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Change in prevalence and severity of metabolic syndrome in the Sami and non-Sami population in rural Northern Norway: the SAMINOR Study

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Change in prevalence and severity of metabolic syndrome in the Sami and non-Sami population in rural Northern Norway: the SAMINOR Study

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Abstract: Change in prevalence and severity of metabolic syndrome in the Sami and non-Sami population in rural Northern Norway: the SAMINOR Study

Objective: In 2003-2004, metabolic syndrome (MetS) was common in both Sami and non-Sami in Northern Norway using the MetS definition by the International Diabetes Federation. Due to a lack of knowledge regarding the development of MetS, we used updated definitions to examine the change in both the prevalence and the severity of MetS in this population.

Methods: Two cross-sectional surveys with participants aged 40-79 years from ten municipalities in Northern Norway were used: the SAMINOR 1 Survey (2003-2004, N=6308) and the SAMINOR 2 Clinical Survey (2012-2014, N=5866). MetS prevalence was determined using an updated definition of MetS: the harmonised Adult Treatment Panel III (ATP-III) criteria. MetS severity was measured with the MetS severity Z-score. Generalised estimating equation regression was used to compare prevalence and severity between the two surveys; an interaction term (survey x ethnicity) was included to determine if variations differed by ethnicity.

Results: The overall, age-standardised ATP-III-MetS prevalence was 31.2% (95% confidence interval [CI]: 29.8-32.6) in SAMINOR 1 and 35.6% (95% CI: 34.0-37.3) in SAMINOR 2. Both ATP-III-MetS prevalence and mean MetS severity Z-score increased between the surveys in all strata of sex and ethnicity, except for the ATP-III-MetS prevalence in non-Sami women, which remained stable. Sami showed a slightly larger increase in MetS severity than non-Sami, more so in men ($p<0.001$) than in women ($p=0.024$): the β coefficients for survey for Sami and non-Sami men were 0.20 (95% CI: 0.14 to 0.25) and 0.06 (95% CI: 0.01 to 0.10), respectively. Abdominal obesity increased markedly between the surveys in all strata of sex and ethnicity.

Conclusion: The prevalence and severity of MetS increased over time in rural Northern Norway. Sami men had a larger increase in severity than non-Sami. Abdominal obesity appeared to drive the increase in ATP-III-MetS prevalence.

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ARTICLE SUMMARY

Strengths and limitations

- This study included data from two cross-sectional surveys with acceptable attendance rates and relatively high proportions with Sami ethnicity
- The change in metabolic syndrome over time was examined using generalised estimating equations, thus accounting for repeated measures and obtaining population averaged regression coefficients
- We were able to detect ethnic differences with a continuous severity score that were not detectable with the dichotomous definition of metabolic syndrome
- A wide range of sensitivity analyses with respect to the diagnostic criteria and ethnic classification were conducted to ensure the internal validity of the study
- The results cannot be generalised to the entire Sami population, and we were not able to include potential confounders such as physical activity and diet

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INTRODUCTION

The co-occurrence of hypertension, abdominal obesity, impaired fasting glucose, low high-density lipoprotein (HDL) cholesterol, and increased triglycerides is known as metabolic syndrome (MetS) [1]. MetS is viewed as a state of excess adiposity and insulin resistance [1] that increases the risk of cardiovascular disease [2] and type 2 diabetes mellitus (T2DM) [3]. The worldwide prevalence of obesity has doubled since 1980 [4], and excess visceral adiposity is associated with cardiometabolic abnormalities in both obese and non-obese individuals [5]. Ethnic differences in body composition further complicate this relationship [6], but the dichotomised nature of MetS does not capture this complexity [7]. Assuming a pathological process underlying MetS, Gurka et al. constructed a sex- and ethnicity-specific continuous MetS severity Z-score that predicts coronary heart disease [8] and T2DM [9], independent of the individual MetS risk factors.

Northern Norway is inhabited by Norwegians, Sami, and Kven. The Sami is an ethnic minority living in Sápmi: a settlement area covering northern parts of Norway, Sweden, Finland, and Russia, and is regarded as an indigenous people in Norway. The Sami culture traditionally centred on reindeer herding, farming, fishing and hunting, but nowadays few are left in these occupations. Internationally, indigenous and minority groups have elevated prevalences of chronic lifestyle diseases compared with majority populations [10], but little to no differences in the prevalences of cardiovascular disease and MetS (using the International Diabetes Federation definition) have been found in Sami and non-Sami in Norway [11–13]. However, recent data have shown unfavourable prevalences of obesity (women) and T2DM (women and men) among Sami when compared with non-Sami [14,15]. Therefore, we used updated definitions to examine the prevalence and severity of MetS in Sami and non-Sami at two points in time, and examined whether variations in MetS prevalence and severity differed by ethnicity.

METHODS

We used data from two cross-sectional surveys of the Population-based Study on Health and Living Conditions in Regions with Sami and Norwegian Populations – The SAMINOR Study, which is run by the Centre for Sami Health Research at UiT The Arctic University of Norway. The first survey (SAMINOR 1) was carried out in collaboration with the National Institute of Public Health during 2003-2004 in 24 municipalities in Northern and Central Norway [16]. The SAMINOR 2 Clinical Survey (SAMINOR 2) was carried out during 2012-2014 in ten of the municipalities included in SAMINOR 1. The present analyses are restricted to these ten municipalities.

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In both surveys, all inhabitants from these ten municipalities who were registered in the National Registry and aged 40-79 years were invited to participate. Of all the inhabitants invited in SAMINOR 1 (N=11,518) and SAMINOR 2 (N=12,455), 6550 (56.9%) and 6004 (48.0%), respectively, attended the clinical examination and signed an informed consent. The SAMINOR Project Board and The Regional Committee for Medical and Health Research Ethics approved this study.

Patient and public involvement

During the planning of the SAMINOR Study, the Centre for Sami Health Research consulted with the Sami Parliament. In addition, researchers/health workers who are either Sami or work in Sami core areas were consulted in order to meet the needs of the Sami community. In the case of pathologic findings during examination, participants were encouraged to visit their primary physician. We intend to report the results of this study to decision makers, regional health establishments and authorities. An important aim of CSHR has always been to give the knowledge back to the participants of the study, often through popular science forums, meetings and lectures.

Self-administered questionnaire

In both surveys, information on duration of education (years), use of blood pressure (BP) medication (currently/previously, but not now/never), diabetes mellitus (DM, yes/no), alcohol consumption, physical activity, and diet was taken from a self-administered questionnaire. The questions on DM were not identical (SAMINOR 1: *Do you have or have you had diabetes?* SAMINOR 2: *Have you ever been diagnosed with diabetes (elevated blood sugar levels)?*). We did not include information on self-reported alcohol consumption, physical activity, or diet in the analyses, as these questions were not similar enough for comparison.

Information on ethnic background cannot be recorded in Norwegian registries or medical records, but it can be solicited for research purposes. Three main aspects of ethnicity –language, ethnic background, and self-perceived ethnicity – were explored in the questionnaire through a total of 11 questions: *What language do/did you/your mother/your father/ [all 4 of] your grandparents speak at home?*; *What is your/your father's/your mother's ethnic background?; What [ethnicity] do you regard yourself as?* Response options were: Norwegian, Sami, Kven, or other, and participants could choose more than one answer. In order to be categorised as Sami, participants had to respond that 1) their own ethnic background or self-perceived ethnicity was Sami, and 2) their home

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language for at least one of their grandparents, parents, or themselves was Sami. All participants who did not meet these criteria were categorised as non-Sami.

Clinical examination

Trained personnel performed all clinical measurements and blood sampling using similar procedures in both surveys. BP was taken with a Dinamap-R automatic device (Criticon, Tampa, Florida, USA) in SAMINOR 1 and a CARESCAPE™ V100 monitor (GE Healthcare, Milwaukee, Wisconsin, USA) in SAMINOR 2, following at least 2 minutes of seated rest, with participants' arms resting on a table. Three BP measurements were recorded at 1-minute intervals; the average of the second and third measurements was used in the analyses. Waist circumference (WC) was recorded to the nearest centimetre at the umbilicus, with the participant standing and breathing normally. Non-fasting blood samples were drawn by venipuncture, with participants in a seated position. In SAMINOR 1, serum was sent by mail and analysed consecutively at the Ullevål University Hospital, Oslo. In SAMINOR 2, serum was frozen on site at -20 °C and sent to the biobank in Tromsø, where it was stored at -70 °C and later analysed at the University Hospital of North Norway, Tromsø. Lipids were measured by an enzymatic method (Hitachi 917 autoanalyzer, Roche Diagnostic, Switzerland) in SAMINOR 1, and with a homogeneous enzymatic colorimetric method (Roche/Hitachi Cobas 8000B system, Roche Diagnostics GmbH, Mannheim, Germany) in SAMINOR 2.

Criteria for metabolic syndrome

MetS was defined based on the harmonised Adult Treatment Panel III (ATP-III) criteria, which state that a combination of any three of the following five risk factors is considered MetS [17]:

1. Hypertension: systolic BP ≥130 mmHg, diastolic BP ≥85 mmHg, or current use of BP medication.
2. Abdominal obesity: WC ≥80 cm in women and ≥94 cm in men, as recommended for a European population [5].
3. Elevated non-fasting serum glucose ≥7.8 mmol/L. We chose this cut-off as it is a proxy for prediabetes defined with an oral glucose tolerance test [18]. Participants with self-reported DM were also considered to have elevated glucose.
4. Reduced non-fasting serum HDL cholesterol <1.3 mmol/L in women and <1.0 mmol/L in men.
5. Elevated non-fasting serum triglycerides ≥1.7 mmol/L.

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The severity of MetS was determined based on an ethnicity- and sex-specific, continuous Z-score (http://mets.health-outcomes-policy.ufl.edu/calculator/) developed by Gurka et al. This score was constructed through confirmatory factor analyses to determine the weighted contribution of the five MetS risk factors to a latent MetS factor, with data from US adults aged 20-65 years [19]. We used the sex-specific formula for non-Hispanic-whites for both Sami and non-Sami [19].

Final study sample

Of the 6550 and 6004 individuals who participated in SAMINOR 1 and SAMINOR 2, we excluded those who did not fill in the questionnaire (SAMINOR 1 n=175/SAMINOR 2 n=21); those with missing information on all ethnicity questions (n=27/n=75); and those with missing information on MetS risk factors (systolic and diastolic BP, WC, glucose, HDL cholesterol, and triglycerides, n=40/n=42). Thus, the final analyses included 6308 and 5866 participants, respectively. Some of these participants had missing information on education (SAMINOR 1 n=419/SAMINOR 2 n=240), use of BP medication (n=105/n=221) and DM (n=351/n=138).

Statistical analyses

All analyses were stratified by sex. Sample characteristics are presented for Sami and non-Sami participants at the two surveys; continuous variables are given as mean (standard deviation) or median (interquartile range) where appropriate; categorical variables are given as numbers (percentage). In order to allow for comparison with international data, the overall prevalence for each survey was age-standardised by the direct method, using a European standard population from 2013. We compared values at the two surveys for ATP-III-MetS prevalence, MetS severity Z-score, and all five MetS risk factors (seven outcomes in total) with generalised estimating equation (GEE) regression models with an exchangeable working correlation matrix. This method gives population averaged regression coefficients while accounting for dependencies between repeated measures, as 3110 individuals participated twice (25.5% overlapping observations). The MetS severity Z-score was log-transformed in models with skewed distribution of the model residuals: In order to make all values positive, we added 2.5, and then transformed these using the natural logarithm. Mean Z-scores were transformed back for presentation in tables. First, in order to compare values at the two surveys among Sami and non-Sami participants separately, models were stratified by ethnicity and run with age and survey as covariates. We calculated the age-adjusted prevalence or mean of all seven outcomes using the 'marginal' command in STATA, holding age constant at the sex-specific mean age for both surveys together (57.49 years for women, 58.15 years for men). Second, we tested whether variations in ATP-III-MetS prevalence and MetS severity Z-score differed by ethnicity, by using

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interaction terms (ethnicity x survey) in models that were not stratified by ethnicity. The interaction term was excluded from a model if p≥0.05. All statistical tests had a two-sided significance level of 0.05.

