Sex-specific height-correction of weight in a population with ethnic groups that differ in stature - the SAMINOR 1 Survey: a cross-sectional study

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Background: Body mass index (BMI, weight/height^2) is a common proxy for body fatness, but it is negatively correlated with height. In Norway, the ethnic Sami people have had higher BMI and lower height than their non-Sami peers. This article aimed to examine if previous findings of higher obesity measures in Sami compared to non-Sami persist when applying an adequately height-corrected weight index.
Methods: We estimated a sex-specific height-corrected weight index—the Benn index—that is, weight/height^p where p is estimated from log(weight)-log(height) regression. We used data on 15 717 men and women aged 30 and 36–79 years who participated in the SAMINOR 1 Survey (2003–2004). Correlations between height and weight and the indices BMI and Benn index were calculated using Pearson's correlation coefficient.
Results: BMI and height had a modest, negative correlation. Analyses were stratified by sex due to a statistically significant interaction (sex * log(height), p<0.001). There was no interaction with ethnicity (ethnicity * log(height), p=0.07 in women and p=0.24 in men). The p (95% confidence interval) in Benn index (weight/height^p) was estimated to 1.29 (1.21, 1.38) in women and 1.90 (1.83, 1.98) in men. Higher BMI in Sami compared to non-Sami was most evident in women, but Benn index did not differ by ethnicity in either sex.
Conclusion: Previous findings of higher obesity measures in Sami than in non-Sami may be biased. Future studies should take into account the marked height differences between these groups when comparing obesity indices.

Introduction

Bodyweight is an indirect measure of body fatness. Because weight is expected to vary between people merely due to differences in height, height-corrected measures of weight have been developed. The most common height-corrected weight index is known as the body mass index (BMI). However, the BMI is prone to many errors when used as a measure of body fatness (1).

In 1972, weight/height^2, with weight measured in kilograms and height in metres, was termed BMI by Keys et al. (2). The formula was already known as the Quetelet index, after its creation in the mid-1800s by the Belgian statistician Adolphe Quetelet. Premises of the BMI include being independent of height (i.e. no correlation) and being a measure of relative adiposity for which weight is a proxy (i.e. strong correlation). In 1995, an Expert Committee of the World Health Organization promoted the BMI as a crude, but simple body fatness measure essentially independent of height (3). However, the Committee noted a modest negative correlation with height and warned that the BMI biases individuals on either end of the height spectrum. Already in 1971, Benn advised that p in weight/height^p, should be population-specific whenever possible as to avoid a negative correlation with height (4). The value of p typically falls between 1.07 and 2.35, with higher values in men than in women (5,6).

The Sami people populate northern parts of Norway, Sweden, Finland and the Kola Peninsula in the Russian Federation, and is acknowledged as indigenous by the Norwegian Government. Studies conducted in Northern Norway have repeatedly shown that Sami women have had higher mean BMI than non-Sami women, whereas Sami men have had slightly higher or similar BMI compared with non-Sami men (7–9). On average, Sami are almost 6 cm shorter than non-Sami in Northern Norway (7,9,10). A recent study showed that at the same BMI value, Sami had slightly more favourable levels of some cardiometabolic risk factors (e.g. lipids, blood pressure) than non-Sami. However, this was eliminated by height adjustment, suggesting that BMI does not sufficiently correct for height in this ethnic group (10).

This article aimed to examine if previous findings of differences in obesity prevalence (based on BMI) in Sami and non-Sami persist when applying an appropriately height-corrected weight index. We used data from the SAMINOR 1 Survey, a population survey in Northern Norway, and aimed to 1) estimate the p in weight/height^p (Benn index) and test for interactions with ethnicity and sex, 2) estimate the correlation between height and weight and the indices BMI and Benn index, respectively, and 3) compare BMI and Benn index in Sami and non-Sami.

