4 | 31.7 | 36.0 | 40.5 | 46.4 | | | | | |
| | | Growth | NA | 2.9 | 3.4 | 3.3 | 4.3 | 4.5 | 5.9 | | | | | |
| | | Japan | 21.3 | 23.9 | 27.0 | 30.4 | 34.0 | 38.2 | 44.0 | | | | | |
| | | Girls | 21.5 | 24.3 | 27.6 | 31.4 | 35.7 | 40.8 | 45.5 | | | | | |
| | | Growth | NA | 2.7 | 3.3 | 3.8 | 4.3 | 5.1 | 5.0 | | | | | |
| | | Japan | 20.9 | 23.5 | 26.4 | 29.7 | 34.0 | 39.0 | 43.7 | | | | | |
| | 2006 | Boys | 22.0 | 24.8 | 28.0 | 32.1 | 35.8 | 40.4 | | | | | | |
| | | Growth | NA | 2.8 | 3.2 | 4.1 | 3.7 | 4.6 | | | | | | |
| | | Japan | 21.3 | 24.0 | 26.9 | 30.6 | 34.2 | 38.4 | | | | | | |
| | | Girls | 21.7 | 24.4 | 27.7 | 31.6 | 35.9 | 40.9 | | | | | | |
| | | Growth | NA | 2.7 | 3.3 | 3.9 | 4.3 | 5.0 | | | | | | |
| | | Japan | 20.9 | 23.4 | 26.4 | 29.8 | 34.0 | 39.1 | | | | | | |

Abbreviation: NA, not available.
Errors rounded off at the first decimal place.