We used STATA version 15.1 (StataCorp, College Station, Texas, USA) for all statistical analyses. Graphics were created using the 'ggplot2' package for the open-source statistical software R version 3.4.2 (The R Foundation for Statistical Computing, URL https://www.R-project.org/).

Sensitivity analyses

In order to avoid spurious conclusions, we performed a wide range of sensitivity analyses, as recommended in ethnic health research [20]. We repeated analyses with

1. alternative cut-offs for ATP-III-MetS risk factors: 1) WC ≥88 cm in women and ≥102 cm in men; 2) excluding WC, so that having ≥3 of 4 remaining risk factors qualified as ATP-III-MetS; 3) glucose ≥11.1 mmol/L; 4) triglycerides ≥2.1 mmol/L [21],
2. a "healthier" sample, excluding participants that currently used BP or DM medication (tablets or insulin), or if they reported ever having had a myocardial infarction, angina pectoris, or DM,
3. two alternative measures of ethnicity: 1) answered 'Sami' on all 11 questions, answered 'Sami' on 1-10 questions, did not answer 'Sami' on any question; 2) solely based on self-perceived ethnicity,
4. stratification by geographical regions (Inland Finnmark County, coastal Finnmark County and Troms/Nordland County),
5. adjustment for education.

RESULTS

The proportion of Sami in SAMINOR 1 and SAMINOR 2 was 36.0% and 40.9%, respectively. On average, the SAMINOR 2 participants were older than the SAMINOR 1 participants had a longer education, higher prevalence of self-reported DM, and larger WC (Table 1).

The overall, age-standardised prevalence of MetS was 31.2% (95% confidence interval [CI]: 29.8-32.6) in SAMINOR 1 and 35.6% (95% CI: 34.0-37.3) in SAMINOR 2 (data not shown).

Age-adjusted proportion of hypertension decreased modestly from SAMINOR 1 to SAMINOR 2, whereas abdominal obesity increased markedly in all four strata of sex and ethnicity (between +15.3 percentage points (pp) and +26.4 pp). The proportion with elevated triglycerides increased markedly among both Sami women (+4.2 pp) and men (+9.1 pp). Both ATP-III-MetS

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prevalence and MetS severity Z-score increased for all strata of sex and ethnicity, except for ATP-III-MetS in non-Sami women, which remained unchanged. In absolute numbers, ATP-III-MetS prevalence increased the most among Sami and non-Sami men (+8.2 pp and +7.5 pp, respectively, p<0.001 for both), whereas MetS severity Z-score increased the most among Sami women and Sami men (+0.13 and +0.21, respectively, p<0.001 for both) (Table 2).

In the models assessing whether variations in ATP-III-MetS prevalence and MetS severity Z-score between the surveys differed by ethnicity, interactions between ethnicity and survey were found for MetS severity, with Sami men having a larger increase than non-Sami men (p<0.001) (Table 3). The calculated β coefficients for survey from the model, separate for the two ethnic groups, were 0.20 (95% CI: 0.14 to 0.25) for Sami men and 0.06 (95% CI: 0.01 to 0.10) for non-Sami men (data not shown). In women, the interaction term between ethnicity and survey was also significant (p=0.024), but the effect size was quite small (Table 3).

Abdominal obesity increased across all age groups in all strata of sex and ethnicity between the surveys (Figure 1). The MetS severity Z-score increased more for Sami men than non-Sami men (Figure 2).

Overall, sensitivity analyses including alternative ethnic classifications, region, and education did not change the results (data not shown). Results for Sami women were sensitive to alterations in cut-offs for ATP-III-MetS risk factors. Excluding abdominal obesity from the ATP-III-MetS criteria left only Sami men with a minor increase in prevalence (+3.5 pp, p=0.014) (Supplementary Table 1). The interaction between ethnicity and survey for MetS severity was confirmed in the "healthier" sample (in women and men) and using alternative ethnicity classifications (only in men) (data not shown).

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Table 1. Sample characteristics stratified by sex, ethnicity and survey, given in mean (SD) or n (%). The SAMINOR 1 Survey (2003-2004, N=6308) and the SAMINOR 2 Clinical Survey (2012-2014, N=5866).

	Sami participants		non-Sami participants	
	SAMINOR 1	SAMINOR 2	SAMINOR 1	SAMINOR 2
Women	N=1150	N=1283	N=2176	N=1899
Age (years)	55.5 (10.2)	58.5 (10.4)	56.5 (10.1)	59.1 (10.7)
Education (years)	10.8 (4.7)	12.5 (4.4)	10.9 (3.8)	12.3 (4.0)
Waist circumference (cm)	86.5 (12.0)	93.6 (12.1)	85.6 (12.0)	92.9 (12.0)
Systolic BP (mmHg)	130.6 (21.6)	130.0 (19.3)	133.0 (20.1)	131.1 (18.6)
Diastolic BP (mmHg)	72.7 (10.3)	71.7 (9.2)	73.0 (10.5)	72.3 (9.0)
Triglycerides (mmol/L)[a]	1.36 (0.98)	1.4 (0.9)	1.35 (0.92)	1.4 (0.9)
Glucose (mmol/L)[a]	5.29 (1.07)	5.3 (1.1)	5.29 (1.09)	5.2 (1.0)
HDL cholesterol (mmol/L)	1.45 (0.37)	1.45 (0.41)	1.49 (0.40)	1.55 (0.45)
Self-reported diabetes mellitus	53 (4.8)	104 (8.3)	113 (5.6)	156 (8.5)
Current use of BP medication	270 (23.8)	352 (28.5)	556 (26.0)	550 (30.0)
Men	N=1118	N=1113	N=1864	N=1571
Age (years)	56.3 (10.1)	59.8 (10.3)	56.4 (9.8)	60.3 (10.2)
Education (years)	10.3 (4.1)	11.4 (3.8)	10.9 (3.7)	11.8 (3.6)
Waist circumference (cm)	92.5 (10.6)	98.6 (10.6)	93.9 (10.2)	100.2 (10.7)
Systolic BP (mmHg)	135.4 (20.0)	134.6 (18.0)	136.1 (17.6)	135.1 (17.2)
Diastolic BP (mmHg)	78.3 (10.0)	77.0 (9.9)	78.2 (10.0)	77.8 (9.4)
Triglycerides (mmol/L)[a]	1.55 (1.27)	1.7 (1.2)	1.58 (1.14)	1.5 (1.1)
Glucose (mmol/L)[a]	5.42 (1.02)	5.4 (1.1)	5.41 (1.15)	5.4 (1.1)
HDL cholesterol (mmol/L)	1.27 (0.36)	1.23 (0.38)	1.28 (0.34)	1.28 (0.38)
Self-reported diabetes mellitus	48 (4.5)	107 (9.8)	75 (4.3)	146 (9.4)
Current use of BP medication	236 (21.5)	308 (29.0)	408 (22.3)	483 (31.9)

SD = standard deviation. BP = blood pressure. HDL = High-density lipoprotein. All blood samples are non-fasting. Continuous variables are given as mean (SD) unless otherwise indicated. Categorical variables are given as n (%). For some variables, the total adds up to a lower number due to missing data. The maximum number missing (n=419) was for 'education' in SAMINOR 1.

[a]Median (interquartile range) due to substantially right skewed data.

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Table 2. Age-adjusted proportion or mean (95% CI) of five cardiometabolic risk factors, ATP-III MetS and MetS severity Z-score in Sami and non-Sami in the two surveys.

	Sami participants			Non-Sami participants		
	SAMINOR 1	SAMINOR 2		SAMINOR 1	SAMINOR 2	
Women	N=1150	N=1283	p-value[a]	N=2176	N=1899	p-value[a]
Hypertension, %	60.2 (57.0-63.4)	54.7 (51.7-57.6)	0.004	64.2 (62.0-66.3)	57.7 (55.3-60.2)	<0.001
Abdominal obesity, %	73.2 (70.6-75.9)	88.5 (86.8-90.2)	<0.001	66.7 (64.7-68.7)	87.7 (86.2-89.2)	<0.001
Elevated glucose, %	7.5 (6.0-9.0)	8.5 (6.9-10.1)	0.29	8.3 (7.2-9.3)	8.8 (7.5-10.1)	0.57
Reduced HDL cholesterol, %	35.4 (32.6-38.1)	33.6 (31.1-36.1)	0.28	32.4 (30.5-34.4)	26.3 (24.4-28.3)	<0.001
Elevated triglycerides, %	35.0 (32.2-37.8)	39.2 (36.5-41.8)	0.018	31.3 (29.4-33.2)	32.8 (30.7-35.0)	0.26
ATP-III MetS, %	35.2 (32.4-37.9)	39.2 (36.5-41.9)	0.019	33.5 (31.5-35.5)	34.0 (31.8-36.1)	0.73
MetS severity Z-score, mean	-0.01 (-0.06 to 0.03)	0.12 (0.08 to 0.17)	<0.001	-0.06 (-0.09 to -0.03)	-0.01 (-0.05 to 0.03)	0.024
Men	N=1118	N=1113		N=1864	N=1571	
Hypertension, %	69.5 (66.6-72.3)	63.4 (60.4-66.3)	0.001	72.4 (70.3-74.5)	67.7 (65.3-70.0)	0.001
Abdominal obesity, %	44.2 (41.3-47.1)	66.7 (64.0-69.4)	<0.001	46.9 (44.6-49.1)	73.3 (71.1-75.4)	<0.001
Elevated glucose, %	8.3 (6.7-9.9)	11.4 (9.4-13.3)	0.007	8.5 (7.3-9.8)	9.7 (8.2-11.2)	0.18
Reduced HDL cholesterol, %	21.1 (18.7-23.5)	22.6 (20.2-25.0)	0.33	19.6 (17.8-21.5)	19.6 (17.6-21.5)	0.97
Elevated triglycerides, %	42.5 (39.6-45.4)	51.6 (48.6-54.5)	<0.001	43.3 (40.9-45.6)	45.0 (42.5-47.5)	0.27
ATP-III MetS, %	29.9 (27.2-32.5)	38.1 (35.3-40.9)	<0.001	30.2 (28.1-32.2)	37.7 (35.3-40.0)	<0.001
MetS severity Z-score, mean	0.29 (0.24-0.34)	0.50 (0.45-0.55)	<0.001	0.31 (0.28-0.33)	0.37 (0.33-0.41)	0.036

CI = confidence interval. MetS = metabolic syndrome. HDL = high-density lipoprotein. Survey-specific proportions or means (95% CI) are age-adjusted post-estimated marginal means from generalised estimating equation (GEE) models, holding age constant at the sex-specific mean for both surveys together (57.49 years for women, 58.15 years for men). The GEE logistic or linear regression models were stratified by ethnicity and run with age and survey as covariates.

[a]P-values for survey, i.e. p-value for change in proportion or mean from SAMINOR 1 to SAMINOR 2.

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Table 3. Sex-stratified GEE models examining potential interactions between survey and ethnicity for ATP-III MetS and MetS severity Z-score.

