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ORIGINAL PAPER

The Landscape of Overweight and Obesity in Icelandic Adolescents: Geographic Variation in Body-Mass Index Between 2000 and 2009

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Abstract The prevalence of overweight and obesity has increased globally. This study examined the geographic variation in overweight and obesity trends among Icelandic adolescents in urban and rural areas. Data from two cross-sectional population-based samples of 14- and 15-year-old students attending the compulsory 9th and 10th grades of the Icelandic secondary school system in 2000 and 2009 were used to calculate body mass index (BMI). Overweight and obesity rates were represented for 17 zones on maps created with the ArcGis geographic information and imaging software. Results were that males had higher rates of overweight and obesity than females in both 2000 and 2009, with a significant difference for both genders between years. Mean BMI was higher for rural areas than urban areas in both study years. Out of 17 geographic zones, the prevalence of obesity increased between 2000 and 2009 for males in 16; however, the one remaining zone had the highest increase in overweight. Obesity increased in 13 zones for girls and decreased in four from 2000 to 2009. Mean BMI rose between the study years but fewer zones differentiated from each other in 2009 than 2000. The prevalence of overweight and obesity increased among Icelandic adolescents in both urban and rural areas; however, rural areas have higher rates of obesity, overweight, and mean BMI than urban areas. Because of diminishing differences between areas from 2000 to 2009 the increase in mean BMI, increases in overweight, and obesity appear to be more rapid in urban areas than rural areas.

Keywords Adolescence · BMI · Geographic variation · Obesity · Overweight · Rural · Urban

Background

The prevalence of overweight and obesity among all ages is now a global problem [1]. More children and adolescents are becoming overweight and obese [2]. The upward trends in adiposity have now been documented in many countries, including the United Kingdom [3], the United States [4], Canada [5], Finland [6], Denmark [7], Sweden [8, 9], Norway [10], and Iceland [11].

In 2004, it was estimated that approximately 10% of the world's school-aged children carried excess body fat. Excess body fat can lead to overweight and obesity which increases the risk of developing chronic diseases [2]. Obesity in childhood can increase the likelihood of adult obesity [12] and adolescents who are overweight are almost 18 times more likely than their peers who are not overweight to become obese adults [13]. Childhood and adolescent obesity is associated with higher mortality rates from several causes of death [14] and increased risk of coronary heart disease in adulthood [15]. Childhood obesity is not found to be an independent variable in cardiovascular disease (CVD) in adulthood [16] but a factor that can contribute to ongoing obesity and then increased risk of CVD.

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Overweight and obesity are typically measured by using BMI, which is calculated using the individual weight in kilograms divided by height in square meters [17]. The World Health Organization [1] defines overweight as a BMI equal to or more than 25 kg/m^2, and obesity as a BMI equal to or more than 30 kg/m^2. BMI cut-off scores are the same for both sexes but not for children and adolescents under 18 years of age where they are both age- and gender-specific [18]. Studies have shown that BMI cut-off scores can also vary with ethnicity/race [19]. Overweight and obesity are also defined as excessive fat accumulation that may impair health [1], with obesity being linked to several adverse health outcomes [20].

The use of geographic information systems for health surveillance can be utilized to recognize changes in trends over time using cross-sectional data as well as identifying geographic variation in at-risk groups, environmental and social hazards, and shortages of treatment and prevention [21, 22]. Findings from studies in Scandinavian countries show geographic variation in overweight and obesity between urban and rural areas [8, 23, 24]. Monitoring the changes in BMI trends is an important challenge for public health practitioners in order to identify developments in prevalence, trends, and the effects of preventive measures in different areas. To date, no spatial studies of overweight and obesity among Icelandic adolescents have been reported.

Aims

The general aims of this study were to: (1) geographically map BMI among Icelandic adolescents from two population-based surveys, (2) examine the changes in rates of overweight and obesity between 2000 and 2009, and (3) identify patterns of geographic variation in adolescent overweight and obesity in Iceland by urban and rural area.

