Mapping geographical variation in obesity in Finland

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Background: The prevalence of obesity varies across countries. However, less is known about the geographical, within-country variation. This study investigated and visualized the geographical differences in general obesity defined by body mass index (BMI) and in abdominal obesity defined by waist circumference and waist-to-hip ratio (WHR) in Finland. Subjects and methods: Data for the study consisted of three large population surveys: Health 2000 Survey with a nationally representative sample together with the National FINRISK Study conducted in five areas in 1997 and six areas in 2002. Altogether, 17 816 men and women aged 30–64 years participated in the surveys. In each survey, subjects’ weight, height and circumferences of waist and hip were measured. The geographical pattern of mean anthropometric values and obesity prevalence were studied applying a Bayesian hierarchical approach and Geographical Information Systems. Results: Both in men and women, the prevalence of obesity (BMI ≥ 30 kg m⁻²) varied little across geographical areas, but it was smaller in cities compared with other areas across the country. In men, the prevalence of abdominal obesity defined both by waist circumference and WHR was higher in western Finland compared with southern and northern Finland. Also in women, the prevalence of abdominal obesity was highest in western Finland, especially as defined by waist circumference. Conclusions: Geographical variation in BMI was different and less prominent than in waist circumference and WHR. Abdominal obesity was surprisingly high in western Finland, the area seldom investigated. Mapping obesity gives a useful tool for professionals working in the field of health promotion.

Keywords: body fat distribution, geographical variation, health surveys, obesity, waist-to-hip ratio

Introduction

The prevalence of obesity has increased worldwide both in developing and developed countries during the past decades. However, the global overview of secular trends in obesity reveals that there is large geographical variation in the rate of obesity.1 Also in Europe, wide country-to-country variation has been reported.2 For example, the prevalence of obesity, defined as body mass index (BMI) greater than 30 kg m⁻², varied from 8% to 40% in men and from 5% to 53% in women among 50- to 64-year-old participants in the European Prospective Investigation into Cancer and Nutrition (EPIC) study including nine countries in Europe.3

Within-country variation in the rate of obesity has been reported in several countries. In the United States, for example, the prevalence of obesity (BMI ≥ 30 kg m⁻²) in adult population has been shown to vary across the states.4 Geographical variation in the prevalence of obesity in Spanish population suggests a trend for higher rates towards the south and southeast of the country,5 whereas no clear north–south division has been shown to vary across the states.4 Geographical variation has been shown to vary across the regions such that the mean BMI was lowest in the capital area (south).7 That study, however, covered four regions in south-west, south and east only.

Obesity is an excess of body fat associated with ill health. To assess fatness, BMI is widely used in clinical settings and population studies.8 BMI is an imprecise but useful measure for overall adiposity.9

More recently, however, it has become more obvious that fat distribution is important in predicting obesity-related health risks.10 It is amply documented that abdominal obesity is strongly associated with cardiovascular and metabolic risk.11 These associations have been investigated by using either waist circumference12–14 or waist-to-hip ratio (WHR)15–18 as an indicator of abdominal obesity. Whether waist circumference or WHR should be used in assessments of obesity-related risks is still under debate. To date, however, few studies have assessed fat distribution and its secular changes in populations using these indicators.19–22 In addition, to our knowledge, no studies have investigated geographical variation in abdominal obesity.

As pointed out by World Health Organization,1 the value of estimating the prevalence of obesity cannot be overemphasized. Knowledge of the level and changes in distribution of obesity can be used to identify populations at particular risk of obesity. This knowledge is of help for policy-makers and public health planners in mobilizing and reallocating resources for the control of health risks and disease.