	ATP-III MetS		MetS severity Z-score	
	OR (95% CI)	p-value	β (95% CI)	p-value
Women				
Survey				
SAMINOR 2 vs. SAMINOR 1	1.08 (0.99-1.18)	0.095	0.02 (0.01 to 0.04)	0.010
Ethnicity				
Sami vs. non-Sami	1.16 (1.03-1.30)	0.011	0.02 (-0.01 to 0.04)	0.14
Survey x ethnicity				
SAMINOR 2 x Sami	-		0.03 (0.00 to 0.05)	0.024
Age (per 10 years)	1.37 (1.30-1.45)	<0.001	0.09 (0.08 to 0.10)	<0.001
Men				
Survey				
SAMINOR 2 vs. SAMINOR 1	1.43 (1.29-1.58)	<0.001	0.06 (0.01 to 0.10)	0.021
Ethnicity				
Sami vs. non-Sami	1.00 (0.89-1.13)	0.95	-0.02 (-0.07 to 0.04)	0.62
Survey x ethnicity				
SAMINOR 2 x Sami	-		0.14 (0.07 to 0.21)	<0.001
Age (per 10 years)	1.06 (1.00-1.12)	0.034	-0.04 (-0.06 to -0.02)	0.001

GEE = generalised estimating equation. MetS = metabolic syndrome. CI = confidence interval. OR = odds ratio. We tested whether the change in ATP-III MetS and MetS severity Z-score differed by ethnicity, by using interaction terms (ethnicity x survey) in GEE logistic or linear models that included age, survey and ethnicity as covariates. Analyses were not stratified by ethnicity. The interaction term was excluded from a model if $p \geq 0.05$. When interpreting the coefficients for survey and ethnicity in the models for MetS severity Z-score, one should be aware that these must be interpreted together with the interaction term.

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DISCUSSION

From 2003-2004 to 2012-2014, we observed an increase in both the prevalence (based on ATP-III criteria) and severity of MetS in rural Northern Norway. The increases in prevalence were largest in men and were confirmed by sensitivity analyses. Non-Sami women had stable measures of MetS prevalence, but a small increase in MetS severity. Sami of both sexes had a slightly larger increase in MetS severity than non-Sami; this finding was most pronounced and most robust in men. Abdominal obesity increased markedly in all strata of sex and ethnicity.

Strengths and limitations

The relatively large sample size (N=6308 and N=5866) is a strength of our study, and we had an acceptable attendance rate (54.8% and 47.1%). In general, non-attendance was high among men aged 40-49 years. We could not evaluate ethnicity-specific non-attendance rates, as national registers do not record ethnicity. Due to design issues and varying response rates across municipalities, the SAMINOR 1 sample includes a lower proportion of people from Sami majority areas in Finnmark County and a higher proportion from Northern Troms County as compared to the SAMINOR 2 sample. These different geographic and ethnic compositions challenge our ability to compare the samples, nor can we generalise the results of this study to the entire Sami population. Analyses of participants excluded due to missing data (N=242 in SAMINOR 1, N=138 in SAMINOR 2) revealed that they were older, had lower education, and had a slightly worse cardiometabolic profile; we could not determine if this varied by ethnic belonging. However, the internal validity of this study is high. We performed a wide range of sensitivity analyses with alterations in cut-offs for MetS risk factors, restricted samples, and ethnic classification. We assumed that the prevalence and severity of MetS could be defined in the same way in Sami and non-Sami, thus our results would be invalid if these assumptions were revealed to be incorrect. Despite the limitations, we believe that we have added novel information on cardiometabolic health by utilising a MetS severity Z-score.

Comparison with other studies

The overall ATP-III-MetS prevalences we report in this study from rural Northern Norway were much higher than that reported in the 6th survey of the Tromsø Study (2007-2008, 22.6%), which sampled from an urban area in Northern Norway [22]. Thus, regional differences in MetS may be larger than ethnic differences in MetS in rural areas. Consequently, public health efforts to reduce the burden of MetS risk factors should focus more on region than on ethnicity. The ATP-III-MetS prevalences we found were also higher than those reported in other Arctic populations,

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such as the Greenland Inuit [23], the Yup'ik Eskimo [24], and indigenous Nenets women in Russia [25]. However, valid comparisons of MetS prevalences are challenging due to differences in study years, age distributions, MetS criteria, and fasting vs. non-fasting blood samples. Decreases in hypertension and increases in abdominal obesity have been reported both nationally and internationally [26–28]. Abdominal obesity, which appeared to be the driving force behind the increased ATP-III-MetS prevalences in our study, was present in nearly 90% of women and in more than two-thirds of men in 2012-2014. The cut-offs for waist circumference that we used are quite strict, such that we found a large proportion with abdominal obesity with only one or no additional MetS risk factors. General obesity (body mass index >30), without MetS, is known as metabolically healthy obesity, and has been reported to confer significant risk of cardiovascular disease and T2DM in long-term follow-up studies [29,30]. As research has indicated that metabolically healthy obesity is an unstable condition [31], efforts should be made to prevent weight gain and promote weight loss in all obese individuals, regardless of MetS presence.

Possible implications of ethnic differences

The ethnic differences in the change of MetS severity from 2003-2004 to 2012-2014, were more robust in men than in women. Additionally, the effect sizes for women were small. The MetS severity increased by 0.20 (95% CI: 0.14 to 0.25) for Sami men and 0.06 (95% CI: 0.01 to 0.10) for non-Sami men, which is a modest difference. However, in a longitudinal study it was shown that, irrespective of baseline MetS severity Z-scores, individuals with a change of ≥0.5 in this score had an increased risk of T2DM compared to those with a change of ≤0 [32]. Moreover, in a cohort study that followed nearly 300,000 individuals for 25 years, subtle elevations in metabolic risk factors (waist obesity, glucose, and triglycerides) were observed decades before T2DM onset [33]. Thus, even minor differences may be indicative of future differences in DM. Interestingly, in 1974-1975, Sami in Finnmark County had a reduced risk of T2DM compared with non-Sami [13]. But, in 2012-2014, a study from Northern Norway, including parts of Finnmark, Troms, and Nordland counties, reported that Sami had a higher prevalence of self-reported T2DM than non-Sami; this was evident in both sexes [15]. Conversely, no ethnic differences in the 10-year risk of non-fatal cardiovascular disease or self-reported myocardial infarction was found in rural Northern Norway [11,34]. In fact, both ATP-III-MetS and MetS severity Z-score have stronger associations with T2DM than with coronary heart disease [2,3,8,32]. The MetS severity Z-score has the highest factor loadings for HDL cholesterol and triglycerides [19], which probably explains why this score increased more among Sami, as there was ethnic heterogeneity in the distribution of these two MetS risk factors. In sum, available

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research may indicate a more detrimental metabolic development associated with T2DM in Sami than non-Sami men.

Possible explanations for ethnic differences

Ethnicity is comprised of an interplay of lifestyle, geography, culture, and possibly genes and epigenetics. It is likely that lifestyle factors such as diet and physical activity – which are strongly associated with MetS development [35] – mediate, at least to some degree, the association between ethnicity and MetS. There are some studies on differences in physical activity and dietary habits in Sami and non-Sami [36–38], but they are both insufficient (i.e. no information on total level of physical activity) and cross-sectional. Unfortunately, we were not able to include such variables in our analyses. A complex facet of ethnicity is represented by potential differences in body composition [6]; thus, if such difference exists between Sami and non-Sami, it could have led us to misclassify some participants as obese. For instance, the Greenland Inuit have a more favourable cardiometabolic profile and lower amounts of visceral adipose tissue at the same level of obesity as Danes [39,40]. On average, Sami have a shorter stature than non-Sami, and when adjusting for waist-to-height-ratio, the differences in T2DM between Sami and non-Sami in SAMINOR 2 were eliminated [15]. Additionally, we emphasise that there is heterogeneity in all aspects comprising ethnicity within the Sami population, just as there are heterogeneity between the Sami and the non-Sami. Our results suggests that further research on the ethnic differences in adiposity-related MetS risk profile in rural Northern Norway is warranted.

CONCLUSION

We found a high burden of MetS in rural Northern Norway. From 2003-2004 to 2012-2014, both the prevalence and severity of MetS increased in the ten selected municipalities. The largest increases in prevalence were observed in Sami and non-Sami men. In Sami men, the increase in MetS severity was slightly larger in than in non-Sami. Abdominal obesity appeared to be the driving force behind the increase in ATP-III-MetS and should be a public health target regardless of ethnicity or MetS presence.

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COMPETING INTERESTS

The authors declare no competing interests.

DATA SHARING

The data that support the findings of this study are available from the SAMINOR Study (www.saminor.no), but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available upon reasonable request to the SAMINOR Project Board and with permission of the Regional Committee for Medical and Health Research Ethics.

CONTRIBUTORS

The idea behind the study was conceived by ARB. VLM performed all the data analyses, produced the tables and the figures, and drafted the manuscript. SS and MM guided and assisted in the data analyses and the interpretation of the results. KK, JS and ARB were involved in the design of the study, the preparation for the data analyses and the interpretation of the results. All authors were involved in revision of the manuscript and approved the final version.

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FIGURE LEGENDS

Figure 1. Proportion with values above the cut-off for each cardiometabolic risk factor comprising metabolic syndrome (A-J), per 10-year age group, with vertical error bars (95% confidence interval). P-values for survey are age-adjusted and were obtained with generalised estimating equation (GEE) logistic regression. Models were stratified by sex and ethnic group. A and B: Hypertension defined as systolic blood pressure ≥130 mmHg, diastolic blood pressure ≥85 mmHg or current use of blood pressure medication. C and D: Abdominal obesity defined as waist circumference ≥80 cm in women and ≥94 cm in men. E and F: Elevated glucose defined as glucose ≥7.8 mmol/L or self-reported diabetes mellitus. G and H: Reduced HDL cholesterol defined as HDL cholesterol <1.3 mmol/L in women and <1.0 mmol/L in men. I and J: Elevated triglycerides defined as triglycerides ≥1.7 mmol/L.

Figure 2. MetS = metabolic syndrome. ATP-III = Adult Treatment Panel III. P-values for survey are age-adjusted and were obtained with generalised estimating equation (GEE) logistic or linear regression. Models were stratified by sex and ethnic group. A and B: Prevalence of MetS defined by the harmonised ATP-III criteria, per 10-year age group with vertical error bars (95% confidence interval). C and D: Mean of MetS severity Z-score as a function of age with 95% confidence interval bands shaded in grey.

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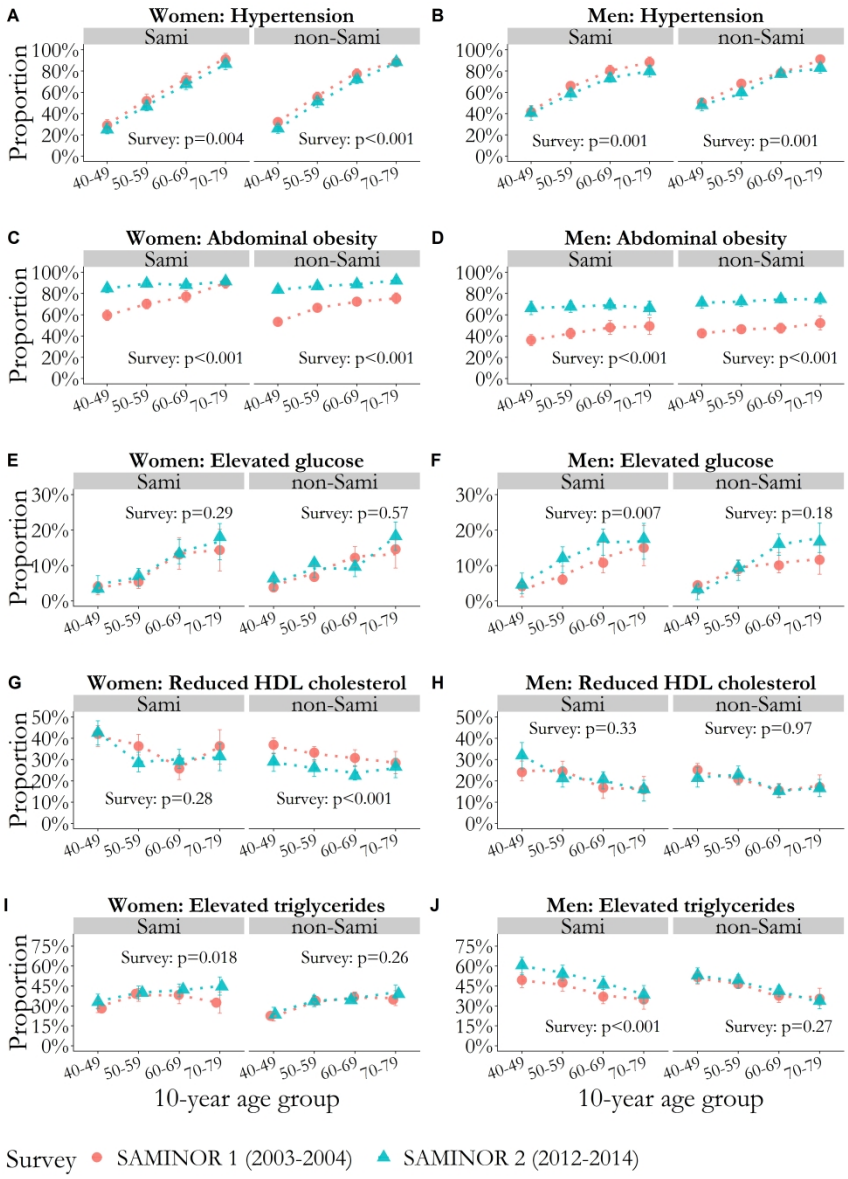

