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Original Contribution

Determining Lifestyle Correlates of Body Mass Index using Multilevel Analyses: The Tromsø Study, 1979–2001

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Increases in overweight and obesity have been observed globally in both developed and developing countries. The authors assessed the relation between lifestyle factors and body mass index (BMI) (weight (kg)/height (m)^2) in a population-based longitudinal study, using BMI and its subsequent change as responses in a multilevel model. The authors included 11,115 men and women aged 20–61 years at baseline who were living in the municipality of Tromsø, Norway, and who participated in three or four consecutive health surveys between 1979–1980 and 2001. Baseline age, physical activity at work, coffee consumption, and desired BMI (i.e., the BMI that the subjects reported they would like to have) were positively associated with baseline BMI, whereas height, alcohol consumption, leisure-time physical activity, and level of education were inversely associated. Most relations were found to be stronger in women than in men. Clinically relevant effect sizes were observed for most of the significant associations, especially in women. For instance, on an ordinal scale, a one-category increase in educational level would decrease the mean baseline BMI among women by 0.30 kg/m^2. Significant associations between several lifestyle factors and subsequent BMI change revealed that observed baseline associations were strengthened over time, especially in women.

body mass index; longitudinal studies; obesity; population; sex

Abbreviation: BMI, body mass index.

The increasing prevalence of obesity worldwide is a major public health concern (1, 2). Adverse secular trends of obesity have been observed in both developed and developing countries. In low-income countries, obesity is more common among middle-aged women, people of higher socioeconomic status, and people living in urban communities. In more affluent countries, obesity is not only common among middle-aged persons but is becoming increasingly prevalent among younger adults and children (2). The prevalence of obesity in Western countries is suggested to vary between 15 percent and 20 percent (3). According to the World Health Organization, this global epidemic is replacing more traditional public health concerns, such as undernutrition and infectious diseases, as one of the most significant contributors to ill health (1). Overweight and obesity, often measured as body mass index (BMI), have been shown to be associated with adverse levels of blood pressure and serum lipids (4–7). Longitudinal studies demonstrate a direct association between increase in BMI and adverse changes in most of the established risk factors for cardiovascular disease (8–10).

To reverse the ongoing obesity epidemic, it is important to assess lifestyle determinants of BMI and its increase over time. Cross-sectional studies have addressed this issue (11–18), but only a few longitudinal studies have assessed the associations between lifestyle factors and BMI (19–22). In the Tromsø Study, a longitudinal study of more than 11,000 men and women who had their height and weight measured at least three times between 1979–1980 and 2001, we aimed

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TABLE 1. Participation in four population health surveys, The Tromsø Study, 1979–2001

Survey	Year of birth	No. invited		No. who attended		Attendance rate (%)	
		Men	Women	Men	Women	Men	Women
1979–1980	1925–1959*	11,483	9,958	8,478	8,143	73.8	81.8
1986–1987	1925–1966*	14,540	12,981	10,414	10,278	71.6	79.2
1994–1995	<1970	18,481	19,078	12,865	14,293	69.6	74.9
2001	<1972†	4,636	5,717	3,511	4,619	75.7	80.8
Three out of four surveys				5,648	5,837		

* From 1930 onward for women.
† Full birth cohorts were not included. See text for description.

to assess the associations between lifestyle factors and BMI and its change over time using multilevel analyses.

MATERIALS AND METHODS

Study population

The Tromsø Study was initiated in Tromsø, Norway, in 1974, with a main focus on cardiovascular diseases. The study design included five repeated population health surveys carried out in 1974, 1979–1980, 1986–1987, 1994–1995, and 2001. We did not include the first survey in our analyses because it did not include women. Table 1 shows the numbers of participants in each survey. All persons born in the specified years (except those invited to participate in the 2001 survey) who were living in Tromsø at the time of the survey were invited to participate.

In the fourth survey, conducted in 1994–1995, all subjects aged 55–74 years and random 5–10 percent samples of the other age groups were invited to make a second visit for more extensive screening. A total of 7,965 subjects attended at least some part of the screening. Because of financial constraints, the last survey, administered in 2001, was less comprehensive. All subjects living in the municipality of Tromsø aged 30, 40, 45, 60, or 75 years and all those who attended the second screening in 1994–1995 and were still living in Tromsø were invited to participate in the 2001 survey.

A total of 11,486 subjects who attended at least three of the four surveys administered between 1979–1980 and 2001 met the inclusion criteria. Among them, 7,135 subjects attended three surveys and 4,351 subjects attended all four surveys. Subjects with missing BMI values were excluded from the analyses (n =168). Women who were pregnant at the time of any survey were also excluded (n = 203). Thus, the present analyses included 5,594 men and 5,521 women.