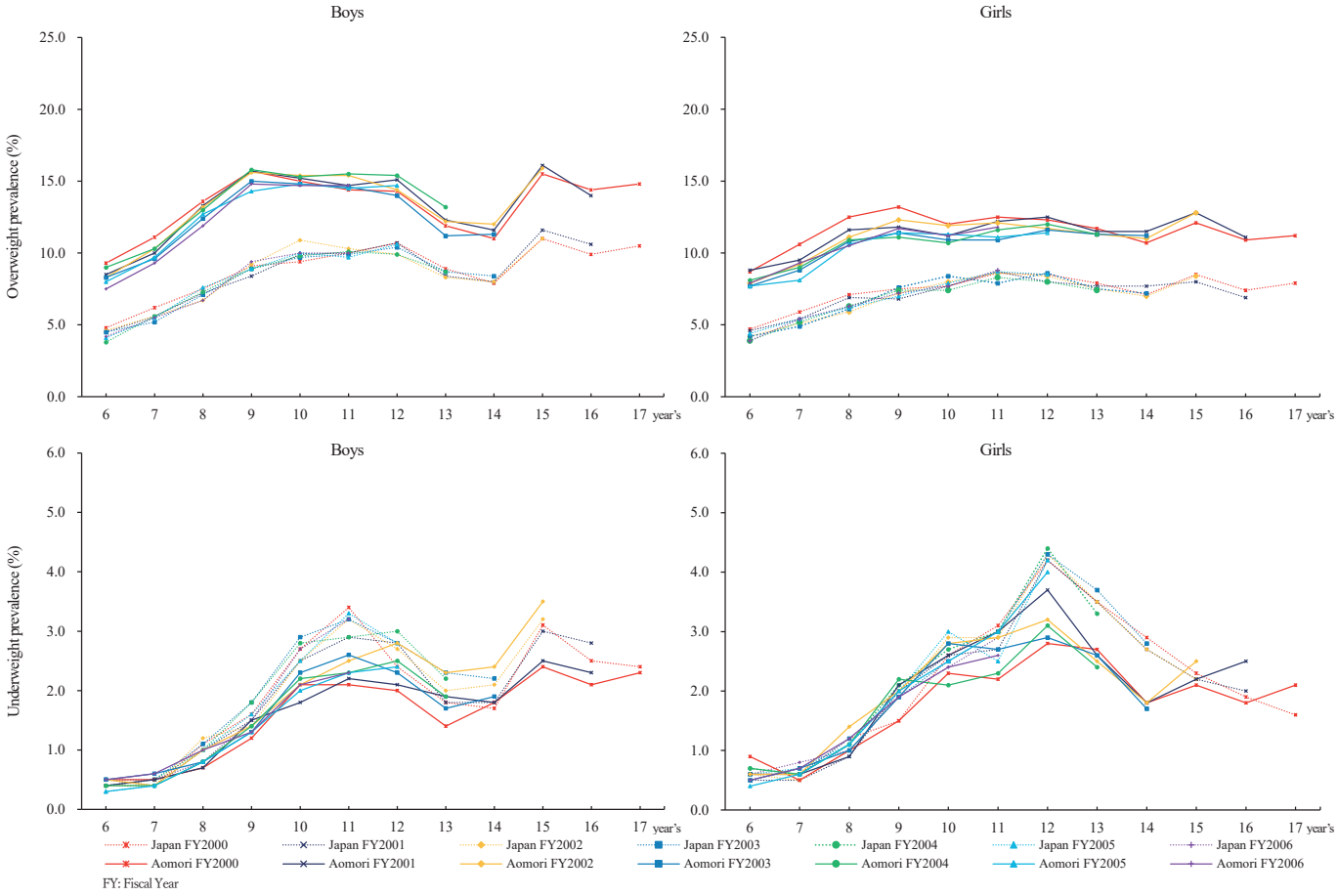


**Figure 2** The change in overweight / underweight prevalence by sex and birth year (Aomori, Japan)

prevalence began to rise again between the ages of 14-15 and decreased once more after age 15.

### 3. Trends in underweight prevalence

In Aomori from the age of 8, prevalence among boys trended lower than the national average, and for girls, it was about the same as the national average until the age of 11, after which it trended lower (**Figure 2**). Prevalence rates for both boys and girls peaked in Aomori as well as nationally at ages 11 or 12. Furthermore, for boys in Aomori as well as nationally and girls in Aomori, underweight prevalence increased from 14 to 15 followed by a decline. For girls nationally, after peaking at age 12, underweight prevalence declined.

### 4. Changes in overweight and underweight prevalence by district and birth cohort

The age at which overweight prevalence peaks differed by district and birth cohort (**Figure 3**). For boys, it peaked at ages 9-11 in Tousei, 8-11 in Seihoku, 9-12 in Chunan, 9-10 in Kamikita, 9-11 in Shimokita and 9-11 in Sanpachi. For girls it peaked at ages 9-12 in Tosei, 7-11 in Seihoku, 8-11 in Chunan, 8-12 in Kamikita, 8-9 in Shimokita and 8-9 in Sanpachi. Overweight prevalence remained high across all ages if it was high at age 6. Furthermore, overweight prevalence showed an upward trend again from age 14 to 15 in both boys and girls. On the other hand, underweight prevalence peaks at ages 10-12 in both boys and girls with an increase observed in boys from age 14 to 15 (**Figure 4**). Districts with increases and decrease for both overweight and underweight prevalence could be seen by birth cohort. Districts in which increases were seen in both overweight and underweight prevalence were Tousei and Seihoku for boys and Chunan for girls.

## IV. Discussion

The results of the MEXT *Annual Report of School Health Statistics Researches* and *Aomori Prefecture children and Student's Health and Physical Fitness Survey Report* were used to perform a longitudinal analysis of overweight and underweight prevalence in Aomori school children by birth cohort. This allowed