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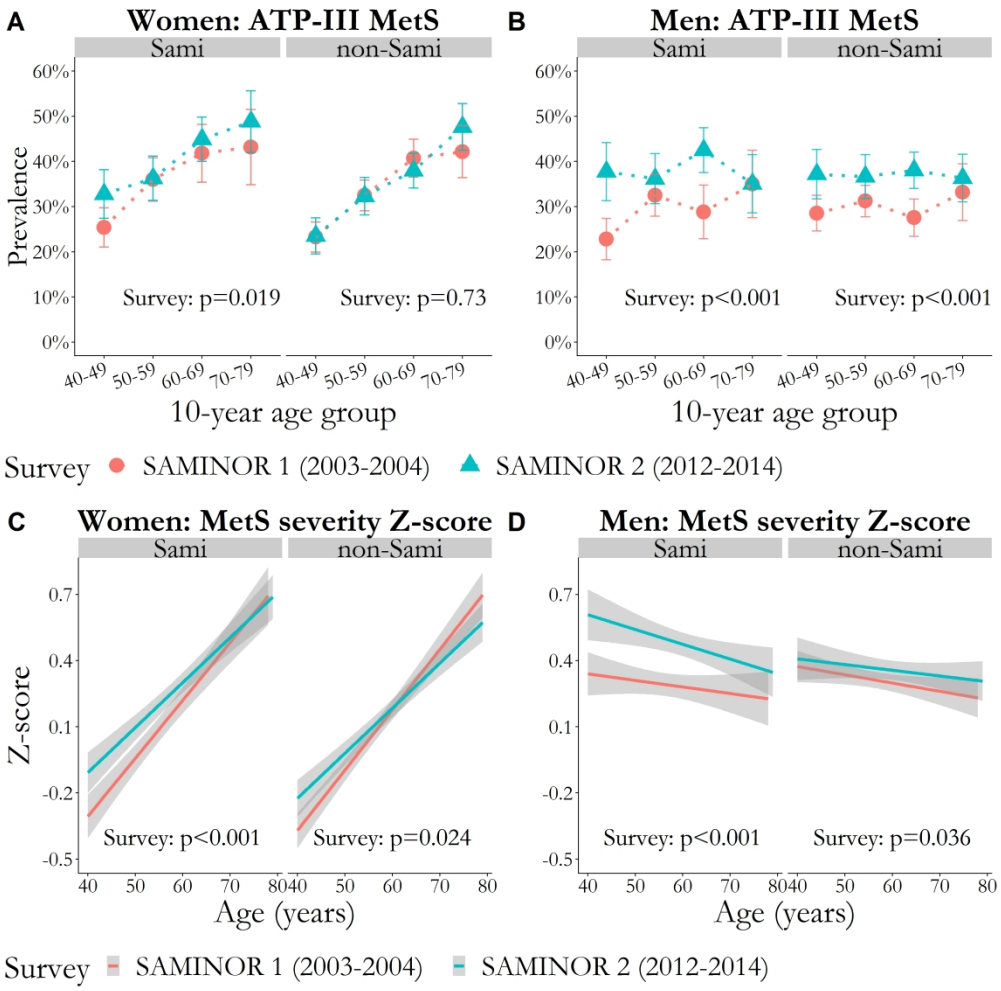

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Supplementary Table 1. Sensitivity analyses of the age-adjusted prevalence of ATP-III MetS and mean of MetS Z-score in Sami and non-Sami in the two surveys, with altered MetS definitions and restricted samples, including an examination of potential interactions between survey and ethnicity using GEE models.

	Sami participants			non-Sami participants			
	SAMINOR 1	SAMINOR 2	p-value[a]	SAMINOR 1	SAMINOR 2	p-value[a]	p-value for interaction (survey x ethnicity)[b]
Women							
ATP-III MetS: Waist ≥88 cm, %	28.9 (26.3-31.5)	35.3 (32.7-37.9)	<0.001	27.3 (25.5-29.2)	30.2 (28.1-32.2)	0.022	0.12
ATP-III MetS: Excluded waist criteria, %	16.6 (14.4-18.7)	16.3 (14.2-18.3)	0.82	14.2 (12.8-15.7)	13.5 (11.9-15.0)	0.42	0.91
ATP-III MetS: Glucose ≥11.1 mmol/L, %	34.6 (31.9-37.4)	38.7 (36.0-41.4)	0.018	32.6 (30.6-34.5)	33.4 (31.2-35.5)	0.54	0.22
ATP-III MetS: Triglycerides ≥2.1 mmol/L, %	29.2 (26.6-31.8)	31.2 (28.7-33.8)	0.20	27.4 (25.5-29.3)	26.9 (24.9-28.9)	0.67	0.32
ATP-III MetS: "Healthier" sample, %	20.4 (17.4-23.4)	28.9 (25.9-31.9)	<0.001	21.0 (18.8-23.2)	23.3 (20.9-25.6)	0.13	0.03
MetS Z-score: "Healthier" sample, mean	-0.15 (-0.21 to -0.11)	0.06 (0.01 to 0.11)	<0.001	-0.20 (-0.24 to -0.17)	-0.07 (-0.11 to -0.03)	<0.001	0.025
Men							
ATP-III MetS: Waist ≥102 cm, %	21.8 (19.4-24.2)	29.6 (26.9-32.3)	<0.001	21.7 (19.8-23.5)	28.8 (26.5-31.0)	<0.001	0.62
ATP-III MetS: Excluded waist criteria, %	14.4 (12.4-16.5)	17.9 (15.7-20.2)	0.014	13.5 (11.9-15.0)	15.6 (13.8-17.4)	0.057	0.47
ATP-III MetS: Glucose ≥11.1 mmol/L, %	28.3 (25.6-30.9)	37.4 (34.6-40.2)	<0.001	29.3 (27.2-31.4)	37.2 (34.9-39.6)	<0.001	0.47
ATP-III MetS: Triglycerides ≥2.1 mmol/L, %	23.7 (21.2-26.1)	31.3 (28.4-33.8)	<0.001	23.5 (21.6-25.4)	30.2 (28.0-32.5)	<0.001	0.74
ATP-III MetS: "Healthier" sample, %	20.0 (17.0-23.0)	27.8 (24.6-31.1)	<0.001	23.0 (20.6-25.4)	29.0 (27.0-32.8)	<0.001	0.53
MetS Z-score: "Healthier" sample, mean	0.10 (0.04 to 0.16)	0.36 (0.30 to 0.41)	<0.001	0.17 (0.12 to 0.21)	0.24 (0.19 to 0.29)	0.017	<0.001

GEE = generalised estimating equation. CI = confidence interval. MetS = metabolic syndrome. HDL = high-density lipoprotein. A "healthier" sample was constructed by excluding participants if they currently used blood pressure medication or diabetes medication or if they reported ever having had a myocardial infarction, angina pectoris or diabetes mellitus. Survey-specific proportions or means (95% CI) are age-adjusted post-estimated marginal means from GEE models, holding age constant at the sex-specific mean for the entire sample (i.e. both surveys).

[a]P-values for survey, i.e. p-value for change in proportion or mean from SAMINOR 1 to SAMINOR 2. The GEE logistic or linear regression models were stratified by ethnicity and run with age and survey as covariates.

[b]P-values for the interaction term (survey x ethnicity) in GEE models not stratified by ethnicity. P<0.05 indicates that the change in outcome over time differs by ethnic group.

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STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4-5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4-5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5-6
Bias	9	Describe any efforts to address potential sources of bias	7
Study size	10	Explain how the study size was arrived at	6-7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7
		(*b*) Describe any methods used to examine subgroups and interactions	7
		(*c*) Explain how missing data were addressed	7
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	-
		(*e*) Describe any sensitivity analyses	7-8
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5-7
		(b) Give reasons for non-participation at each stage	6
		(c) Consider use of a flow diagram	-
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8 Table 1
		(b) Indicate number of participants with missing data for each variable of interest	7
Outcome data	15*	Report numbers of outcome events or summary measures	Table 2
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 2 Table 3

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		(*b*) Report category boundaries when continuous variables were categorized	6
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	8
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9/Supp. Table 1
Discussion			
Key results	18	Summarise key results with reference to study objectives	13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-14
Generalisability	21	Discuss the generalisability (external validity) of the study results	15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Change in prevalence and severity of metabolic syndrome in the Sami and non-Sami population in rural Northern Norway using a repeated cross-sectional population-based study design—the SAMINOR Study

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Change in prevalence and severity of metabolic syndrome in the Sami and non-Sami population in rural Northern Norway using a repeated cross-sectional population-based study design—the SAMINOR Study

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Abstract: Change in prevalence and severity of metabolic syndrome in the Sami and non-Sami population in rural Northern Norway using a repeated cross-sectional population-based study design—the SAMINOR Study

Objective: We examined the change in both prevalence and severity of metabolic syndrome (MetS) in the Sami and non-Sami in Northern Norway due to a lack of knowledge regarding the development of MetS in this population.

Design: Repeated cross-sectional study.

Setting: The study is based on data from the SAMINOR 1 Survey (2003–2004, N=6550) and the SAMINOR 2 Clinical Survey (2012–2014, N=6004), conducted in 10 municipalities in Northern Norway.

Participants: Men and women aged 40–79 years were invited. We excluded participants not handing in the questionnaire and with missing information concerning ethnicity-questions or MetS risk factors resulting in a final sample of 6308 (36.0% Sami) and 5866 (40.9% Sami) subjects, respectively.

Outcome measures: MetS prevalence was determined using the harmonised Adult Treatment Panel III (ATP-III) criteria, and severity was assessed with the MetS severity Z-score. Generalised estimating equations with an interaction term (survey x ethnicity) were used to compare prevalence and severity between the two surveys, while accounting for partly repeated measurements.

Results: The overall, age-standardised ATP-III-MetS prevalence was 31.2% (95% confidence interval [CI]: 29.8, 32.6) in SAMINOR 1 and 35.6% (95% CI: 34.0, 37.3) in SAMINOR 2. Both the ATP-III-MetS prevalence and the mean MetS severity Z-score increased between the surveys in all subgroups, except the ATP-III-MetS prevalence in non-Sami women, which remained stable. Over time, Sami men showed a slightly larger increase in MetS severity than non-Sami men ($p<0.001$): the score increased by 0.20 (95% CI: 0.14, 0.25) and 0.06 (95% CI: 0.01, 0.10) in Sami and non-Sami men, respectively. Abdominal obesity increased markedly between the surveys in all subgroups.