Materials and methods

Study sample

The SAMINOR 1 Survey is the first survey of the Population-based Study on Health and Living Conditions in Regions with Sami and Norwegian Populations—the SAMINOR Study and was conducted in 2003–2004 as a collaboration between the Centre for Sami Health Research, UiT The Arctic University of Norway and the Norwegian Institute of Public Health. The survey comprised self-administered questionnaires and a clinical examination including blood samples. All inhabitants (27 987 individuals) aged 30 and 36–79 years in 24 municipalities mainly in northern, rural parts of Norway were invited and 16 865 (60.3%) participated and gave consent to participate in research. All the included municipalities were sparsely populated, with population density ranging from 0.3 to 6 inhabitants per km^2. The only municipality that included a city was Alta which had 17 000 inhabitants at the time of data collection. All other municipalities had 500–4000 inhabitants. Details are found elsewhere (11).

We excluded 851 participants who did not attend the clinical examination. There were missing data for height and weight in 34 participants, whereas 263 participants failed to reply to any ethnicity-related questions. These were excluded, leaving 15 717 participants to analyse.

The SAMINOR Project Board and the Regional Committee for Medical and Health Research Ethics approved this project (REC NORTH reference: 2017/1974). Written informed consent was obtained from all participants.

Height and weight

Height and weight were measured by trained personnel to the nearest 0.1 cm and 100 g, respectively, using an electronic scale with participants wearing light clothing and no shoes.

Ethnicity

Norwegian law states that it is illegal to register ethnicity in medical and population registries, but it is allowed to ask questions regarding ethnicity for research purposes. Eleven questions on ethnicity were posed in the self-administered questionnaire. These included the home language of grandparents, parents and oneself (seven questions), the ethnic background of parents and oneself (three questions) and the person's self-perceived ethnicity (one question). Multiple of the following answers were allowed: Norwegian, Sami, Kven and other. We categorised Sami ethnicity according to a definition used frequently in studies using SAMINOR data, where both of the following criteria had to be fulfilled to be categorised as Sami: [1] answer Sami as home language of any relative or oneself, and [2] answer Sami as one's ethnic background or self-perceived ethnicity. All others were categorised as non-Sami.

Statistical analysis

The distributions of weight and height were visualised using kernel density plots in strata of ethnicity and sex. All variables were normally distributed and presented as mean (standard deviation).

Let w denote weight in kilograms and h denote height in meters. Benn gave mathematical proof that a person's relative weight (the ratio of actual weight to a standard weight for height) can approximately be expressed as a power-type weight index, w/h^p (4). Benn proposed to estimate p as the gradient or slope in a regression of log(w) vs log(h), i.e. the coefficient β in the regression equation

$$\log(w)=\alpha+\beta\log(h) \quad (1)$$

According to Benn, w/h^p is not only (approximately) independent of height, but it is also highly correlated with relative weight.

All analyses were sex-stratified due to evidence of interaction between log(height) and sex (p-value <0.001) in the regression model. There was no interaction between log(height) and ethnicity. In strata of sex, we modelled log(w) on log(h) using linear regression and estimated p as the slope coefficient β. Next, we calculated BMI and the Benn index as weight in kg divided by height in metres raised to a power of 2 and p (the sex-specific β coefficient from log-log regression), respectively. The distributions of weight and height were visualised using kernel density plots in strata of ethnicity and sex.

We used two-sample t-tests to compare the mean of weight, height, BMI and Benn index in Sami and non-Sami participants. We estimated correlations between BMI and height, BMI and weight, and between Benn index and height, and finally Benn index and weight, with Pearson's product-moment correlation coefficient, r, with 95% confidence intervals (CI).

We used the free software *R* version 4.0.0 in all analyses (12).

Results

A total of 3470 (22%) of the participants were categorised with Sami ethnicity. Table 1 displays sample characteristics and Figure 1 displays kernel density plots of the height and weight distributions in strata of sex and ethnicity. On average, Sami were shorter and weighed less than non-Sami.

Table 1. Ethnic- and sex-specific characteristics in the SAMINOR 1 Survey (2003–2004, N=15 717)

	Total	Sami	non-Sami	p-value
Women	N=8213	N=1777	N=6436	
Age, years	53.8 (11.7)	53.3 (11.7)	53.9 (11.7)	0.067
Height, cm	160.9 (6.8)	156.4 (6.1)	162.2 (6.4)	< 0.001
Weight, kg	71.3 (13.0)	69.0 (12.4)	71.9 (13.2)	< 0.001
Men	N=7504	N=1693	N=5811	
Age, years	54.4 (11.3)	54.6 (11.2)	54.3 (11.3)	0.409
Height, cm	173.8 (7.2)	169.3 (6.4)	175.1 (6.9)	< 0.001
Weight, kg	83.5 (13.5)	79.8 (13.3)	84.6 (13.4)	< 0.001

Mean (standard deviation) are given. P-values originate from two-sample t-tests.