Methods

Participants

This study utilized population-wide cross-sectional data from the 2000 and 2009 *Youth in Iceland* surveys, conducted by the Icelandic Centre for Social Research and Analysis (ICSRA), which monitors trends in various demographic data and health-related variables [25]. Participants were adolescents enrolled in the 9th and 10th grades throughout Iceland at the time of the survey, in March 2000 and February 2009. Questionnaires were distributed to all secondary schools in Iceland. Teachers and research assistants supervised student participation in each study and administered the survey questionnaires in regular classrooms. Students were instructed not to write their names, social security number, or any identifying information anywhere on the questionnaire. When the questionnaire was completed, the student placed it in a sealed envelope and returned it to the supervising teacher. The response rate for the 2000 survey was ~82% and in 2009 ~83.5%.

The 2000 questionnaire was completed by 6,314 participants from 129 schools and in 2009 by 7,377 participants from 142 schools. For this study, respondents who provided insufficient information about gender, height, or weight were excluded from the analysis. Race and ethnicity were not included in the analysis because of the population homogeneity of Iceland. In 2000 ~94% of total inhabitants were of non-foreign background with the same ratio among the 14- and 15-year-olds. In 2009 this ratio was 86% among the inhabitants of Iceland and 89% among 14- and 15-year-olds [26]. After filtering of insufficient information the 2000 sample consisted of 5,798 participants, 91.4% (~51.7% females) of the total sample, and the 2009 sample consisted of 6,181 participants, 82.3% of (~52.3% females) the total sample for the analysis. A background check on the non-responses resulted in no particular pattern across regions or schools.

Measure and Classification of BMI Groups

BMI was calculated using self-reported height and weight. Participants who failed to respond to either one were excluded, as well as participants who reported to weigh 30 kg or less and 145 kg or more. Participants who reported to be 130 cm in height or less or 230 cm in height or above were also filtered out. Participants who did not respond to the question on gender were excluded because adolescent BMI cut-off points vary between the genders as well as age groups. The samples were relatively equal regarding age distribution. In the 2000 sample 50.7% were born in 1984; 48.5% in 1985; .3% in 1983 and .5% in 1986. The 2009 sample was similar with 50.2% born in 1993; 48.8% in 1994; .2% in 1992; .6% in 1995; .1% in 1991 and 1997. All participants were categorised as being 15 year olds, using the same internationally validated cut-off points for everyone in the study [18]. According to these cut-off points, 15 year old males were obese if BMI equalled 28.30 kg/m^2 or above and overweight if their BMI was between 23.29 and 28.29 kg/m^2. Girls, 15 year old, were obese if their BMI equalled 29.11 kg/m^2 or above and overweight if their BMI levels were between 23.94 and 29.10 kg/m^2. By using these cut-off points the overweight group did not include the obese group.

Geographic Zones

The size of Iceland is 103,000 km^2 with approximately 317,000 inhabitants [27]. Except for the capital, Reykjavik, where roughly two-thirds of the population reside, and the north town of Akureyri, where 5.5% of the population live, Iceland is not densely populated; it is a predominantly rural country.

Individual schools are the unit of analysis in this study. School size varies within the country, with more students in urban areas due to higher population density. In order to examine geographic variation in trends, we divided Iceland into 17 geographic zones based on the number of students and the location of schools (Fig. 1). Reykjavík and the surrounding area was divided into 9 zones based on the number of schools in each zone, the number of students in each school in 2000 and 2009, and the proximity of schools to each other, i.e., closeness of neighbourhoods. Zones 1–6 represented Reykjavík and Seltjarnarnes (a municipality in the far western part of the capital area), which in this study was merged with the western part of Reykjavík to comprise zone 1. Zones 2–6 are neighbourhoods categorised by the area service centres for the respective zones. The service centers operate in line with the mutual services used by the respective inhabitants and are defined as a functioning unit by the Reykjavik city council. In the outskirts of the capital area, lay zones 7–9, which are considered to be urban areas along with Reykjavík and Akureyri (zone 14) in the north. Rural areas include zones 9–17, zone 14 being an exception. These zones consist of municipalities that were merged due to their geographic location and the number of students within the areas in 2000 and 2009. The number of participants ranged from 157 to 643 within the respective 17 zones, with the largest number in zone 8 and the fewest in zone 15.