Bayesian spatial models have gained popularity due to their flexibility.23 Classical spatial statistics rely on different forms of kriging to provide optimal smoothing.24 The use of kriging requires estimation of covariogram, which is complicated and subjective. The elegance of the Bayesian spatial model is that the strength of the autocorrelation is estimated simultaneously with regression parameters of the model. Geographical variation in the incidence of Type I diabetes,25 acute myocardial infarction26 and medicated parkinsonism27 has been investigated applying a Bayesian approach. As results, maps of estimated incidences revealed regional variation which did not resemble administrational regions. Aggregation of data into administrational regions may be inadequate for the analysis on public health information. In our study, this
Bayesian approach was first time applied in the field of obesity epidemiology by using nationwide data on adult population.

The aim of this study was to provide visual tools for obesity monitoring by making use of a mapping methodology and to illustrate regional variation in the level of obesity using three indicators (BMI, waist and WHR) among Finnish adults. We consider this information to be useful for the local and national decision makers as well as experts and researchers in public health.

**Subjects and methods**


Health 2000 Survey with a nationally representative sample of subjects aged 30 years and older was carried out between fall 2000 and spring 2001 (figure 1). The subjects selected for the survey (n = 8028) were invited to attend a health examination at a local health care centre. Of the invited subjects, 6354 men and women (participation rate 79%) participated in the health examination. As the participants in the National FINRISK Study (see below) were <65 years of age, only participants aged 30–64 years in the Health 2000 Survey (n = 4886) were selected for this study. After excluding the participants with missing anthropometric information or coordinates, data of 4512 subjects were finally included in the study. The study protocol of the Health 2000 Survey has been described in more detail elsewhere.

The National FINRISK Study has been conducted at 5-year intervals since 1972. This study included data from the two most recent surveys which were carried out in 1997 and 2002. For both surveys, a random sample was drawn from the Population Register including people aged 25–64 years. The sample covered five areas in 1997 (n = 10 000) and six areas in 2002 (n = 11 944) (figure 1). In both surveys, participants were invited to a health examination at a local health centre. For this study, data of 7159 subjects aged 30–64 years (participation rate 72%) from the FINRISK 1997 survey and 7784 subjects (participation rate 65%) from the FINRISK 2002 survey were included. The study protocol has been reported in more detail elsewhere.

Altogether, data of 8332 men and 9484 women (n = 17 816) aged 30–64 years were included in the present study. In each survey, trained study nurses measured participants’ weight, height and circumferences of waist and hip. BMI was computed as weight/height2 (kg m−2). WHR was calculated as waist divided by hip. Obesity was defined as BMI 30 kg m−2 or greater. A waist circumference 102 cm or greater for men and 88 cm or greater in women were regarded as high values, i.e. to be cut-off points for abdominal obesity. Abdominal obesity was also defined by using WHR with cut-off points of 1.0 for men and 0.85 for women.

Mean BMI and waist circumference together with prevalence of obesity were estimated using a Bayesian conditional autoregressive model (CAR). The model describes the spatial variation as a network of neighbouring grid cells connected with each other through an autoregressive process. Classical statistical regression models rely on independence of observations as the estimation of the variance covariance structure is complicated. In the CAR model, the strength of the autocorrelation is estimated simultaneously with the regression parameters of the model. This autoregressive process makes it possible to give reasonable estimates even to the grid cell without observations. The interpolated estimates are naturally less accurate and tend to reflect the covariate information as the distance to the observations increases. The variation in the number of participants could be taken into account in analyses. The grid cells having a large number of observations (the maximum number of observations = 924) are estimated very accurately and locally, whereas the grid cells that are far away from the nearest observations have the least precise estimates reflecting the global estimates of the covariate effects.

Prevalences were modelled as binomial counts. Age group, sex, survey, population density and study area of the National FINRISK Study were used as covariates in the models. The effects of the covariates were assumed to be additive on the logit scale. The Bayesian approach requires determination on prior distributions of all the parameters. Non-informative priors were used in this study.

As overall obesity (BMI) could be a confounding factor in geographical pattern of abdominal obesity, these analyses were run also by including BMI in the models. However, as there were no differences between the adjusted and unadjusted results, only the results unadjusted for BMI are presented.

WinBugs (version 1.4.1.) was used to the estimation.