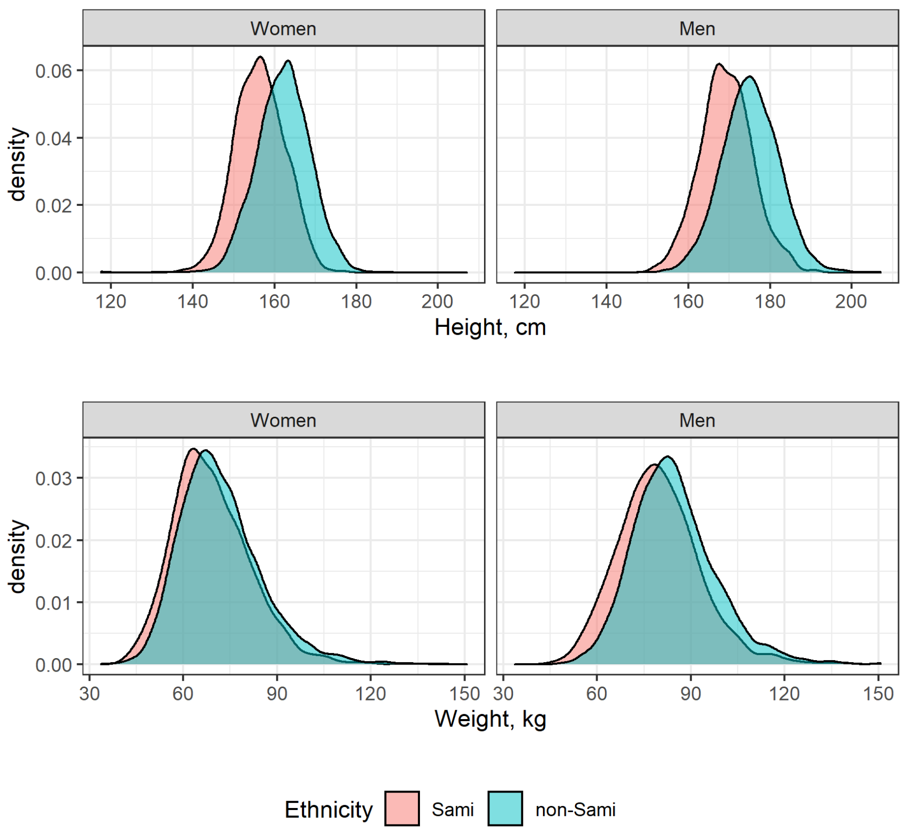

Figure 1. Kernel density plots of distributions of ethnic- and sex-specific height and weight in the SAMINOR 1 Survey (2003–2004, N=15 717).

The correlation coefficient r (95% CI) between weight and height was 0.30 (0.28, 0.32) in women and 0.49 (0.47, 0.50) in men. Hence, height explains 9% and 24% of the variance (r^2) in weight in women and men, respectively.

The slope of log(height) of the log-log-regression, p (95% CI), was 1.29 (1.21, 1.38) in women and 1.90 (1.83, 1.98) in men (p-value for interaction between sex and log(height) <0.001). Ethnicity-stratified analyses showed that p (95% CI) was estimated to 1.16 (0.95, 1.36) in Sami women and 1.36 (1.26, 1.47) in non-Sami women (p-value for interaction between ethnicity and log(height) = 0.07), and 2.01 (1.83, 2.2) in Sami men and 1.90 (1.81, 1.98) in non-Sami men (p-value for interaction = 0.24).

Table 2 shows sex-stratified comparisons of Sami and non-Sami concerning BMI and the Benn index using p=1.29 and p=1.90 for women and men, respectively. For both men and women, BMI was slightly higher in Sami than non-Sami, while no differences were identified for Benn index. Figure 2 displays kernel density plots of the distribution of BMI and Benn index in strata of sex and ethnicity.