Data Analysis

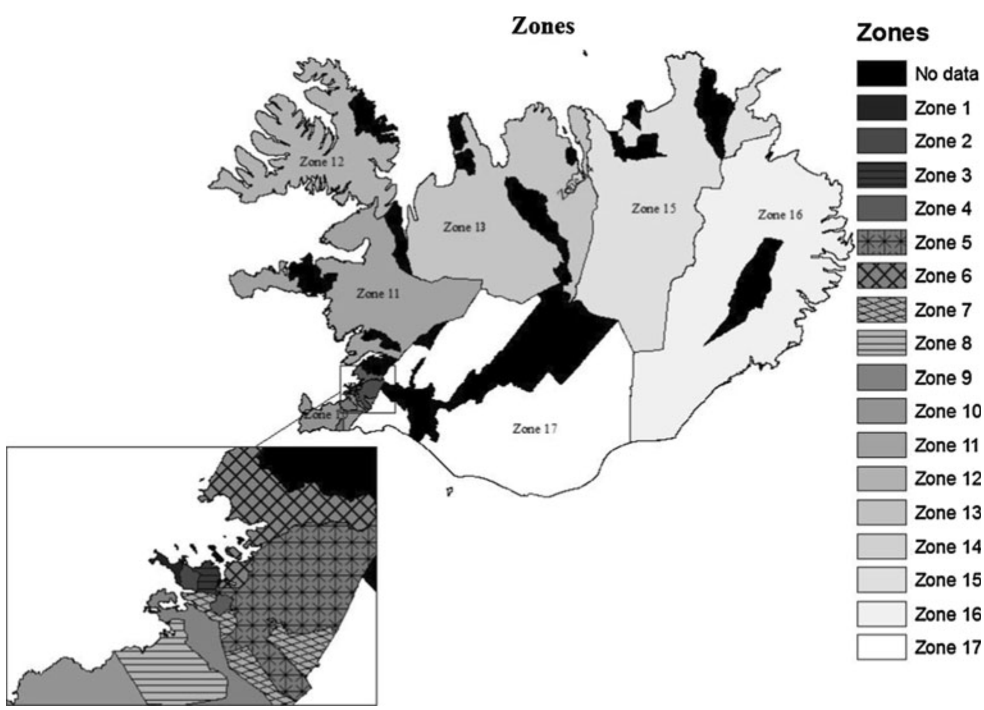
A frequency count was conducted to examine overweight and obesity between years and genders after categorising BMI using BMI cut-offs according to Cole et al. [18]. Data are represented on maps created by ArcGis, a geographic information system using municipal data from Natural Earth. Statistical analyses were performed using SPSS 18.0. Statistical difference between years within genders and zones were analyzed with a chi-square test. The geographic variations in overweight and obesity prevalence were analyzed for urban and rural areas. Analysis of variance (ANOVA) with Tukey's (HDS) post-hoc test was used to examine statistical significance in BMI between zones within each year for both genders.

Results

National Trends

Rates of overweight and obesity were higher for males than females in both 2000 and 2009. The rate of overweight males across Iceland was 17% in 2000 and the obesity rate was

Fig. 1 Categorised zones of study area



3.7%. In 2009, overweight had risen for males to 18.9% and obesity to 6.5%. The overweight rate for females across Iceland was 10.9% in 2000 and the obesity rate was 2.4%. In 2009 these rates had risen to 13 and 3.6%, respectively. A significant difference ($P < .01$) in mean BMI was found between years, with a .43 kg/m^2 increase in mean BMI between 2000 and 2009 for males and females combined. In 2000 and 2009 Mean BMI was significantly lower for girls (M = 20.77, SE = 3.37; M = 21.21, SE = 3.81 respectively) than boys (M = 21.34, SE = 3.26; M = 21.77, SE = 4.39 respectively), the difference in mean BMI was less in 2009 than 2000. A Chi-square test revealed a significant increase in obesity and overweight rates for both genders from 2000 to 2009 [for males χ^2 (2, N = 5,745) = 28.825, $P < .001$; for females χ^2 (2, N = 6,234) = 15.2, $P < .001$].