Coordinates of the respondents were obtained from the Population Register Centre using a unique personal identity number (ID) that every resident in Finland has. The population data were located according to the map coordinates using ID numbers and Geographical Information Systems (GIS). Data were aggregated into grid cells with a resolution of 10 km by 10 km covering the whole country.

**Results**

The average BMI exceeded the upper limit of normal weight (25 kg m−2) both in men and women in all parts of Finland. In men, mean BMI did not vary across geographical areas, whereas in women, mean BMI seemed to be greater in western Finland than in southern Finland (maps not shown). In both genders, BMI and the prevalence of obesity (BMI ≥ 30 kg m−2) (figure 2) were smaller in cities compared with other areas across the country, which was seen by lighter colours around the locations of ten biggest cities in Finland.

Both in men and women, mean waist circumference seemed to be greater in western and eastern Finland and lower in southern and the most northern part of Finland. In addition, the prevalence of abdominal obesity defined as high values in waist circumference (waist ≥ 102 cm in men and ≥88 cm in women) was higher in western Finland compared with other parts of the country (figure 3).

When using WHR to define abdominal obesity, the rate in men and women did not vary between western and eastern Finland (figure 4). Both in men and women, the lowest prevalence in abdominal obesity seemed to be in southern and in the most northern parts of Finland (Lapland). The results of the geographical pattern in abdominal obesity did not change after adjusting for BMI (data not shown).

**Discussion**

In our study, BMI was smaller in cities compared with other areas across the country. This finding was not supported by a recent study investigating obesity among 50–79-year-old Europeans (n = 16 695) in rural and urban settings. Data from 10 European countries showed no differences in the prevalence of obesity (BMI ≥ 30 kg m−2) between rural and urban areas.

The rural–urban differences in obesity have also been studied elsewhere. Living in rural areas were more likely to be obese than their urban counterparts.
As obesity was examined in 7735 middle-aged men in 24 British towns, considerable variation in the rate of obesity between the towns were observed. The prevalence of obesity (BMI ≥ 30 kg m⁻²) varied from 11% to 28%. This variation was suggested to be determined to some extent by social class. In the same study, social class differences in BMI were significant, with obesity to be more marked in manual workers. Our finding of lower level of mean BMI and obesity (BMI ≥ 30 kg m⁻²) in cities may also be determined at least partly by socioeconomic status as people living in cities are more educated than people living in the countryside. Consistent with several earlier studies, just recently, Finnish men and women with higher education were observed to be less likely obese compared with their less educated counterparts.

Geographical differences in abdominal obesity, defined by high values both in waist circumference and WHR, seemed to be surprisingly large compared with the differences in general obesity (BMI ≥ 30 kg m⁻²). As far as the authors know, the present study is one of the first describing geographical variations in abdominal obesity. As a result, comparisons of these findings with other western populations are not possible to make. However, different patterns observed in overall and abdominal obesity are in concordance with studies that have shown differences between secular trends in overall and abdominal obesity in Finland and Sweden. These studies have observed WHR to increase over the past decades, whereas BMI has remained quite stable over the same period in both genders but especially in women. More recently, it was shown that while the distribution of BMI values did not change much, a remarkable shift toward higher waist circumference values was observed in 15 years both in men and women.

Mean waist circumference and the prevalence of abdominal obesity, especially as defined by high values in waist circumference, seemed to be highest in western parts of
Figure 2 The prevalence of obesity (BMI $\geq 30$ kg m$^{-2}$) in 8332 men and 9484 women

Figure 3 The prevalence of abdominal obesity defined as waist circumference $\geq 102$ cm in 8332 men and $\geq 88$ cm in 9484 women
the country. Explanations for geographical differences in abdominal obesity with only minor differences in BMI may relate to variation in health behaviour. Lifestyle factors, i.e. physical activity, smoking, alcohol consumption and food choices, have been shown to be associated with body fat distribution. For example, a high intake of alcohol has been found to be related to larger waist circumference. In Finland, a prominent increase in alcohol consumption has occurred both in men and women during the past decades. However, it is still least consumed in western Finland where, in contrast to our expectations, high rates of abdominal obesity were detected.