Conclusion: The prevalence and severity of MetS increased over time in rural Northern Norway. Abdominal obesity appeared to drive the increase in ATP-III-MetS prevalence. Sami men had a slightly larger increase in severity than non-Sami.

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ARTICLE SUMMARY

Strengths and limitations

- This study included data from two cross-sectional surveys with acceptable attendance rates and relatively high proportions with Sami ethnicity
- The change in metabolic syndrome over time was examined using generalised estimating equations, thus accounting for repeated measures and obtaining population averaged regression coefficients
- We were able to detect ethnic differences in metabolic syndrome risk with a continuous severity score that were not detectable with the dichotomous definition of metabolic syndrome
- A wide range of sensitivity analyses with respect to the diagnostic criteria and ethnic classification were conducted to ensure the internal validity of the study
- The results cannot be generalised to the entire Sami and non-Sami population, and we were not able to include potential confounders such as physical activity and diet

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INTRODUCTION

The co-occurrence of hypertension, abdominal obesity, impaired fasting glucose, low high-density lipoprotein (HDL) cholesterol, and increased triglycerides is known as metabolic syndrome (MetS).[1] MetS is viewed as a state of excess adiposity and insulin resistance [1] that increases the risk of cardiovascular disease [2] and type 2 diabetes mellitus (T2DM).[3] The worldwide prevalence of obesity has doubled since 1980;[4] however, excess visceral adiposity is associated with cardiometabolic abnormalities in both obese and non-obese individuals.[5] Ethnic differences in body composition related to cardiometabolic abnormalities further complicate this relationship.[6] The dichotomous definition of MetS has been criticised for being a crude marker of risk that more likely operates on a continuous scale, and for the lack of consensus regarding the ethnic-specific cut-offs for abdominal obesity.[7] Recently, Gurka et al. constructed a sex- and ethnicity-specific continuous MetS severity Z-score [8] that predicts coronary heart disease [9] and T2DM,[10] independent of the individual MetS risk factors.

Northern Norway is inhabited by Norwegians, Sami, and Kven. The Sami is an ethnic minority living in Sápmi, a settlement area covering northern parts of Norway, Sweden, Finland, and Russia, and is regarded as an indigenous people in Norway. The Sami culture has traditionally centred around reindeer herding, farming, fishing and hunting, but nowadays few are left in these occupations. Internationally, indigenous and minority groups have elevated prevalences of chronic lifestyle diseases compared with majority populations,[11] but little to no differences in the prevalences of cardiovascular disease and MetS (using the International Diabetes Federation definition) have been found in Sami and non-Sami in Norway.[12–14] However, recent data have shown unfavourable prevalences of obesity (women) and T2DM (women and men) among Sami when compared with non-Sami.[15,16]

We used the most up-to-date consensus definition of MetS, which is the harmonised Adult Treatment Panel-III (ATP-III) criteria,[17] in addition to the MetS severity Z-score,[8] to examine the prevalence and severity of MetS in Sami and non-Sami at two points in time, and to examine whether variations in MetS prevalence and severity differed by ethnicity.

METHODS

We used data from two cross-sectional surveys of the Population-based Study on Health and Living Conditions in Regions with Sami and Norwegian Populations—The SAMINOR Study, which is run by the Centre for Sami Health Research (CSHR) at UiT The Arctic University of Norway. The first survey (SAMINOR 1) was carried out in collaboration with the National

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Institute of Public Health during 2003–2004 in 24 municipalities in Northern and Central Norway.[18] The SAMINOR 2 Clinical Survey (SAMINOR 2) was carried out during 2012–2014 in 10 of the municipalities included in SAMINOR 1.[19] The present analyses are restricted to these 10 municipalities.

In both surveys, all inhabitants from these 10 municipalities who: 1) were registered in the National Registry and 2) aged 40–79 years were invited to participate. Of all the inhabitants invited in SAMINOR 1 (N=11,518) and SAMINOR 2 (N=12,455), 6550 (56.9%) and 6004 (48.0%) individuals, respectively, attended the clinical examination and signed an informed consent (3872 participated in both surveys). The SAMINOR Project Board and The Regional Committee for Medical and Health Research Ethics approved this study.

Patient and public involvement

During the planning of the SAMINOR Study, CSHR consulted with the Sami Parliament. In addition, researchers/health workers who are either Sami or work in Sami core areas were consulted in order to meet the needs of the Sami community. In the case of abnormal findings during examination, participants were encouraged to visit their primary physician. We intend to report the results of this study to decision makers, regional health establishments and authorities. An important aim of CSHR has always been to give the knowledge back to the participants of the study, often through popular science forums, meetings and lectures.

Self-administered questionnaire

In both surveys, information on duration of education (years), use of blood pressure (BP) medication (currently/previously, but not now/never), diabetes mellitus (DM, yes/no), alcohol consumption, physical activity, and diet was taken from a self-administered questionnaire. The questions on DM were not identical (SAMINOR 1: *Do you have or have you had diabetes?* SAMINOR 2: *Have you ever been diagnosed with diabetes (elevated blood sugar levels)?*). We did not include information on self-reported alcohol consumption, physical activity, or diet in the analyses, as these questions were not similar enough for comparison.

Information on ethnic background cannot be recorded in Norwegian registries or medical records, but it can be solicited for research purposes. Three main aspects of ethnicity—language, ethnic background, and self-perceived ethnicity—were explored in the questionnaire through a total of 11 questions: *What language do/did you/your mother/your father/[all 4 of] your grandparents speak at home?*; *What is your/your father's/your mother's ethnic background?; What [ethnicity] do you regard yourself as?* Response options were: Norwegian, Sami, Kven, or other, and participants could

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choose more than one answer. In order to be categorised as Sami, participants had to respond that 1) their own ethnic background or self-perceived ethnicity was Sami, and 2) the home language for at least one of their grandparents, parents, or themselves was Sami. All participants who did not meet these criteria were categorised as non-Sami.

Clinical examination

Trained personnel performed all clinical measurements and blood sampling using similar procedures in both surveys. BP was taken with a Dinamap-R automatic device (Criticon, Tampa, Florida, USA) in SAMINOR 1 and a CARESCAPE™ V100 monitor (GE Healthcare, Milwaukee, Wisconsin, USA) in SAMINOR 2, following at least 2 minutes of seated rest, with participants' arms resting on a table. Three BP measurements were recorded at 1-minute intervals; the average of the second and third measurements was used in the analyses. Waist circumference (WC) was recorded to the nearest centimetre at the umbilicus, with the participant standing and breathing normally. Non-fasting blood samples were drawn by venipuncture, with participants in a seated position. In SAMINOR 1, serum was sent by mail and analysed consecutively at the Ullevål University Hospital, Oslo. In SAMINOR 2, serum was frozen on site at -20 °C and sent to the biobank in Tromsø, where it was stored at -70 °C and later analysed at the University Hospital of North Norway, Tromsø. Lipids and glucose were measured by an enzymatic method (Hitachi 917 autoanalyzer, Roche Diagnostic, Switzerland) in SAMINOR 1, and with a homogeneous enzymatic colorimetric method (Roche/Hitachi Cobas 8000B system, Roche Diagnostics GmbH, Mannheim, Germany) in SAMINOR 2.

Criteria for metabolic syndrome

MetS was defined using the harmonised ATP-III criteria, which state that a combination of any three of the following five risk factors qualifies for a diagnosis of MetS:[17]

1. Hypertension: systolic BP ≥130 mmHg, diastolic BP ≥85 mmHg, or current use of BP medication.
2. Abdominal obesity: WC ≥80 cm in women and ≥94 cm in men, as recommended for a European population [5].
3. Elevated non-fasting serum glucose ≥7.8 mmol/L. We chose this cut-off as it is a proxy for prediabetes defined with an oral glucose tolerance test [20]. Participants with self-reported DM were also considered to have elevated glucose.
4. Reduced non-fasting serum HDL cholesterol: <1.3 mmol/L in women and <1.0 mmol/L in men.
5. Elevated non-fasting serum triglycerides ≥1.7 mmol/L.

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Common approaches when estimating the severity of MetS include to simply count the number of risk factors (0-5) with levels above the cut-offs, or to sum up Z-scores of the five risk factors. However, these methods do not take into account the need for different weighting of risk factors in discrete ethnic groups and the two sexes. Nor have these methods been validated regarding future disease occurrence. Therefore, we chose to estimate the severity of MetS based on an ethnicity- and sex-specific, continuous Z-score (https://metscalc.org/) developed by Gurka et al. in 2014. This score was constructed through confirmatory factor analyses to determine the weighted contribution of the five MetS risk factors to a latent MetS factor, with data from the NHANES survey on US adults aged 20–65 years.[8] The score correlates with high levels of high sensitivity C-reactive protein, uric acid, and insulin resistance,[8] and predicts coronary heart disease [9] and T2DM [10] independent of its individual components. It operates like a Z-score, with mean 0 and standard deviation 1, meaning that a score above/below 0 indicates a higher/lower severity of MetS than the average US adult aged 20–65 years. The score has been useful when applied in populations outside the US as well.[21–23] No cut-offs are available for the score, but this is less important in our study as our intention was to compare figures in the two ethnic groups. We used the sex-specific formula for non-Hispanic-whites for both Sami and non-Sami,[8] assuming similar weighting of risk factors.

Final study sample

Of the 6550 and 6004 individuals who participated in SAMINOR 1 and SAMINOR 2, we excluded those who did not fill in the questionnaire (SAMINOR 1 n=175/SAMINOR 2 n=21); those with missing information on all ethnicity questions (n=27/n=75); and those with missing information on one or several MetS risk factors (systolic and diastolic BP, WC, glucose, HDL cholesterol, and triglycerides, n=40/n=42). Thus, the final analyses included 6308 and 5866 participants, respectively. Some of these participants had missing information on education (SAMINOR 1 n=419/SAMINOR 2 n=240), use of BP medication (n=105/n=221) and DM (n=351/n=138).

Statistical analyses

All analyses were stratified by sex. Sample characteristics are presented for Sami and non-Sami participants in the two surveys; continuous variables are given as mean (standard deviation) or median (interquartile range) where appropriate; categorical variables are given as numbers (percentage). In order to allow for comparison with international data, the overall prevalence for each survey was age-standardised by the direct method, using a European standard population

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from 2013. We compared values in the two surveys for ATP-III-MetS prevalence, MetS severity Z-score, and all five MetS risk factors (seven outcomes in total) with generalised estimating equation (GEE) regression models with an exchangeable working correlation matrix.[24] This method gives population averaged regression coefficients while accounting for dependencies between repeated measures, as 3110 individuals participated twice (25.5% overlapping observations). The MetS severity Z-score was log-transformed in models with skewed distribution of the model residuals: In order to make all values positive, we added 2.5, and then transformed these using the natural logarithm. Mean Z-scores were transformed back for presentation in tables. First, in order to compare values in the two surveys among Sami and non-Sami participants separately, models were stratified by ethnicity and run with age and survey as covariates. We calculated the age-adjusted prevalence or mean of all seven outcomes using the 'marginal' command in STATA, holding age constant at the sex-specific mean age in both surveys together (57.49 years for women, 58.15 years for men). Second, we tested whether variations in ATP-III-MetS prevalence and MetS severity Z-score differed by ethnicity, by using interaction terms (ethnicity x survey) in models that were not stratified by ethnicity. The interaction term was excluded from a model if $p \geq 0.05$. All statistical tests had a two-sided significance level of 0.05.