Geographic Variation

Figures 2, 3, 4 and 5 show the geographic variation in overweight and obesity for males and females and by urban and rural areas. Adolescents living in urban areas (zones

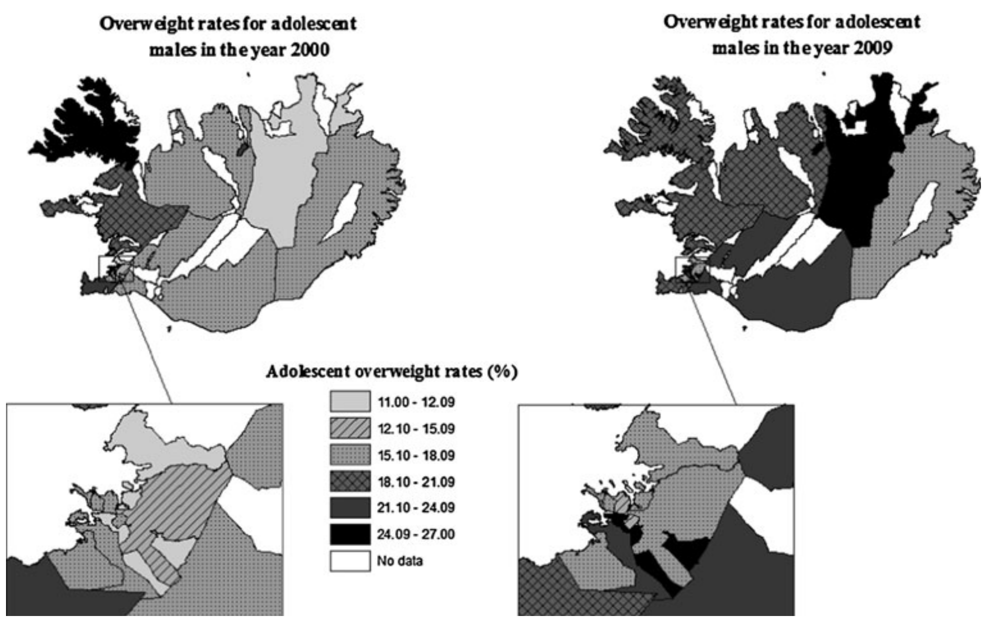


Fig. 2 Overweight rates for adolescent males, 14- to 15-years-old, in 2000 and 2009