Table 3 and Figure 3 show correlation coefficients and scatterplots, respectively, of weight vs BMI, weight vs Benn index, height vs BMI and height vs Benn index. BMI and height had a negative correlation that was stronger in women than in men. By contrast, no correlation was found between Benn index and height. Both BMI and Benn index correlated highly with weight; estimates were somewhat higher for Benn index, in women particularly.

Table 2. Ethnic- and sex-specific means (standard deviation) of Benn index and body mass index in the SAMINOR 1 Survey (2003–2004, N=15 717)

	Total	**Sami**	**non-Sami**	**p-value**
Women				
Body mass index, kg/m^2	27.5 (4.9)	28.2 (5.1)	27.4 (4.8)	< 0.001
Benn index, $kg/m^{1.29}$	38.5 (6.7)	38.7 (6.8)	38.4 (6.7)	0.164
Men				
Body mass index, kg/m^2	27.6 (3.9)	27.8 (4.1)	27.6 (3.9)	0.016
Benn index, $kg/m^{1.90}$	29.1 (4.1)	29.3 (4.3)	29.1 (4.1)	0.114

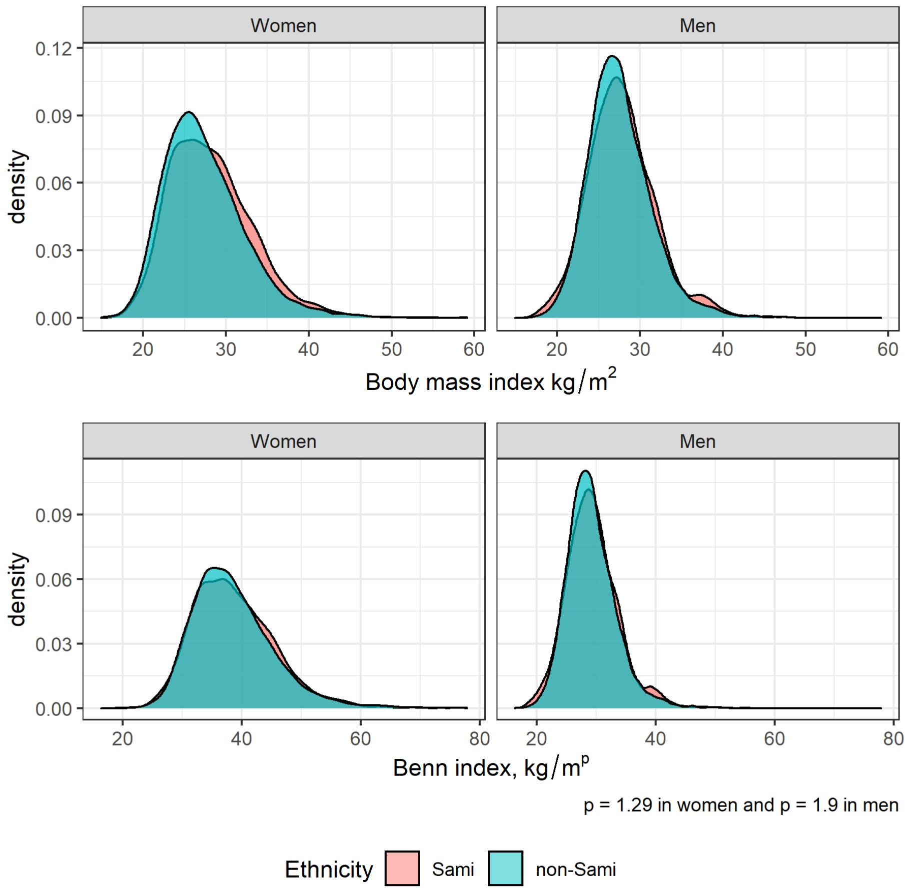

Figure 2. Kernel density plots of ethnic- and sex-specific distributions of body mass index and Benn index in the SAMINOR 1 Survey (2003–2004, N=15 717). The p's below the graphs are the power p identified for Benn index.