Sensitivity analyses

In order to avoid spurious conclusions, we performed a wide range of sensitivity analyses, as recommended in ethnic health research.[25] We repeated the analyses with

1. alternative cut-offs for ATP-III-MetS risk factors: 1) WC ≥88 cm in women and ≥102 cm in men; 2) excluding WC, so that having ≥3 of 4 remaining risk factors qualified as ATP-III-MetS; 3) glucose ≥11.1 mmol/L; 4) triglycerides ≥2.1 mmol/L,[26]
2. a "healthier" sample, excluding participants that currently used BP or DM medication (tablets or insulin), or if they reported ever having had a myocardial infarction, angina pectoris, or DM,
3. two alternative measures of ethnicity: 1) answered 'Sami' on all 11 questions, answered 'Sami' on 1-10 questions, did not answer 'Sami' on any question; 2) solely based on self-perceived ethnicity,
4. stratification by geographical regions (Inland Finnmark County, coastal Finnmark County and Troms/Nordland County),
5. adjustment for education.

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We used STATA version 15.1 (StataCorp, College Station, Texas, USA) for all statistical analyses. Graphics were created using the 'ggplot2' package for the open-source statistical software R version 3.4.2 (The R Foundation for Statistical Computing, URL https://www.R-project.org/).

RESULTS

The proportion of Sami in SAMINOR 1 and SAMINOR 2 was 36.0% and 40.9%, respectively. On average, the SAMINOR 2 participants were older than the SAMINOR 1 participants, had a longer education, higher prevalence of self-reported DM, and larger WC (Table 1).

The overall, age-standardised prevalence of MetS was 31.2% (95% confidence interval [CI]: 29.8, 32.6) in SAMINOR 1 and 35.6% (95% CI: 34.0, 37.3) in SAMINOR 2 (data not shown).

The age-adjusted proportion of hypertension decreased modestly from SAMINOR 1 to SAMINOR 2, whereas the proportion of abdominal obesity increased markedly in all four strata of sex and ethnicity (between +15.3 percentage points (pp) and +26.4 pp). The proportion with elevated triglycerides increased markedly among both Sami women (+4.2 pp) and men (+9.1 pp). Both ATP-III-MetS prevalence and MetS severity Z-score increased in all strata of sex and ethnicity, except for ATP-III-MetS in non-Sami women, which remained unchanged. In absolute numbers, ATP-III-MetS prevalence increased the most among Sami and non-Sami men (+8.2 pp and +7.5 pp, respectively, $p<0.001$ for both), whereas MetS severity Z-score increased the most among Sami women and Sami men (+0.13 and +0.21, respectively, $p<0.001$ for both) (Table 2).

In the models assessing whether variations in ATP-III-MetS prevalence and MetS severity Z-score between the surveys differed by ethnicity, interactions between ethnicity and survey were found for MetS severity, with Sami men having a larger increase than non-Sami men ($p<0.001$) (Table 3). From the first to the second survey, the score increased by 0.20 (95% CI: 0.14, 0.25) in Sami men and 0.06 (95% CI: 0.01, 0.10) in non-Sami men (data not shown). In women, the interaction term between ethnicity and survey was also significant ($p=0.024$), but the difference in effect size was negligible (Table 3).

Abdominal obesity increased across all age groups in all strata of sex and ethnicity between the surveys (Figure 1). The MetS severity Z-score increased more in Sami men than in non-Sami men (Figure 2).

Overall, sensitivity analyses including alternative ethnic classifications, region, and education, did not change the conclusions (data not shown). Results in Sami women were sensitive to alterations in cut-offs for ATP-III-MetS risk factors. Excluding abdominal obesity from the ATP-III-MetS criteria left only Sami men with a minor increase in prevalence (+3.5 pp, $p=0.014$)

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(Supplementary Table 1). The interaction between ethnicity and survey for MetS severity was confirmed in the "healthier" sample (in women and men) and using alternative ethnicity classifications (only in men) (data not shown).

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Table 1. Sample characteristics stratified by sex, ethnicity and survey, given in mean (SD) or n (%). The SAMINOR 1 Survey (2003–2004, N=6308) and the SAMINOR 2 Clinical Survey (2012–2014, N=5866).

	Sami participants		non-Sami participants	
	SAMINOR 1	SAMINOR 2	SAMINOR 1	SAMINOR 2
Women	N=1150	N=1283	N=2176	N=1899
Age (years)	55.5 (10.2)	58.5 (10.4)	56.5 (10.1)	59.1 (10.7)
Education (years)	10.8 (4.7)	12.5 (4.4)	10.9 (3.8)	12.3 (4.0)
Waist circumference (cm)	86.5 (12.0)	93.6 (12.1)	85.6 (12.0)	92.9 (12.0)
Systolic BP (mmHg)	130.6 (21.6)	130.0 (19.3)	133.0 (20.1)	131.1 (18.6)
Diastolic BP (mmHg)	72.7 (10.3)	71.7 (9.2)	73.0 (10.5)	72.3 (9.0)
Triglycerides (mmol/L)[a]	1.36 (0.98)	1.40 (0.90)	1.35 (0.92)	1.40 (0.90)
Glucose (mmol/L)[a]	5.29 (1.07)	5.30 (1.10)	5.29 (1.09)	5.20 (1.00)
HDL cholesterol (mmol/L)	1.45 (0.37)	1.45 (0.41)	1.49 (0.40)	1.55 (0.45)
Self-reported diabetes mellitus	53 (4.8)	104 (8.3)	113 (5.6)	156 (8.5)
Current use of BP medication	270 (23.8)	352 (28.5)	556 (26.0)	550 (30.0)
Men	N=1118	N=1113	N=1864	N=1571
Age (years)	56.3 (10.1)	59.8 (10.3)	56.4 (9.8)	60.3 (10.2)
Education (years)	10.3 (4.1)	11.4 (3.8)	10.9 (3.7)	11.8 (3.6)
Waist circumference (cm)	92.5 (10.6)	98.6 (10.6)	93.9 (10.2)	100.2 (10.7)
Systolic BP (mmHg)	135.4 (20.0)	134.6 (18.0)	136.1 (17.6)	135.1 (17.2)
Diastolic BP (mmHg)	78.3 (10.0)	77.0 (9.9)	78.2 (10.0)	77.8 (9.4)
Triglycerides (mmol/L)[a]	1.55 (1.27)	1.70 (1.20)	1.58 (1.14)	1.50 (1.10)
Glucose (mmol/L)[a]	5.42 (1.02)	5.40 (1.10)	5.41 (1.15)	5.40 (1.10)
HDL cholesterol (mmol/L)	1.27 (0.36)	1.23 (0.38)	1.28 (0.34)	1.28 (0.38)
Self-reported diabetes mellitus	48 (4.5)	107 (9.8)	75 (4.3)	146 (9.4)

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Current use of BP medication	236 (21.5)	308 (29.0)	408 (22.3)	483 (31.9)

SD=standard deviation. BP=blood pressure. HDL=High-density lipoprotein. All blood samples are non-fasting. Continuous variables are given as mean (SD) unless otherwise indicated. Categorical variables are given as n (%). For some variables, the total adds up to a lower number due to missing data. The maximum number missing (n=419) was for 'education' in SAMINOR 1.

[a]Median (interquartile range) due to right skewed data.

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Table 2. Age-adjusted proportion or mean (95% CI) of five MetS risk factors, ATP-III MetS and MetS severity Z-score in Sami and non-Sami in the SAMINOR 1 Survey (2003–2004, N=6308) and the SAMINOR 2 Clinical Survey (2012–2014, N=5866).

	Sami participants			Non-Sami participants		
	SAMINOR 1	SAMINOR 2		SAMINOR 1	SAMINOR 2	
Women	N=1150	N=1283	p-value[a]	N=2176	N=1899	p-value[a]
Hypertension, %	60.2 (57.0, 63.4)	54.7 (51.7, 57.6)	0.004	64.2 (62.0, 66.3)	57.7 (55.3, 60.2)	<0.001
Abdominal obesity, %	73.2 (70.6, 75.9)	88.5 (86.8, 90.2)	<0.001	66.7 (64.7, 68.6)	87.7 (86.2, 89.2)	<0.001
Elevated glucose, %	7.5 (6.0, 9.0)	8.5 (6.9, 10.1)	0.29	8.3 (7.2, 9.4)	8.8 (7.5, 10.1)	0.57
Reduced HDL cholesterol, %	35.4 (32.6, 38.1)	33.6 (31.1, 36.1)	0.28	32.4 (30.5, 34.4)	26.3 (24.4, 28.3)	<0.001
Elevated triglycerides, %	35.0 (32.2, 37.8)	39.2 (36.5, 41.8)	0.018	31.3 (29.4, 33.2)	32.8 (30.7, 35.0)	0.26
ATP-III MetS, %	35.2 (32.4, 37.9)	39.2 (36.5, 41.9)	0.019	33.5 (31.5, 35.5)	34.0 (31.8, 36.1)	0.73
MetS severity Z-score, mean[b]	-0.01 (-0.06, 0.03)	0.12 (0.08, 0.17)	<0.001	-0.06 (-0.09, -0.03)	-0.01 (-0.05, 0.03)	0.024
Men	N=1118	N=1113		N=1864	N=1571	
Hypertension, %	69.5 (66.6, 72.3)	63.4 (60.4, 66.3)	0.001	72.4 (70.3, 74.5)	67.7 (65.3, 70.0)	0.001
Abdominal obesity, %	44.2 (41.3, 47.1)	66.7 (64.0, 69.4)	<0.001	46.9 (44.6, 49.2)	73.3 (71.1, 75.4)	<0.001
Elevated glucose, %	8.3 (6.7, 9.9)	11.4 (9.4, 13.3)	0.007	8.5 (7.3, 9.8)	9.7 (8.2, 11.2)	0.18
Reduced HDL cholesterol, %	21.1 (18.7, 23.5)	22.6 (20.2, 25.0)	0.33	19.6 (17.8, 21.4)	19.6 (17.6, 21.5)	0.97
Elevated triglycerides, %	42.5 (39.6, 45.4)	51.6 (48.6, 54.5)	<0.001	43.3 (40.9, 45.6)	45.0 (42.5, 47.5)	0.27
ATP-III MetS, %	29.9 (27.2, 32.5)	38.1 (35.3, 40.9)	<0.001	30.2 (28.1, 32.3)	37.7 (35.3, 40.0)	<0.001
MetS severity Z-score, mean	0.29 (0.24, 0.34)	0.50 (0.45, 0.55)	<0.001	0.31 (0.28, 0.35)	0.37 (0.33, 0.41)	0.036

CI=confidence interval. MetS=metabolic syndrome. HDL=high-density lipoprotein. Survey-specific proportions or means (95% CI) are age-adjusted post-estimated marginal means from generalised estimating equation (GEE) models, holding age constant at the sex-specific mean in both surveys together (57.42 years for women, 58.15 years for men). The GEE logistic or linear regression models were stratified by ethnicity and run with age and survey as covariates.

[a]P-values for survey, i.e. p-value for change in proportion or mean from SAMINOR 1 to SAMINOR 2.

[b]Geometric means due to log-transformed outcome.

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Table 3. Sex-stratified GEE models examining potential interactions between survey and ethnicity for ATP-III MetS and MetS severity Z-score.

	ATP-III MetS		MetS severity Z-score	
	OR (95% CI)	p-value	β (95% CI)	p-value
Women				
Survey				
SAMINOR 2 vs. SAMINOR 1	1.08 (0.99, 1.18)	0.095	0.02 (0.01, 0.04)	0.010
Ethnicity				
Sami vs. non-Sami	1.16 (1.03, 1.30)	0.011	0.02 (-0.01, 0.04)	0.14
Survey x ethnicity				
SAMINOR 2 x Sami	—		0.03 (0.00, 0.05)	0.024
Age (per 10 years)	1.37 (1.30, 1.45)	<0.001	0.09 (0.08, 0.10)	<0.001
Men				
Survey				
SAMINOR 2 vs. SAMINOR 1	1.43 (1.29, 1.58)	<0.001	0.06 (0.01, 0.10)	0.021
Ethnicity				
Sami vs. non-Sami	1.00 (0.89, 1.13)	0.95	-0.02 (-0.07, 0.04)	0.62
Survey x ethnicity				
SAMINOR 2 x Sami	—		0.14 (0.07, 0.21)	<0.001
Age (per 10 years)	1.06 (1.00, 1.12)	0.034	-0.04 (-0.06, -0.02)	0.001

GEE=generalised estimating equation. MetS=metabolic syndrome. CI=confidence interval. OR=odds ratio. We tested whether the change in ATP-III MetS and MetS severity Z-score differed by ethnicity, by using interaction terms (ethnicity x survey) in GEE logistic or linear models that included age, survey and ethnicity as covariates. Analyses were not stratified by ethnicity. The interaction term was excluded from a model if p≥0.05. In women, the MetS severity Z-score was log-transformed. When interpreting the coefficients for survey and ethnicity in the models for MetS severity Z-score, one should be aware that these must be interpreted together with the interaction term.