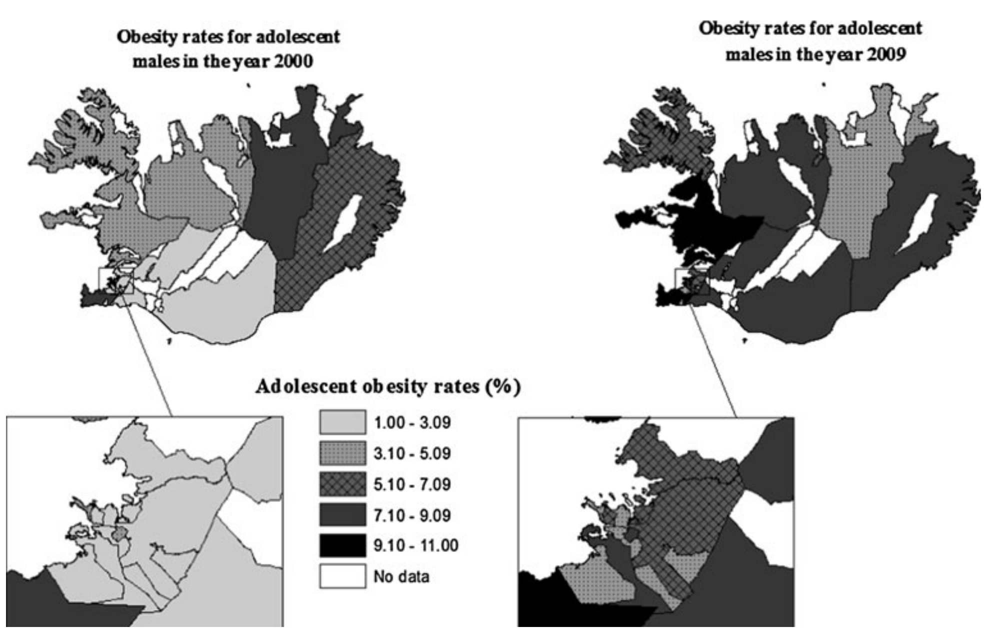


Fig. 3 Obesity rates for adolescent males, 14- to 15-years-old, in 2000 and 2009

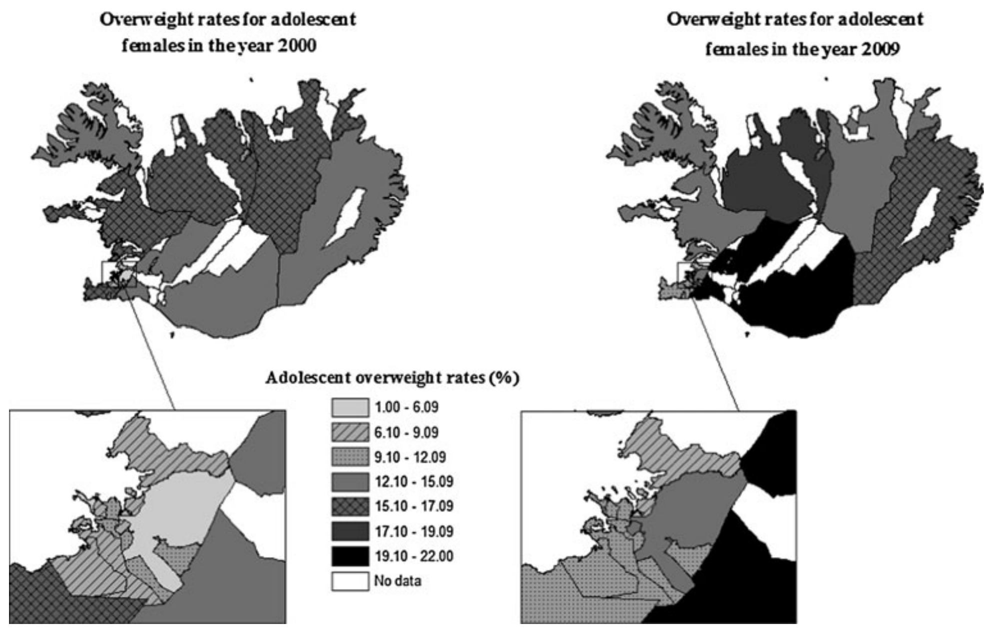


Fig. 4 Overweight rates for adolescent females, 14- to 15-years-old, in 2000 and 2009

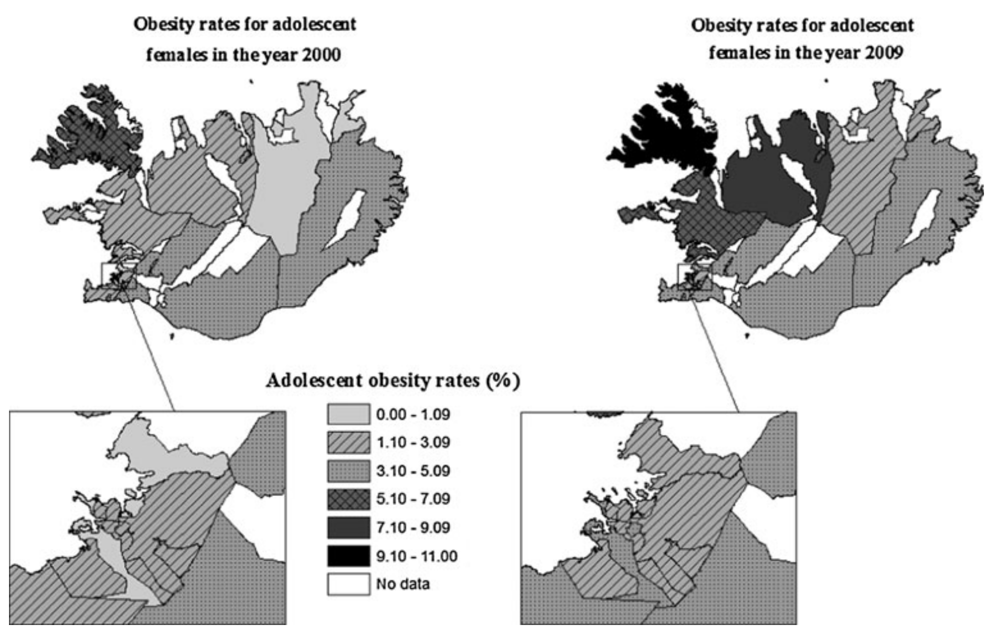


Fig. 5 Obesity rates for adolescent females, 14- to 15-years-old, in 2000 and 2009