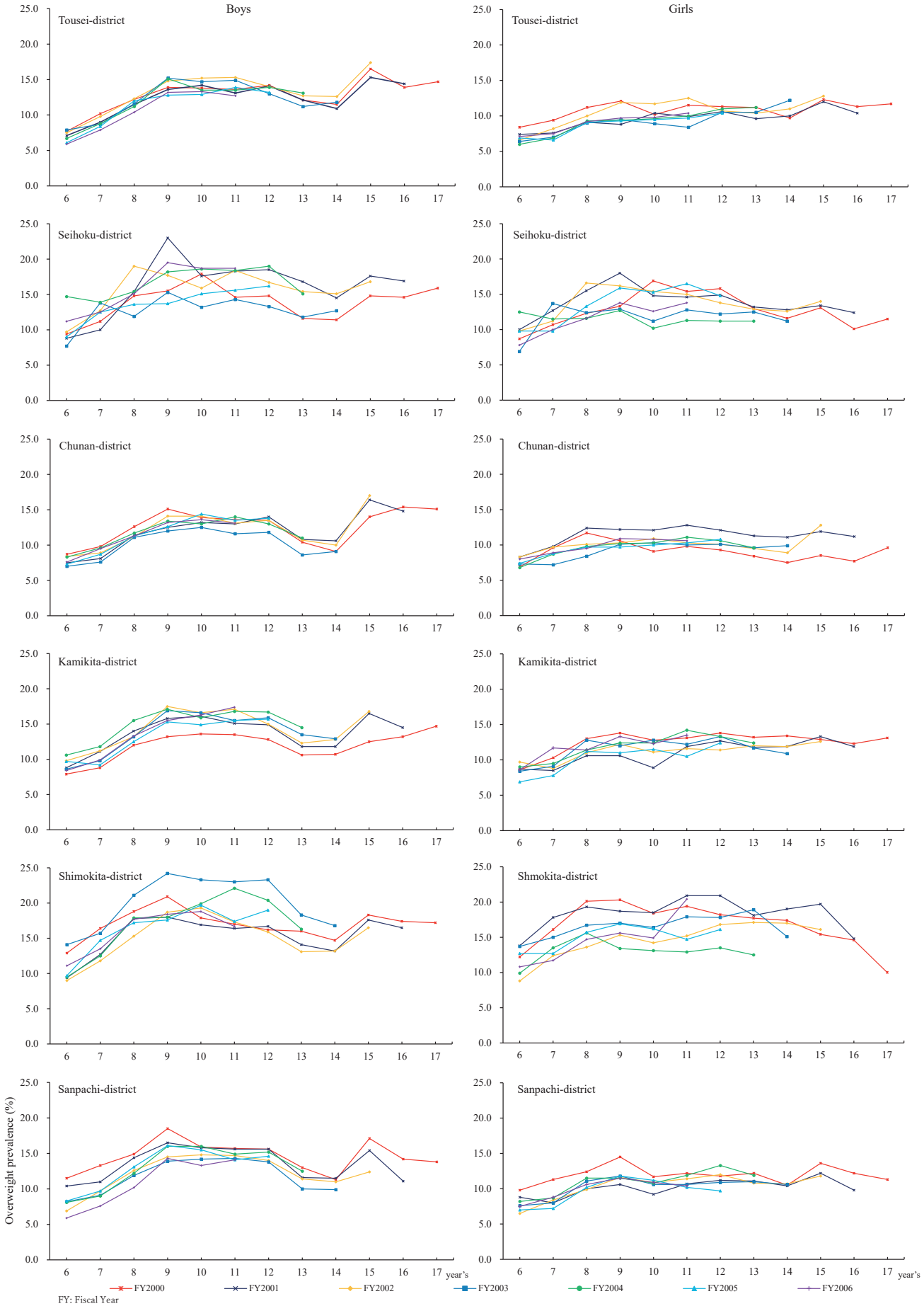


**Figure 3** The change in overweight prevalence by sex and birth year for each district

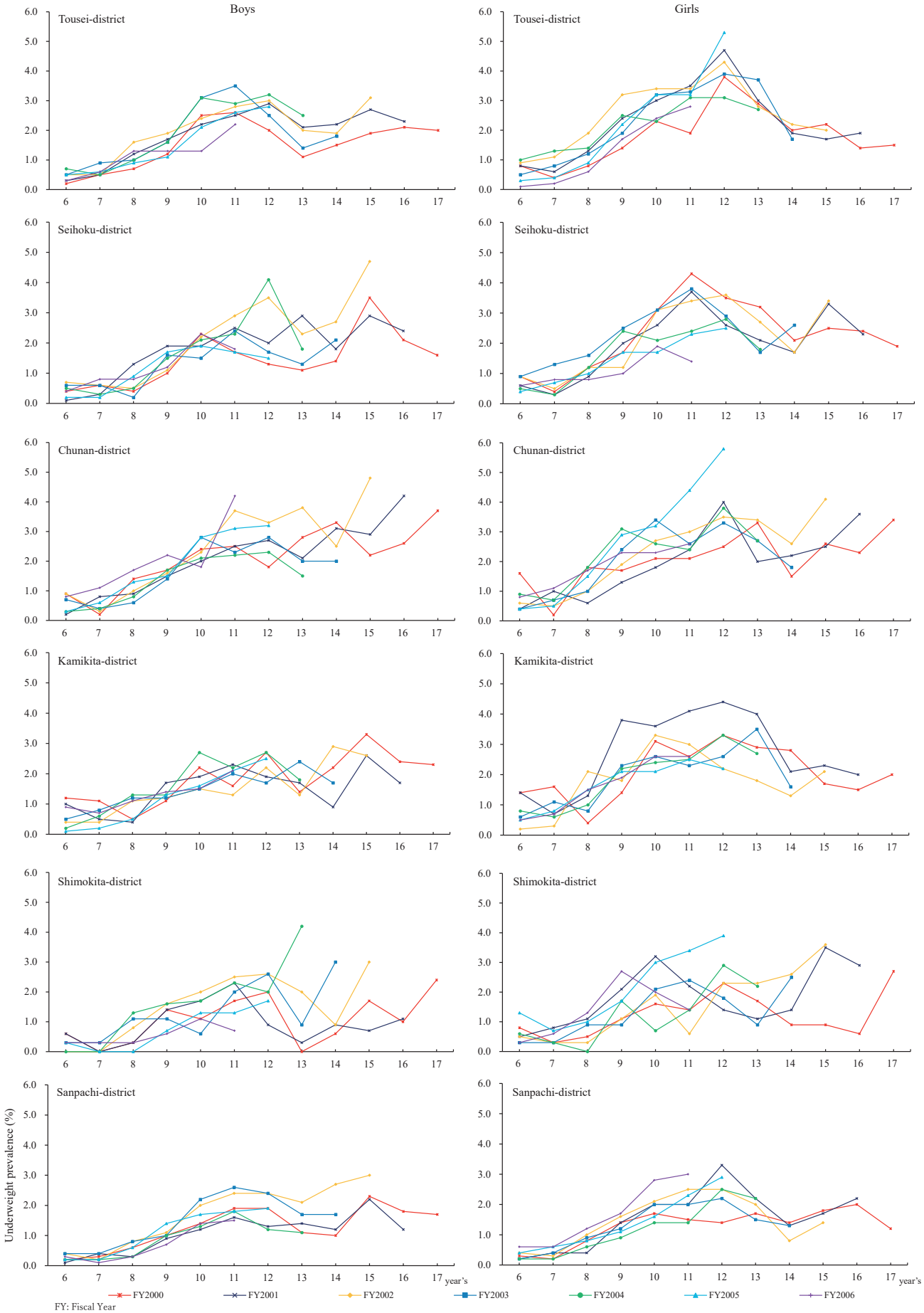


**Figure 4** The change in underweight prevalence by sex and birth year for each area

us to identify changes in prevalence trends overtime. In addition, by performing the analysis by district, the possibility of health guidance based on regional health differences and birth cohort characteristics for children can be seen. The population approach for obesity in children and adolescents have been used before in dietary education. However, through identifying overweight prevalence trends overtime by district it becomes possible to decided when to effectively implement a high-risk approach.

At present, the majority of Japanese boys grow the most in height between the ages of 11-12 and most girls between the ages of 9-10, and both have their largest growth-related weight gain between the ages of 11-12[33]. Because the ages for these growth spurts in boys and girls in Aomori Prefecture were about the same, we ruled out the possibility that the groups in this analysis may have been growing at a faster rate than the national average. However, in Kida et al's report on the physical development of children and adolescents in 10 prefectures in Japan (including Aomori), the 1969-1985 Aomori birth cohorts weight continues to increase long after height growth has peaked compared to other prefectures[34]. It is speculated that this continuous increase in weight led to high values in the Rohrer index. This analysis did not examine the development of children and adolescents nationally therefore we could not verify this reported increase in weight. In addition, obesity cannot be determined by body mass alone, the amount of body fat must also be considered. In Aomori Prefecture, surveys on body fat in children and adolescents are not conducted. However, according to the Aomori prefectural resident Nutrition Survey, subcutaneous fat thickness values (ages 15-19) where higher than the national average in 1991 and 1996[35][36]. Body fat percentages calculated through the impedance method were 19.9±6.4% for boys and 26.4±4.7% in girls (ages 10-19) in 1996 and 19.1±4.2% in boys and 23.0±2.9% in girls (15 and older, below 20) in 2005[37]. Although these values are lower than the standard for determining child obesity[38], it outlines the necessity to also measure body fat for the sake of child and adolescent obesity in Aomori.