The Tromsø Study protocol was approved by the regional board of research ethics. The University of Tromsø and local health authorities were responsible for the study, and the examinations were carried out in cooperation with the National Health Screening Service.

Measurements

During the first part of each survey, the participants were mailed a questionnaire that included questions on current and previous cardiovascular diseases, physical activity in leisure time (sedentary, moderate, intermediate, or intensive) and at work (sedentary, walking, lifting and walking, or heavy manual), smoking habits (current smoker, previous smoker, or nonsmoker), and ethnic origin. The validity of responses to the question on smoking was investigated in 140 randomly selected men (23). The question on physical activity has been widely used in Scandinavian studies (24), and the physical activity levels have been correlated with physical fitness (25). The questionnaire was returned when participants attended the physical examination.

During the physical examination, specially trained personnel measured blood pressure, and nonfasting blood samples were taken. Height and weight were measured with participants wearing light clothes and no shoes. BMI was calculated as weight in kilograms divided by the square of height in meters (kg/m^2). A second questionnaire was handed out, and the participants were asked to complete it at home and return it by mail. This questionnaire included questions on dietary habits, including intake of alcohol, use of drugs, education, current and previous illnesses, and social and psychological conditions. For women only, the questionnaire requested information on menopausal status, oral contraceptive use, and reproductive characteristics. The concordance between information on alcohol consumption obtained by questionnaire and that obtained by dietary history interview was assessed after the 1979–1980 survey in a group of men with high risk of cardiovascular disease (26). Spearman's correlation coefficients between 0.59 and 0.64 were found for beer, wine, and liquor consumption (unpublished observations).

The procedures used were mainly the same in each survey, but some of the questions were not included in all surveys. Eating breakfast every day (yes/no), drinking boiled coffee daily (yes/no), and parity were first included in the 1986–1987 questionnaire. (Boiled coffee, in contrast to filtered coffee, is locally the predominant way of brewing coffee. It is brewed by adding coarsely ground coffee to a pot of boiling water; the pot is removed from the electric plate approximately 10–15 minutes before serving.) The variable "family economy during childhood" was included only in the 1979–1980 questionnaire. In 1994–1995, the subjects were asked about the weight that they would like to have. On this basis, we calculated each participant's "desired BMI."

The categories of the variables included in the present analyses are given in table 2. Further details are provided in previous publications (27–30).

Statistical analyses

The associations between lifestyle factors and BMI and its change were assessed using multilevel analyses (31). Our model can be divided into two levels. The level 1 submodel represents the initial value and the change each member of the population experiences during the time period of the study. If we wanted to fit BMI as a linear function of time, the level 1 submodel would resemble a regular regression model,

$$\mathrm{BMI}_{ij} = \pi_{0i} + \pi_{1i}\mathrm{time}_{ij} + \varepsilon_{ij}, \qquad (1)$$

where BMI_{ij} is subject i's BMI value at time j, π_{0i} is each subject's true BMI value at time 0 (intercept), π_{1i} is subject i's true annual rate of BMI change (slope), and ε_{ij} is the residual variation. The level 2 submodel represents the association between a specified predictor and each subject's intercept and slope. If baseline age and height were predictors, the level 2 submodel would be

$$\pi_{0i} = \beta_{00} + \beta_{01}\mathrm{age}_i + \beta_{02}\mathrm{height}_i + \zeta_{0i};$$
$$\pi_{1i} = \beta_{10} + \beta_{11}\mathrm{age}_i + \beta_{12}\mathrm{height}_i + \zeta_{1i}. \qquad (2)$$

Like the level 1 submodel, each of the two models in the level 2 submodel resembles a regular regression model. For instance, the coefficients β_{01} and β_{11} represent the effect of the predictor ''age'' on BMI intercept and BMI slope, respectively. In many software programs, the level 1 and level 2 submodels are expressed as a composite specification. We used SAS (32) for all analyses and Proc Mixed for the multilevel analysis. After equations 1 and 2 have been combined, the composite model is

$$\mathrm{BMI}_{ij} = (\beta_{00} + \beta_{01}\mathrm{age}_i + \beta_{02}\mathrm{height}_i + \beta_{10}\mathrm{time}_{ij} + \beta_{11}\mathrm{age}_i \times \mathrm{time}_{ij} + \beta_{11}\mathrm{height}_i \times \mathrm{time}_{ij}) + (\zeta_{0i} + \zeta_{1i}\mathrm{time}_{ij} + \varepsilon_{ij}), \qquad (3)$$

where the parentheses distinguish the fixed and stochastic components of the model.