Table 3. Sex-specific correlations between height and BMI, height and Benn index, weight and BMI, and weight and Benn index in the SAMINOR 1 Survey (2003–2004, N=15 717)

	Height		Weight	
Women	r (95% CI)	p-value	r (95% CI)	p-value
Body mass index, kg/m^2	-0.17 (-0.19, -0.15)	< 0.001	0.89 (0.88, 0.89)	< 0.001
Benn index, kg/$m^{1.29}$	-0.00 (-0.02, 0.02)	0.753	0.95 (0.95, 0.96)	< 0.001
Men				
Body mass index, kg/m^2	-0.03 (-0.05, -0.01)	< 0.001	0.85 (0.85, 0.86)	< 0.001
Benn index, kg/$m^{1.90}$	0.00 (-0.02, 0.02)	0.689	0.87 (0.87, 0.88)	< 0.001

r = Pearson's correlation coefficient, CI = confidence interval

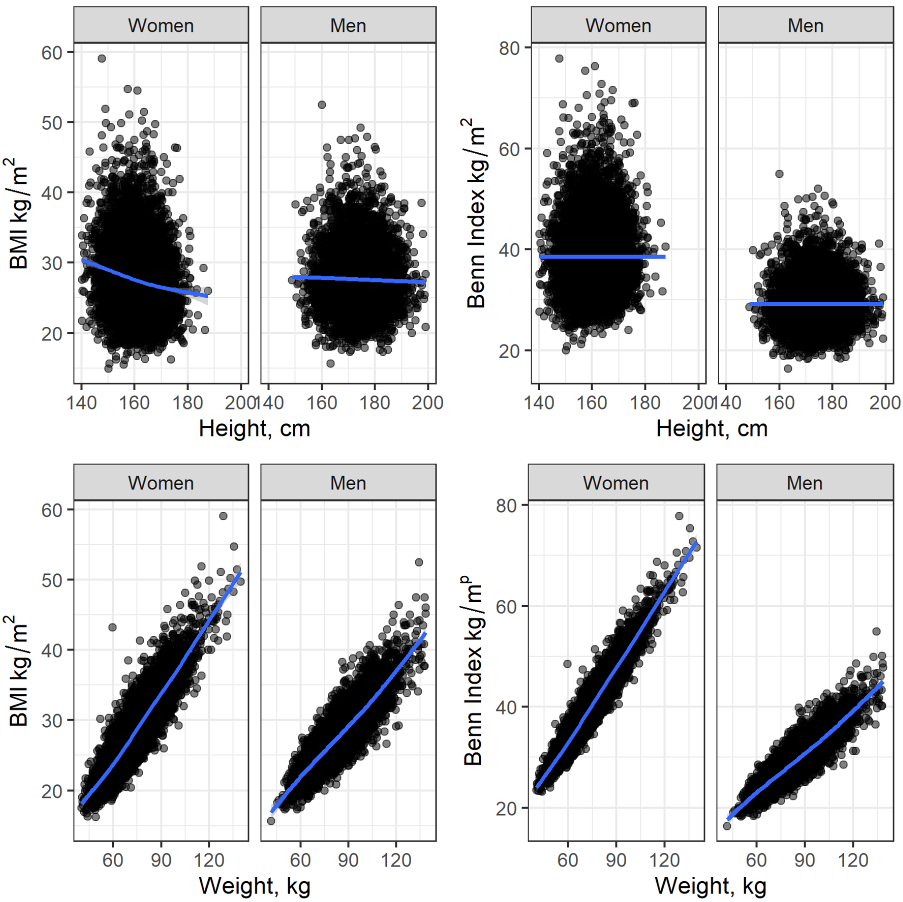

Figure 3. Sex-specific scatterplots of weight vs body mass index (BMI) and Benn index, respectively, and of height vs BMI and Benn index, respectively, with fitted lines in the SAMINOR 1 Survey (2003–2004, N=15 717).

Discussion

In this population-based study of approximately 16 000 adult women and men from rural, Sami-core areas in Northern Norway, we show a negative correlation between BMI and height, but no correlation between Benn index and height. Whereas mean BMI differs between Sami and non-Sami, mean Benn index does not differ between the ethnic groups. The estimated power p is markedly lower in women than in men (1.28 vs 1.90, respectively), corresponding with findings from several previous large studies from a wide variety of geographical regions, ages, ethnic groups and periods (5,6,13,14). We found no evidence of effect modification by ethnicity. Therefore, we used the same sex-specific p in both ethnic groups, which is an advantage in order to compare figures between the groups.