Since 1990, The national averages for overweight prevalence in birth cohorts has been decreasing with each subsequent cohort[5]. While the prefectural averages in this analysis showed a similar tendency, there were some school districts in which the average prevalence increased. A major premise in epidemiology is that local conditions need to be considered, but national and prefectural averages alone do not provide sufficient information to accurately capture differences regional characteristics. Therefore, in addition to comparisons based on averages for the entire prefecture, comparisons need to be made using regional averages. Furthermore, data on the number of subjects in a survey is vital which we hope future prefectural reports will include.

Overweight prevalence in both Aomori boys and girls increased between the ages of 6-9, peaking 1 year earlier than children nationally. Nationally, the longitudinal trend in childhood obesity has been for obesity in boys to peak at age 11 and in girls at ages 11-12; furthermore, prevalence rates in the FY2000 cohort were lower than in the FY1990 birth cohort[5]. A study looking at changes in BMI between the ages of 5-17, dividing subjects into early-, average- and late-maturity types, found that growth in boys peaked at an average age of 11.46 ± 0.17 and girls at an average age of 9.12 ± 0.35[39]. Another study based on height and weight measurements for individual children from the first to the sixth grades found that if children were obese in first grade, then compared to children with normal weights, the odds ratio that they were still obese going into the 7$^{th}$ grade was 35.0 for boys and 63.9 for girls[40]. An overseas study of obesity between the ages of 16-18 found that weight between 18 months and 4 years of age was associated with later increases in BMI[41]. Considering that in our analysis overweight prevalence was found to have already peaked in both boys and girls at age 9 and that they tended to be taller and to weigh more than the national average, with boys growing most at 12 and girls at ages 10-11, this suggests that the underlying causes of overweight may have begun before the children even started school. Although there are numerous reports on the relationship between obesity and life-style habits, it is necessary to examine the changes in life-style habits that occur in Aomori children between age 6 to 8 when overweight prevalence increases. Aomori Prefecture annually conducts life-style surveys following MEXT'S physical strength test on children and adolescents or subjects chosen through random sampling, and publicly announces the results. The survey consists of questions on aspects such as exercise habits, skipping breakfast, sleeping habits, time spent watching TV and so on. When examining the results for 6 to 8-year olds, there is an increase in responses for desirable life-style habits in questions regarding sports club membership, exercising and playing sport every day[42]. However, at the same time, there is also an increase in responses for undesirable life-style habits in questions regarding frequency of skipping breakfast, time spent watching TV and/or

playing games daily, daily sleep duration and quality of sleep. This trend was also observed in results from 2007 to 2018. Through examination of the undesirable responses it is suspected that increases in time spent watching and/or playing games leads to decreased sleep duration and sleep quality causing morning waking time to become late which, in turn, increases the frequency of skipping breakfast. However, as these results are not separated by district, it is impossible to identify regional characteristics. Examining why undesirable life-style changes occur between age 6 to 8 should be the subjects of future research.