1–9, 14) accounted for 60.4 and 64.6% of the respondents, in 2000 and 2009, respectively. Mean BMI for females and males combined living in urban areas was 20.71 kg/m^2 in 2000 and 21.29 kg/m^2 in 2009, compared to 21.56 kg/m^2 in 2000 and 21.83 kg/m^2 in 2009 for adolescents living in rural areas.

Overall, BMI was lower in 2000 than 2009, for females and males in both urban and rural areas. The variation in mean BMI between years for each zone was statistically significant ($P < .05$) in three zones for males (zone 6, 7, and 17) and two for females (zone 1 and 13). Between-zone difference in mean BMI for the entire sample in 2000 and 2009 was statistically significant [F (16, 5,782) = 7.986, $P < .05$; F (16, 6,172) = 3.093, $P < .05$, respectively]. There was a statistically significant difference between zones in mean BMI for females in 2000 and 2009 [F (16, 2,985) = 5.332, $P < .05$; F (16, 3,225) = 2.737, $P < .05$ respectively], but only for males in 2000 [F (16, 2,783) = 3.595, $P < .05$]. The F values decreased between 2000 and 2009, which indicates a decrease in variability of mean BMI between zones over time. A post-hoc analysis revealed that fewer areas differentiated, in mean BMI, from each other in 2009 than in 2000. In 2000 one or more of zone 1–9, which are urban areas, significantly differentiated from two or more of zones 10–17, which are all rural areas except for zone 14. In 2009 only zone 8, with the lowest mean BMI, significantly differentiated from three zones with the highest mean BMI (zones 12, 13, and 17). (Due to the large number of groups compared in these tests, data are not shown but are available upon request.)

The prevalence of overweight increased for males in 10 zones between 2000 and 2009 (Fig. 2). The prevalence of obesity increased in all areas for males between the survey years except for zone 15 (Fig. 3). However, the overweight prevalence increased by 15% in zone 15 during this period. Similarly, the prevalence of overweight increased in 11 zones for girls during the study period (Fig. 4). The prevalence of obesity increased for girls in 13 zones and decreased slightly in 4 zones (zones, from the least decrease to the most, 5, 17, 3, and 8) (Fig. 5).

Discussion

The prevalence of overweight and obesity increased among Icelandic adolescents between 2000 and 2009. Overweight prevalence increased 1.9% for adolescent males and 2.1% for females and obesity prevalence increased 2.8 and 1.2% for males and females, respectively. Similar trends have been documented in other countries, including the United Kingdom, Canada, and the United States [3–5]. However, these countries have higher rates of overweight and obesity and have experienced a more dramatic increase over time than Iceland. Finland, Denmark, Sweden, and Norway have all experienced increases in the rates of childhood and adolescent overweight and obesity that are similar to Iceland [6–10].

Overweight rates were higher on average for Icelandic 14- to15-year-old males than females in both 2000 and 2009. However, the increase in overweight was greater among females than males between the years studied, as reported. Males had higher obesity rates than females in both 2000 and 2009 and the increase in obesity was also greater for males than females. The Young-HUNT study among Norwegian adolescents aged 14–18 years found that there is a marked gender difference in time trends for both the prevalence and extent of overweight and obesity in Norway, and a greater increase between 1966–1969 and 1995–1997 among males than females [10]. A study among Finnish adolescents [6] reported higher rates of overweight and obesity among males than females based on self-reported height and weight from 1977 to 1999, whereas the opposite was found for Swedish children and adolescents [8].