Our findings from a multiethnic population-based sample correspond with a previous multi-ethnic study from the U.S. In 1981, Lee et al. compared several indices of weight corrected for height (weight/height, weight/height^2, weight/height^3, weight/height^p) and their correlation with weight and height in five ethnic groups in the US (White, Japanese, Chinese, Filipino and Hawaiian) (5). The *p* differed substantially between the sexes but differed less between ethnic groups within the same sex (1.18–1.59 in women and 1.65–2.09 in men). When estimating *p* from the overall ethnic heterogeneous sample, weight/height^p was unbiased with respect to height. Consequently, the authors supported the same Benn index for height-unbiased weight comparisons across population groups that differ in height (5). However, the study by Lee et al. is four decades old.

In 2005, a research collaboration group analysed the weight-height relationship in 72 adult subgroups from 25 diverse countries from the US, Europe and Asia, including more than 380 000 individuals (and ethnicities) (6). A negative correlation between BMI and height was found in 31 of 40 samples of men and all 32 samples of women. The summary estimates of *p* from log-log regression were 1.92 (95% CI, 1.87–1.97) in men and 1.45 (95% CI, 1.39–1.51) in women. These correspond quite well with our findings (1.90 and 1.28 in men and women, respectively). In 2016, Sperrin et al. analysed height and weight data from 1992 to 2011 on more than 180 000 men and women from England (13). Based on their findings that BMI and height are negatively correlated and that *p* differ by sex, the authors suggested more sophisticated statistical modelling than simple mean BMI contrasts when comparing heterogeneous populations (13). These studies support the findings of our study, that the weak negative correlation between BMI and height may be a source of bias when comparing population subgroups differing in height.

Ultimately, the goal is to find an index that optimally estimate the complications of having too much body fat. Neither BMI nor Benn index are direct measures of fat, but measures of relative weight. An increased waist circumference is a better predictor of adverse health outcomes than BMI (and Benn index) (15–17). A meta-analysis concluded that both waist circumference and waist-to-height ratio were better than BMI in the detection of cardiometabolic risk (17). Waist-to-height ratio was slightly superior to waist circumference, and the authors promoted it as a universal measure across various ethnic groups, sexes and ages (17). However, the correlation between height and waist circumference and waist-to-height ratio is positive and negative, respectively (18). Recognising that BMI and waist circumference is highly correlated (typically with a correlation coefficient ~0.9), Krakauer et al. quite recently created a body shape index (ABSI) from weight, height and waist circumference that is independent of BMI and predictive of mortality (19). Hence, there are several other body fatness and body composition indices that may be better epidemiological measures of obesity than the simple BMI.

This article aimed to examine if previous findings of higher obesity prevalence in Sami compared to non-Sami persist when applying an adequately height-correcting weight index. We have shown that it does not. However, our aim was not to develop an obesity measure to be used clinically or in epidemiologic research, which requires more data and sophisticated modelling. Rather, we have here shown that relative weight does not differ between the two ethnic groups when the measure used for comparison is not correlated with height. Hence, previous findings of higher obesity prevalence in Sami than non-Sami may be biased. Future studies should aim for properly height-corrected measures when comparing relative weight, or obesity, in Sami and non-Sami.

Strenghts and limitations

Strengths of this study include a large sample size, objectively measured height and weight by trained personnel, negligible missing data for height and weight, and several self-reported questions relating to various facets of ethnicity. Limitations include a moderate participation rate (~60%) that may have induced selection bias. Information about the ethnicity of the invitees is not available. Hence, it is impossible to know whether response rates differ between Sami and non-Sami. Further, there is no consensus on how to define Sami ethnicity. Some of those categorised as non-Sami in our analyses have Sami ancestors but do not consider themselves Sami. Finally, it is a limitation that we were not able to include precise information on body fatness e.g. DXA in our analyses.

Conclusion

The frequently reported difference in BMI between Sami and non-Sami is biased due to a negative correlation between BMI and height. When the power p in weight/height^p is estimated through sex-specific linear regression of log(weight) on log(height) (Benn index), we find that mean levels of this index do not differ between Sami and non-Sami. However, no weight-for-height indices are direct measures of body fatness or distribution of body fat. The actual level of body fatness in the Sami and non-Sami population remains unknown.

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