All analyses were sex-specific, and results were adjusted for baseline age and smoking status. We fitted separate models with interaction terms in order to assess whether sex or age was an effect modifier—that is, whether there were age differences in the association between a predictor and BMI intercept or BMI slope. The interaction terms were included as cross-products between the effect modifier (sex or age) and the predictor of interest.

$$\pi_{0i} = \beta_{00} + \beta_{01}\mathrm{age}_i + \beta_{02}\mathrm{height}_i + \beta_{03}\mathrm{age}_i \times \mathrm{height}_i + \zeta_{0i};$$
$$\pi_{1i} = \beta_{10} + \beta_{11}\mathrm{age}_i + \beta_{12}\mathrm{height}_i + \beta_{13}\mathrm{age}_i \times \mathrm{height}_i + \zeta_{1i}. \qquad (4)$$

In all tests for interaction, two-sided p values less than 0.01 were considered statistically significant.

Although people's habits may change over time, we chose not to update such information in our model. Our rationale was that interpretation of the results would be different. For example, we would not be able to directly assess the associations between baseline characteristics and longitudinal change in BMI.

The independent variables considered were both categorical and continuous. After carefully checking associations between the categorical variables and BMI intercept or BMI slope, we found that all of them, except for baseline smoking status and parity, could be included as continuous variables in the multilevel models. Parity was dichotomized with a cutoff at three children, and smoking status was included as two indicator variables, leaving nonsmokers as the reference group. The variables conveying questionnaire information from each person's first study visit (in either 1979–1980 or 1986–1987) were used as time-independent variables. The exceptions were level of education (we used information from the 1994–1995 questionnaire, because every subject should have finished his or her education by that time), eating breakfast every day, drinking boiled coffee daily, and parity, which were first included in the 1986–1987 questionnaire. The variable ''family economy during childhood'' was included only in the 1979–1980 questionnaire. Consequently, the variable was coded as missing for persons who first entered the study in 1986–1987.

RESULTS

Table 2 shows the frequency distributions of all categorical variables in men and women. In men, depending on the type of alcohol consumed, less than 1.3 percent reported daily alcohol intake, and less than 7.9 percent reported consuming alcohol 2–3 times per week. More than 69 percent of men reported consuming alcohol less frequently than weekly. Alcohol intake in women was generally lower than that in men. University-level or equivalent education was reported by 25.7 percent of men and 22.0 percent of women. Women were less physically active than men, both during leisure time and at work, and coffee consumption (cups/day; four categories) was higher among men than among women. A greater percentage of men reported engaging in shift work or night work, and men were more likely to be treated for hypertension than women. Women were more likely than men to be teetotalers and to eat breakfast regularly.

The mean baseline BMI and BMI at the end of the study were estimated to 24.4 kg/m^2 and 26.3 kg/m^2, respectively, in men and 22.7 kg/m^2 and 25.6 kg/m^2, respectively, in women (table 3). The desired BMI reported in 1994–1995 was 24.5 kg/m^2 in men and 22.7 kg/m^2 in women; this corresponded well with the baseline BMI values observed 15–16 years before.

The multilevel model had two intercepts, one for baseline BMI at age 20 years and another for subsequent linear change in BMI over time (equation 2). Baseline BMI and BMI change over a 10-year period for a man aged 20 years were estimated to be 23.0 kg/m^2 and 1.75 kg/m^2, respectively (table 4). Baseline age was positively associated with baseline BMI. For each 10-year increase in age, the estimated

TABLE 2. Distribution of lifestyle and demographic characteristics at baseline, by sex, The Tromsø Study, 1979–2001

Baseline variable	Men		Women	
	No.	%	No.	%
Total alcohol abstinence	4,901		4,851	
No	4,602	93.9	4,345	89.6
Yes	299	6.1	506	10.4
How often do you consume beer?	4,941		4,815	
Never or a few times per year	1,873	37.9	3,183	66.1
1–2 times per month	1,538	31.1	1,119	23.2
1 time per week	1,088	22.0	426	8.8
2–3 times per week	385	7.8	79	1.6
Daily	57	1.2	8	0.2
How often do you consume wine?	4,867		4,886	
Never or a few times per year	3,506	72.0	3,324	68.0
1–2 times per month	999	20.5	1,159	23.7
1 time per week	282	5.8	331	6.8
2–3 times per week	78	1.6	66	1.4
Daily	2	0.0	6	0.1
How often do you consume liquor?	4,961		4,919	
Never or a few times per year	1,715	34.6	2,977	60.5
1–2 times per month	1,956	39.4	1,509	30.7
1 time per week	1,047	21.1	396	8.1
2–3 times per week	223	4.5	36	0.7
Daily	20	0.4	1	0.0
Level of education in 1994–1995	5,568		5,492	
Primary school	2,058	37.0	2,372	43.2
1–2 years of high school	1,749	31.4	1,591	29.0
3–4 years of high school	327	5.9	320	5.8
University, <4 years	881	15.8	647	11.8
University, ≥4 years	553	9.9	562	10.2
Leisure-time physical activity	5,583		5,516	
Sedentary	1,056	18.9	1,207	21.9
Moderate	2,600	46.6	3,586	65.0
Regular training	1,618	29.0	675	12.2
Hard training	309	5.5	48	0.9
Physical activity at work	5,587		5,505	
Sedentary	2,106	37.7	1,581	28.7
Walking	1,416	25.3	2,960	53.8
Lifting and walking	1,355	24.3	895	16.3
Heavy manual	710	12.7	69	1.3