Thus, the important time to provide health education related to being overweight may be between the ages of 6-8, before obesity prevalence has peaked. Furthermore, the fact that after age 9 obesity prevalence decreased, but only slowly, suggests that once a child is overweight, it may be difficult to change that situation[43]. This has been shown to be the case in a longitudinal study of BMI that suggested that if BMI was high at age 6, it would still be high at age 17[44]. Given that in the FY2000 and FY2002 cohorts, the average overweight prevalence around the age of 15 returned to what it was at age 9, students who had become a normal weight must have returned to being overweight. This is possible because from the third year in junior high school (age 14) there are no extracurricular sports club activities until entering high school (age 15), exercise time deceases while time spent in sedentary behaviors, such as studying for high school entrance examinations, increases leading to an overall decrease in physical activity. This is reflected in the *Aomori life-style survey* with sports club membership dropping from 84.5% to 73.9% in boys and from 64.4% to 46.7% in girls from age 14 to 15[42]. Furthermore, the percentage of responses for spending less than 30 minutes a day exercising or playing sports (excluding school Physical Education) increased from 12.0% to 18.9% in boys and from 28.7% to 40.6% for girls the same age[42]. Therefore, it is necessary to actively promote guidance for life-style habits and physical activities during this period in order to prevent overweight. This also suggests the need to integrate weight-related health education into the curriculum regarding health-related behaviors so as to help students avoid becoming overweight when they are 14-15 years old, before they start high school.

The prevalence of underweight increased in both boys and girls from age 7 to 11 or 12, and after age 12 it declined. This trend was similar to that found in a previous study in which it increased in boys from age 6 to 10-11 and in girls from age 6 to 12[6]. By birth cohort these results were the same. However, comparing cohorts in both boys and girls shows a tendency for underweight prevalence to increase more in the FY2001 cohort than in the FY2006 cohort. The existence of a gender-related difference in the desire to be thin has been previously reported, with that desire shown to be stronger in girls[45]. That gender difference was seen in the Aomori data as well. While being underweight during adolescence is known to negatively impact later growth processes in many ways, Aomori Prefecture has no policy goal related to case of underweight children, even though there is a goal to reduce the case of overweight[15]. This suggests that the problem of increasing underweight among children is being overlooked. Therefore, in the future, it will be important to implement health education for children immediately after they start elementary school to teach them the importance of not becoming too thin.

Recently, in Japan, the use of growth charts to monitor children's physical development from early childhood is being promoted in daycare centers and educational facilities as a way to keep children from becoming over- or underweight[46) 47)]. Furthermore, approaches to preventing obesity, such as monitoring a child's physical development and teaching them good food habits from ages 3-5 before they start school, have been shown to be effective in reducing the prevalence of obesity in children after entering school, and it is important that their growth continue to be monitored[48]. In a past study, we were interested in the strength of the tendency for children in Aomori Prefecture to be overweight before starting school and to what extent parents were aware of the importance of monitoring their children's physical development. As a result, we investigated how mothers with pre-school children monitored their physical growth[49]. Our results showed that about 30% of the mothers used the growth charts in their *boshi-techō* ("Mother and Child Health Notebook") at most once a year, suggesting that while keeping notes in the *boshi-techō* was important for the official health check-ups for young children, once those check-ups stopped, mothers stopped using the notebooks. Mothers who were not using the growth charts knew the results of the physical examinations performed at daycare facilities, but from those measurements alone it was difficult for them to properly monitor their children's physical development. The growth charts in the *boshi-techō* can be used through 18 years of age, and, as part of their health education, students in Aomori Prefecture can record and monitor themselves using an on-line application on their own from elementary school until they graduate from high school[50]. Our results suggest that

to prevent children from becoming over- or underweight, it is important to properly monitor their growth from early childhood and provide them with health education and a home environment that enables them to monitor their physical development themselves so as to maintain a normal weight.