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DISCUSSION

From 2003–2004 to 2012–2014, we observed an increase in both the prevalence (based on ATP-III criteria) and the severity of MetS in rural Northern Norway. The increases in prevalence were largest in men and were confirmed by sensitivity analyses. Non-Sami women had stable measures of MetS prevalence, but a small increase in MetS severity. Sami of both sexes had a slightly larger increase in MetS severity than non-Sami; this finding was most pronounced and most robust in men. Abdominal obesity increased markedly in all strata of sex and ethnicity.

Strengths and limitations

The relatively large sample size (N=6308 and N=5866) is a strength of our study, and we had an acceptable attendance rate (54.8% and 47.1%). In general, non-attendance was high among men aged 40–49 years. We could not evaluate ethnicity-specific non-attendance rates, as national registers do not record ethnicity. Due to design issues and varying response rates across municipalities, the SAMINOR 1 sample includes a lower proportion of people from Sami majority areas in Finnmark County and a higher proportion from Northern Troms County as compared to the SAMINOR 2 sample. These different geographic and ethnic compositions challenge our ability to compare the samples, nor can we generalise the results of this study to the entire Sami and non-Sami population. Analyses of participants excluded due to missing data (n=242 in SAMINOR 1, n=138 in SAMINOR 2) revealed that they were older, had lower education, and had a slightly worse cardiometabolic profile; we could not determine if this varied by ethnic belonging. An important weakness in our study is that blood samples were non-fasting, as the time schedule was distributed during the entire day. Lipid levels varies little according to fasting state, except mean triglycerides levels, which have been found to vary around 20% between different fasting states.[24] A more important issue is that using non-fasting glucose as a diagnostic tool is not valid regarding neither prediabetes nor diabetes. HbA1c was available in SAMINOR 2 only, such that in order for us to make comparisons between the surveys, we had to choose non-fasting glucose. Other weaknesses included self-reported DM status and drug use, and the lack of socioeconomic factors other than education. However, the internal validity of this study is high. We performed a wide range of sensitivity analyses with alterations in cut-offs for MetS risk factors, restricted samples, and ethnic classification. We assumed that the prevalence and severity of MetS could be defined in the same way in Sami and non-Sami, thus our results would be invalid if these assumptions were revealed to be incorrect. Despite the limitations, we believe that we have added novel information on cardiometabolic health by utilising a MetS severity Z-score.

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Comparison with other studies

The overall ATP-III-MetS prevalences we report in this study from rural Northern Norway were much higher than that reported in the 6th survey of the Tromsø Study (2007–2008, 22.6%), which sampled from an urban area in Northern Norway.[27] Thus, regional differences in MetS may be larger than ethnic differences in MetS in rural areas. Consequently, public health efforts to reduce the burden of MetS risk factors should focus more on region than on ethnicity. The ATP-III-MetS prevalences we found were also higher than those reported in other Arctic populations, such as the Greenland Inuit,[28] the Yup'ik Eskimo,[29] and indigenous Nenets women in Russia.[30] However, valid comparisons of MetS prevalences are challenging due to differences in study years, age distributions, MetS criteria, and fasting vs. non-fasting blood samples. Decreases in hypertension and increases in abdominal obesity have been reported both nationally and internationally.[31–33] Abdominal obesity, which appeared to be the driving force behind the increased ATP-III-MetS prevalences in our study, was present in nearly 90% of women and in more than two-thirds of men in 2012-2014. The cut-offs for waist circumference that we used are quite strict, such that we found a large proportion with abdominal obesity with only one or no additional MetS risk factors. Nevertheless, general obesity (body mass index ≥30 kg/m^2), without MetS, is known as metabolically healthy obesity, and has been reported to confer significant risk of cardiovascular disease and T2DM in long-term follow-up studies.[34,35] As research has indicated that metabolically healthy obesity is an unstable condition,[36] efforts should be made to prevent weight gain and promote weight loss in all obese individuals, regardless of MetS presence.

Possible implications of ethnic differences

The ethnic differences in the change of MetS severity from 2003–2004 to 2012–2014, were more robust in men than in women. The MetS severity increased by 0.20 (95% CI: 0.14, 0.25) in Sami men and 0.06 (95% CI: 0.01, 0.10) in non-Sami men, which is a modest difference. However, in a longitudinal study it was shown that, irrespective of baseline MetS severity Z-scores, individuals with a change of ≥0.5 in this score had an increased risk of T2DM compared to those with a change of ≤0.[10] Moreover, in a cohort study that followed nearly 300,000 individuals for 25 years, subtle elevations in metabolic risk factors (obesity, glucose, and triglycerides) were observed decades before T2DM onset.[37] Thus, even minor differences may be indicative of future differences in DM. As the differences between Sami and non-Sami men are small in our study, we are reluctant to speculate in detail what the implications of the results are. But, a few previous findings are interesting in the light of our results. In 1974–1975, Sami in Finnmark County had a

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reduced risk of T2DM compared with non-Sami.[14] However, in 2012–2014, a study from Northern Norway, including parts of Finnmark, Troms, and Nordland counties, reported that Sami had a higher prevalence of self-reported T2DM than non-Sami; this was evident in both sexes.[16] Conversely, no ethnic differences in the 10-year risk of non-fatal cardiovascular disease or self-reported myocardial infarction was found in rural Northern Norway.[12,38] In fact, both ATP-III-MetS and MetS severity Z-score have stronger associations with T2DM than with coronary heart disease.[2,3,9,10] The MetS severity Z-score has the highest factor loadings for HDL cholesterol and triglycerides,[8] which probably explains why this score increased more among Sami, as there was ethnic heterogeneity in the distribution of these two MetS risk factors. In sum, available research may indicate a more detrimental metabolic development associated with T2DM in Sami than in non-Sami men.

Possible explanations for ethnic differences

Prior to a discussion on possible explanations for the ethnic differences, we emphasise that they are quite small. In an international perspective, it is not common to observe such small differences between an indigenous population and the majority reference population. We speculate that our positive findings may be explained by the fact that the Sami and non-Sami mostly live side-by-side in the same geographical areas. Thus, important social determinants of health, such as education, job opportunities, and health services, should be equally available independent of ethnicity. We also reiterate that regional differences may be of a much larger magnitude than the ethnic differences [27] and this calls for continued public health surveillance in rural Northern Norway. Further, in an effort to explain ethnic health differences, one should keep in mind that ethnicity comprises of an interplay between lifestyle, geography, culture, and possibly genetics. It is likely that lifestyle factors such as diet and physical activity—which are strongly associated with MetS development [39]—mediate, at least to some degree, the (weak) association between ethnicity and MetS. There are some studies on differences in physical activity and dietary habits in Sami and non-Sami,[40–42] but they are both insufficient (i.e. no information on total level of physical activity) and cross-sectional. Unfortunately, we were not able to include such variables in our analyses. A complex facet of ethnicity is represented by potential differences in body composition;[6] thus, if such difference exists between Sami and non-Sami, it could have led us to misclassify some participants as obese. For instance, the Greenland Inuit have a more favourable cardiometabolic profile and lower amounts of visceral adipose tissue at the same level of obesity as Danes.[43,44] On average, Sami have a shorter stature than non-Sami, and when adjusting for waist-to-height-ratio, the differences in T2DM between Sami and non-Sami in SAMINOR 2 were eliminated.[16] Finally, we emphasise that

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there is heterogeneity in all aspects comprising ethnicity within the Sami population, just as there are heterogeneity between the Sami and the non-Sami. Our results suggests that further research on the ethnic differences in adiposity-related MetS risk profile in rural Northern Norway is warranted.

CONCLUSION

We found a high burden of MetS in rural Northern Norway. From 2003–2004 to 2012–2014, both the prevalence (ATP-III-MetS) and the severity (Z-score) of MetS increased in the 10 selected municipalities. The largest increases in prevalence were observed in Sami and non-Sami men. In Sami men, the increase in MetS severity was slightly larger in than in non-Sami. Abdominal obesity appeared to be the driving force behind the increase in ATP-III-MetS and should be a public health target regardless of ethnicity or MetS presence.

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COMPETING INTERESTS

The authors declare no competing interests.

DATA SHARING

The data that support the findings of this study are available from the SAMINOR Study (www.saminor.no), but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available upon reasonable request to the SAMINOR Project Board and with permission of the Regional Committee for Medical and Health Research Ethics.

CONTRIBUTORS

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The idea behind the study was conceived by ARB. VLM performed all the data analyses, produced the tables and the figures, and drafted the manuscript. SS and MM guided and assisted in the data analyses and the interpretation of the results. KK, JS and ARB were involved in the design of the study, the preparation for the data analyses and the interpretation of the results. All authors were involved in revision of the manuscript and approved the final version.

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FIGURE LEGENDS

Figure 1. Proportion with values above the cut-off for each cardiometabolic risk factor comprising metabolic syndrome (A-J), per 10-year age group, with vertical error bars (95% confidence interval). P-values for survey are age-adjusted and were obtained with generalised estimating equation (GEE) logistic regression. Models were stratified by sex and ethnic group. A and B: Hypertension defined as systolic blood pressure ≥130 mmHg, diastolic blood pressure ≥85 mmHg or current use of blood pressure medication. C and D: Abdominal obesity defined as waist circumference ≥80 cm in women and ≥94 cm in men. E and F: Elevated glucose defined as glucose ≥7.8 mmol/L or self-reported diabetes mellitus. G and H: Reduced HDL cholesterol defined as HDL cholesterol <1.3 mmol/L in women and <1.0 mmol/L in men. I and J: Elevated triglycerides defined as triglycerides ≥1.7 mmol/L.

Figure 2. MetS = metabolic syndrome. ATP-III = Adult Treatment Panel III. P-values for survey are age-adjusted and were obtained with generalised estimating equation (GEE) logistic or linear regression. Models were stratified by sex and ethnic group. A and B: Prevalence of MetS defined by the harmonised ATP-III criteria, per 10-year age group with vertical error bars (95% confidence interval). C and D: Mean of MetS severity Z-score as a function of age with 95% confidence interval bands shaded in grey.