Smokers and former smokers have been shown to have higher WHR than non-smokers, and smoking cessation to be associated with waist gain. Data from Finnish surveys reveal that the prevalence of smoking has increased in women and decreased in men during the past decades with an increased number of former male smokers as a result. The geographical differences we observed in abdominal obesity may be determined by smoking. Nevertheless, no geographical variation in smoking has been observed in Finnish men. In women, smoking has been shown to be more common in southern Finland than elsewhere in the country, which does not support our finding of lower waist circumference in southern and northern parts of Finland.

The geographical differences in abdominal obesity may be determined also by physical activity that has been observed to be associated with lower WHR and decreases in waist circumference. In Finland, leisure-time physical activity has increased in adult population, and in all parts of the country over the past 25 years. However, in concordance with our findings, physical activity varies across the regions such that men in western Finland report lower level of physical activity compared with their counterparts elsewhere. In women, such differences were not observed in this study conducted by Helakorpi et al. or in another recently published report, which did not find geographical variation in physical activity in men either. Interestingly, however, Fogelholm observed rural-urban variation in physical activity. Both in men and women, leisure-time physical activity was higher in urban areas compared with rural areas, which is in concordance with our finding of lower mean BMI and prevalence of obesity (BMI ≥ 30 kg m⁻²) in cities compared with other areas in the country.

Unhealthy diet determined by infrequent consumption of fiber-rich foods and frequent consumption of sausages was found to be associated with abdominal obesity among 31-year-old men and women in northern Finland. The main source of fiber is rye bread, the consumption of which varies across the country such that the bread is most consumed in eastern Finland. In contrast to what might be expected, in our study, as high levels of abdominal obesity defined by WHR were observed in eastern part of Finland as in western Finland. However, waist circumference and the prevalence of abdominal obesity defined by waist both in men and women was not that high in eastern parts of the country compared with their counterparts elsewhere in Finland.

The strengths of this study include a unique dataset including more than 17,800 men and women whose weight, height and circumferences of waist and hip were measured. The response rate was fairly high ranging from 65% to 79%. Nevertheless, it is worth of noticing that regional differences in response rate might have had some effect on results since obesity can be assumed to have been more prevalent among non-participants. Evaluation of this issue in more detail, however, is not possible due to the lack of proper analysis of non-participation in the FINRISK and Health 2000 studies.
Geographical variation in obesity was investigated by making use of a mapping methodology applying a Bayesian approach. The data were not originally collected for the mapping, but three data sets having different sampling design were combined. The resulting data set was spatially clustered. The Bayesian modelling method made possible to give reasonable estimates also to grid cells without observations as the autocorrelation structure spreads the local effects. The ‘borrowing of strength’ smooths the estimates but only to the extend concordant with the variability of the data. This interpolation provides a continuous map that allures to human eye. This Bayesian approach should be more often used in the analysis of similar autocorrelated data sets as the availability of user friendly software such as WinBUGS has made these computer intensive statistical methods available for researchers not so familiar with programming.

To conclude, geographical variation in BMI was different and less prominent than in waist circumference. Abdominal obesity, defined both by waist circumference and WHR, was surprisingly high in western Finland, the area seldom investigated. Mapping obesity gives a new useful tool for professionals working in the field of health promotion, especially as geographical variation in obesity seems to exist.

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Key points

- The article introduces new methodology in the fields of obesity epidemiology and public health.
- The geographical differences in obesity were investigated and visualized by applying a Bayesian hierarchical approach and GIS.
- Data from three large population surveys showed geographical variation in body mass index to be different and less prominent than in waist circumference in Finland.
- Abdominal obesity was surprisingly high in western Finland.
- Mapping obesity gives a useful tool for professionals working in the field of health promotion.

References


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