Local differences in the monitoring of children's physical development have been observed by population size[51]. The tendency for children to be overweight has been found to be inversely correlated with population size, with remote rural areas having a higher prevalence of childhood obesity. In addition, the tendency for children to be underweight has been found to be stronger in the more heavily populated Chubu and Kinki Regions of Japan[4]. The school districts in our analysis included a mix of municipality types (cities, agricultural communities and fishing communities) making it impossible to draw similar conclusions. Furthermore, while it is feasible that climate is a factor, overweight prevalence in our analysis was not limited to areas with heavy snowfall, nor were increases in prevalence limited to those areas. In Aomori, the district with the highest overweight prevalence is Shimokita district for both boys and girls even though the area with heaviest snow fall is Tousei district. Regarding the cause of the high overweight prevalence rate in Shimokita district, a survey of nutrition intake and life-style habits was conducted to 10-year olds but there were no significant differences when compared to national averages[52]. Our longitudinal analysis by birth cohort showed that, while the averages for both boys and girls in Shimokita exceeded prefectural averages, they were decreasing, suggesting that the efforts to control overweight in children may be proving effective. It has also been pointed out that socioeconomic background influences child health[53]. According to the *2015 Aomori Prefectural Economic Statistics*, average individual income (in 1,000-yen units) was 3,020 for Kamikita, 2,538 for Sanpachi, 2,437 for Tousei, 2,261 for Chunan, 2,245 for Shimokita and 2,084 for Seihoku[54]. It is suspected that the lower income of the Shimokita and Seihoku districts is related to the high overweight prevalence for these districts. Furthermore, the prevalence of dental caries for children in these two districts is also high[42].

On the other hand, there were increases in Seihoku for boys and in Chunan for girls. Cross-sectional studies have found that overweight prevalence in boys in almost all grades in Seihoku were greater than the prefectural average and that in girls in the Chunan region it was lower[8]. However, this analysis demonstrated that even if a cross-sectional analysis has shown a district to have a lower prevalence than the prefectural average, a longitudinal analysis by birth cohort could show an increase in prevalence in that district. This was also true of underweight prevalence, suggesting that conducting cross-sectional studies alone runs the risk of overlooking the fact that there are regions in which a bipolarization of weight-related problems is underway.

Our results suggest that when evaluating increases in the prevalence of overweight and underweight children, it is important to perform a longitudinal investigation by birth cohort and by region and not simply to compare prefectural and national averages. Furthermore, due to birth cohort differences in when overweight and underweight prevalence peaks in each region, it is necessary to provide health guidance based on regional and birth cohort characteristics rather than a generalized approach based on prefectural averages.

## V. Limitations

As to this analysis's limitations, first, because some high school students live in different municipalities to their schools, the official population of school districts and municipalities differ. Second, we did not consider possible reasons for increases in overweight and underweight prevalence, such as associations with children's health-related behaviors, parents, or socioeconomic background[53]. Third, the analysis did not allow conclusions regarding the extent to which overweight and underweight varied in severity or regarding the number of children returning to a normal weight. However, the analysis was able to show from long-term longitudinal data for children in the same birth cohort in Aomori Prefecture those grades and districts in which increases in overweight and underweight prevalence were seen. The prevention of overweight and underweight has to be implemented across a series of life stages. In the case of Aomori Prefecture, conventional reliance on school-based interventions by grade from elementary through high school may be too late to reduce the prevalence of obesity and underweight, Additionally, it is difficult to address poor but well-established health-related behaviors. Therefore, parents and children may need instruction and preventative support before elementary school to reduce the prevalence of overweight and underweight in childhood by learning to lead healthier lives. In addition, parents need to make use of medical services, such as health check-ups for young children, so that the child can learn and adopt better

dietary habits and other health-related behaviors before starting school, and to monitor their child's physical development using growth charts, especially between the ages of 6 and 8 after starting school and between age 14 to 15.

## VI. Conclusions

1. In the study of overweight and underweight prevalence in school children, it is important to use a longitudinal approach and examine the data by birth cohort and region, given that a cross-sectional comparison of national and prefectural averages cannot identify local differences in trends.
2. Overweight prevalence in Aomori Prefecture were shown to have increased between the ages of 6-9 for both boys and girls, peaking 1 year earlier than at the national average of 10 and increasing once more between age 14 to 15. Underweight prevalence was found to have started to increase at age 7 and to have peaked at age 11 or 12 in both boys and girls.
3. There were regions in which an increase in both overweight and underweight prevalence was observed. Furthermore, regional differences emerged in each birth cohort.
4. It is important to provide guidance based on regional and birth cohort differences for health promotion in school.
5. In the case of Aomori Prefecture, it will be important to prioritize weight-related health interventions between the ages of 6-8 to reduce the prevalence of overweight and underweight children after they start school.

## VII. Conflicts of Interest

The authors have no conflicts of interest to report.

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