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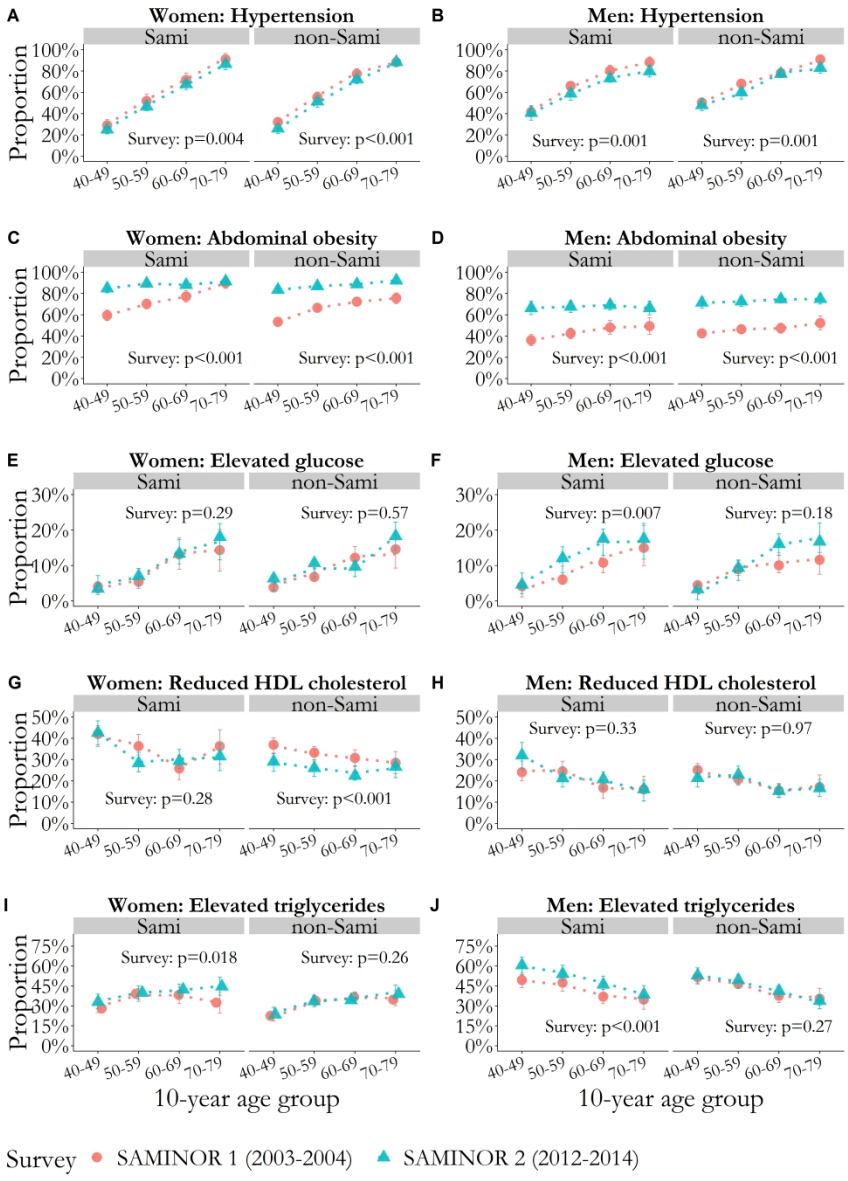

Figure 1. Proportion with values above the cut-off for each cardiometabolic risk factor comprising metabolic syndrome (A-J), per 10-year age group, with vertical error bars (95% confidence interval). P-values for survey are age-adjusted and were obtained with generalised estimating equation (GEE) logistic regression. Models were stratified by sex and ethnic group. A and B: Hypertension defined as systolic blood pressure ≥130 mmHg, diastolic blood pressure ≥85 mmHg or current use of blood pressure medication. C and D: Abdominal obesity defined as waist circumference ≥80 cm in women and ≥94 cm in men. E and F: Elevated glucose defined as glucose ≥7.8 mmol/L or self-reported diabetes mellitus. G and H: Reduced HDL cholesterol defined as HDL cholesterol <1.3 mmol/L in women and <1.0 mmol/L in men. I and J: Elevated triglycerides defined as triglycerides ≥1.7 mmol/L.

420x593mm (300 x 300 DPI)

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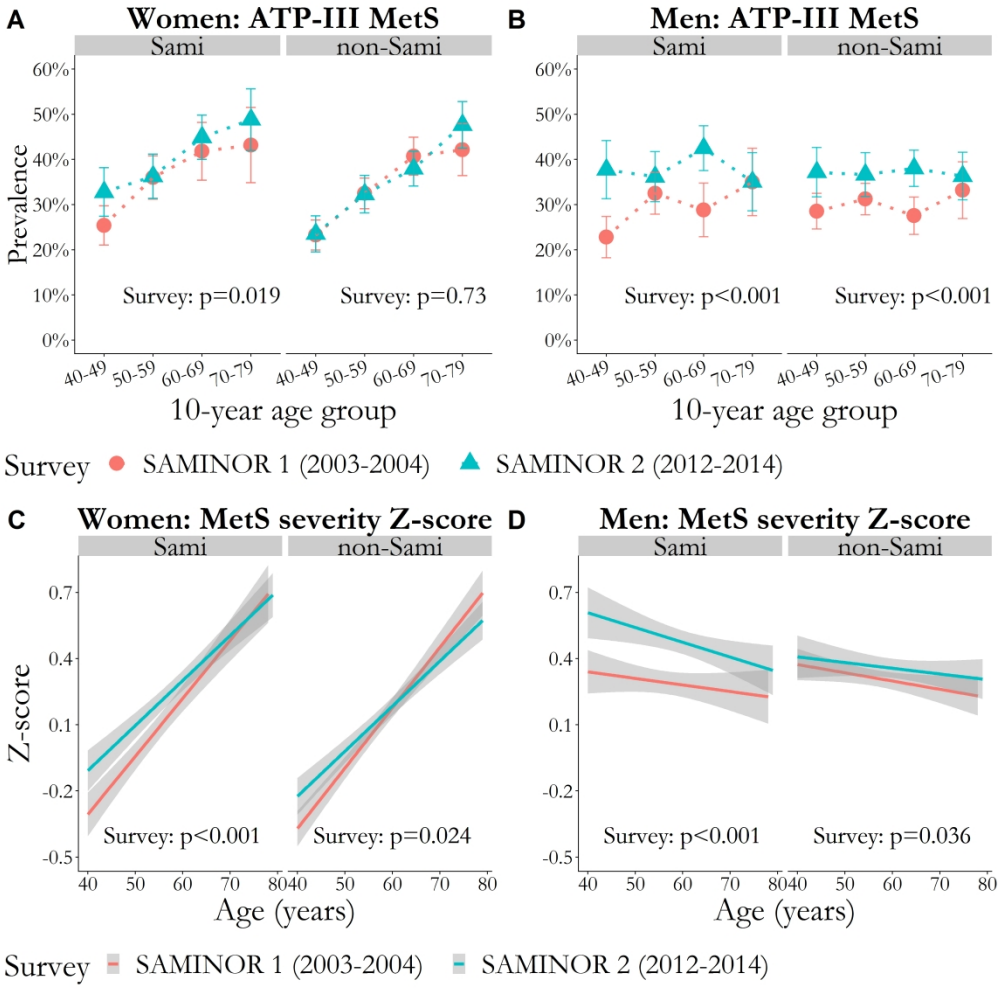

Figure 2. MetS = metabolic syndrome. ATP-III = Adult Treatment Panel III. P-values for survey are age-adjusted and were obtained with generalised estimating equation (GEE) logistic or linear regression. Models were stratified by sex and ethnic group. A and B: Prevalence of MetS defined by the harmonised ATP-III criteria, per 10-year age group with vertical error bars (95% confidence interval). C and D: Mean of MetS severity Z-score as a function of age with 95% confidence interval bands shaded in grey.

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Supplementary Table 1. Sensitivity analyses of the age-adjusted prevalence of ATP-III MetS and mean of MetS Z-score in Sami and non-Sami in the two surveys, with altered MetS definitions and restricted samples, including an examination of potential interactions between survey and ethnicity using GEE models.

	Sami participants			non-Sami participants			
	SAMINOR 1	SAMINOR 2	p-value[a]	SAMINOR 1	SAMIINOR 2	p-value[a]	p-value for interaction (survey x ethnicity)[b]
Women							
ATP-III MetS: Waist ≥88 cm, %	28.9 (26.3, 31.5)	35.3 (32.7, 37.9)	<0.001	27.3 (25.5, 29.2)	32.2 (28.1, 32.2)	0.022	0.12
ATP-III MetS: Excluded waist criteria, %	16.6 (14.4, 18.7)	16.3 (14.2, 18.3)	0.82	14.2 (12.8, 15.7)	13.5 (11.9, 15.0)	0.42	0.91
ATP-III MetS: Glucose ≥11.1 mmol/L, %	34.6 (31.9, 37.4)	38.7 (36.0, 41.4)	0.018	32.6 (30.6, 34.5)	33.4 (31.2, 35.5)	0.54	0.22
ATP-III MetS: Triglycerides ≥2.1 mmol/L, %	29.2 (26.6, 31.8)	31.2 (28.7, 33.8)	0.20	27.4 (25.5, 29.3)	26.9 (24.9, 28.9)	0.67	0.32
ATP-III MetS: "Healthier" sample, %	20.4 (17.4, 23.4)	28.9 (25.9, 31.9)	<0.001	21.0 (18.8, 23.2)	23.3 (20.9, 25.6)	0.13	0.03
MetS Z-score: "Healthier" sample, mean	-0.15 (-0.21, -0.11)	0.06 (0.01, 0.11)	<0.001	-0.20 (-0.24, -0.17)	-0.07 (-0.11, -0.03)	<0.001	0.025
Men							
ATP-III MetS: Waist ≥102 cm, %	21.8 (19.4, 24.2)	29.6 (26.9, 32.3)	<0.001	21.7 (19.8, 23.5)	28.8 (26.5, 31.0)	<0.001	0.62
ATP-III MetS: Excluded waist criteria, %	14.4 (12.4, 16.5)	17.9 (15.7, 20.2)	0.014	13.5 (11.9, 15.0)	15.6 (13.8, 17.4)	0.057	0.47
ATP-III MetS: Glucose ≥11.1 mmol/L, %	28.3 (25.6, 30.9)	37.4 (34.6, 40.2)	<0.001	29.3 (27.2, 31.4)	37.2 (34.9, 39.6)	<0.001	0.47
ATP-III MetS: Triglycerides ≥2.1 mmol/L, %	23.7 (21.2, 26.1)	31.3 (28.4, 33.8)	<0.001	23.5 (21.6, 25.4)	30.2 (28.0, 32.5)	<0.001	0.74
ATP-III MetS: "Healthier" sample, %	20.0 (17.0, 23.0)	27.8 (24.6, 31.1)	<0.001	23.0 (20.6, 25.4)	30.0 (27.0, 32.8)	<0.001	0.53
MetS Z-score: "Healthier" sample, mean	0.10 (0.04, 0.16)	0.36 (0.30, 0.41)	<0.001	0.17 (0.12, 0.21)	0.24 (0.19, 0.29)	0.017	<0.001

GEE = generalised estimating equation. CI = confidence interval. MetS = metabolic syndrome. HDL = high-density lipoprotein. A "healthier" sample was constructed by excluding participants if they currently used blood pressure medication or diabetes medication or if they reported ever having had a myocardial infarction, angina pectoris or diabetes mellitus. Survey-specific proportions or means (95% CI) are age-adjusted post-estimated marginal means from GEE models, holding age constant at the sex-specific mean for the entire sample (i.e. both surveys).

[a]P-values for survey, i.e. p-value for change in proportion or mean from SAMINOR 1 to SAMINOR 2. The GEE logistic or linear regression models were stratified by ethnicity and run with age and survey as covariates.

[b]P-values for the interaction term (survey x ethnicity) in GEE models not stratified by ethnicity. P<0.05 indicates that the change in outcome over time differs by ethnic group.

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STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4-5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4-5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5-6
Bias	9	Describe any efforts to address potential sources of bias	7
Study size	10	Explain how the study size was arrived at	6-7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7
		(*b*) Describe any methods used to examine subgroups and interactions	7
		(*c*) Explain how missing data were addressed	7
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	-
		(*e*) Describe any sensitivity analyses	7-8
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5-7
		(b) Give reasons for non-participation at each stage	6
		(c) Consider use of a flow diagram	-
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8 Table 1
		(b) Indicate number of participants with missing data for each variable of interest	7
Outcome data	15*	Report numbers of outcome events or summary measures	Table 2
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 2 Table 3

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		(*b*) Report category boundaries when continuous variables were categorized	6
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	8
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9/Supp. Table 1
Discussion			
Key results	18	Summarise key results with reference to study objectives	13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-14
Generalisability	21	Discuss the generalisability (external validity) of the study results	15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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