We also found that mean BMI levels were higher in rural areas than urban areas. The prevalence rates of obesity and overweight were also higher in rural areas than urban areas in both years and are consistent with findings from several other international studies. A Swedish study among school children showed that mean BMI levels as well as the prevalence of overweight and obesity were higher in children from countryside schools than urban schools [8]. Overweight rates were also significantly higher in rural areas than in urban areas in a study among 5- and 12-year-olds in Finland [24]. A Norwegian study on urban and rural differences reported that mean BMI, obesity and overweight were higher in rural areas compared to urban areas in 1990. Eleven years later mean BMI levels were still higher for females in rural areas than urban areas, whereas geographic variation had diminished for males [23]. The geographic variation found in the current study for 2000 has been diminishing 10 years later among Icelandic adolescents, revealing much less difference between areas in 2009 than in 2000, suggesting that the prevalence of overweight and obesity is increasing faster in urban areas than rural areas. It may be that food availabilities are more of traditional Icelandic origin in rural areas than in urban areas. Traditionally such food is higher in fat ratio than the more modern food available in urban areas. In urban areas the food selection takes account of modern lifestyles to fast food consumption, soft-drink availability and so on. Furthermore accessibility to modern products high in fat and sugar is off course much easier in urban areas than in rural ones in Iceland.

Strengths and Limitations

Two limitations are worth noting. First, overweight and obesity rates were estimated with self-reported data on height and weight that were used to calculate the BMI scores. The main limitation in using BMI is that it categorises weight regardless of lean body mass, fat or bone weight [28]. Since BMI cut-off points are only used for 15-year-olds there is a chance that the prevalence rate of overweight and obesity is underestimated in the study. The validity of self-reported height and weight has been evaluated for adolescents and the overall correlations for reported and measured dimensions are relatively high, with more accurate reports on height and weight for boys than girls [17]. Girls are more likely than boys to underreport their weights by an average of 1–2 kg [29] and underreporting is more common among heavier respondents of both genders [30]. Studies have shown that height and weight are underestimated in self-reported BMI compared with measured BMI [30]. However, Himes points out that when BMI measurements are used carefully, they can be an excellent indicator of overweight and obesity for population surveillance [17].

Second, by categorising geographic areas into representative zones, spatial anomalies can go undetected and spatial patterns may change depending on the scale used. This is the "Modifiable Areal Unit Problem" [22]. However, data were first examined at the school level to see if there were any abnormalities before being merged into corresponding zones. Each school was viewed with regard to overweight and obesity rates before merging with other schools and then into zones. The reason for this was if a school with abnormally high or low rates of overweight/obesity had been merged with another school with abnormally high or low rates of overweight/obesity, the effect would have zeroed out and the results would not have been important. There were no abnormalities detected that had to be considered. Ideally, each municipality would be represented individually. This was not possible since not all municipalities in Iceland have schools, and in some municipalities, the schools have very few students. Moreover, it was necessary to merge schools into larger units to protect local school identities.

Despite these limitations, the study has several strengths. First, high-quality data were obtained for all 14- and 15-year-olds who attended school on the survey day. Due to the mandatory school system in Iceland, data was collected from virtually the entire population in these age groups, with a high response rate. Second, filtered data are not likely to have influenced the results because of the large number of respondents and the almost universal participation among Icelandic adolescents. Third, spatial anomalies were accounted for by analysing the data at the individual school level before they were merged into larger areas and corresponding zones.

Conclusions

Mean BMI is increasing among Icelandic adolescents aged 14 and 15, with males demonstrating higher rates of overweight and obesity than females. The increase in overweight was higher for females than males, and the increase in obesity was higher for males between 2000 and 2009. While levels of BMI have been rising among adolescents, the geographic variation has decreased over time. Rural areas have higher rates of overweight and obesity and higher mean BMI than urban areas; however, there is little difference between areas in 2009 compared to the marked differences between areas in 2000. Overweight and obesity rates are increasing in both urban and rural areas, with a more rapid increase in urban areas. Geographic surveillance may help public health practitioners and policy makers to more efficiently distribute resources for the prevention and treatment of overweight and obesity.

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Conflict of interest We disclose that we have no conflict of interest.

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