Table continues

baseline BMI increased by 0.71 kg/m^2. Previous smokers had significantly higher (0.44 kg/m^2) baseline BMI values than nonsmokers, but current smokers had significantly lower (-0.19 kg/m^2) baseline BMI values than nonsmokers. Table 4 shows the associations between other lifestyle factors and baseline BMI and its change in men, adjusted for baseline age and smoking status. Baseline liquor consumption, greater physical activity at work, coffee consumption (cups/day), shift work or night work, treatment for hypertension, and desired BMI were directly associated with baseline BMI. Baseline height, consumption of beer and wine, education, leisure-time physical activity, and daily breakfast-eating were inversely associated with baseline BMI. Drinking boiled coffee daily, family economy during childhood,

TABLE 2. Continued

Baseline variable	Men		Women	
	No.	%	No.	%
Family economy during childhood*	4,555		4,503	
Poor	170	3.7	156	3.5
Moderate	1,562	34.3	1,255	27.9
Good	2,652	58.2	2,852	63.3
Very good	171	3.8	240	5.3
Smoking status	5,588		5,515	
Never smoker	1,407	25.2	1,986	36.0
Previous smoker	1,505	26.9	1,010	18.3
Current smoker	2,676	47.9	2,519	45.7
Coffee consumption (cups/day)	5,020		4,992	
<1	342	6.8	340	6.8
1–4	1,618	32.2	2,089	41.8
5–8	2,273	45.3	2,076	41.6
>8	787	15.7	487	9.8
Drinking boiled coffee daily†	5,594		5,521	
No	1,596	28.5	1,515	27.4
Yes	3,998	71.5	4,006	72.6
Eating breakfast every day†	5,095		5,055	
No	978	19.2	709	14.0
Yes	4,117	80.8	4,346	86.0
Shift work or night work	5,587		5,515	
No	4,610	82.5	4,868	88.3
Yes	977	17.5	647	11.7
Treatment for hypertension	5,594		5,521	
No	4,642	83.0	4,788	86.7
Yes	952	17.0	733	13.3
Housekeeping as main occupation			5,518	
No			3,138	56.9
Yes			2,380	43.1
Oral contraceptive use			5,457	
No			5,031	92.2
Yes			426	7.8
Parity (no. of children)			5,125	
0–3			4,433	86.5
≥4			692	13.5

* From the 1979–1980 questionnaire only.
† From the 1986–1987 questionnaire only.

and being a teetotaler were not significantly associated with baseline BMI.

The association between lifestyle factors and BMI change may be assessed together with the association for baseline BMI. If the directions of the associations are similar for both, then the magnitude of the association observed at baseline is further strengthened over time. However, if the signs of the regression coefficients are different, the magnitude of the association observed at baseline is attenuated or the association has changed direction over time. For breakfast-eating and desired BMI reported in 1994–1995, we observed that the associations were significantly strengthened over time. Baseline age, height, education, and drinking boiled coffee daily were also significantly associated with BMI change. However, for the latter associations, the associations observed at baseline were attenuated.

To find the effect of an exposure variable at a given follow-up time point (e.g., after 10 years), one may add the regression coefficient for baseline BMI to the coefficient for 10-year BMI change. For instance, 10 years after the

TABLE 3. Distribution of age and anthropometric characteristics, by sex, The Tromsø Study, 1979–2001

Variable	Men			Women		
	No.	Mean	SD†	No.	Mean	SD
Age (years) at baseline*	5,594	36.7	9.5	5,521	34.5	8.1
BMI†,‡ at baseline*	5,594	24.4	2.8	5,521	22.7	3.2
BMI at end of study§	5,594	26.3	3.4	5,521	25.6	4.4
Desired BMI reported in 1994–1995	4,362	24.5	1.9	4,539	22.7	2.1
Height (cm) at baseline*	5,594	176.9	6.7	5,521	163.7	6.1

* In 1979–1980 or in 1986–1987.
† SD, standard deviation; BMI, body mass index.
‡ Weight (kg)/height (m)^2.
§ In 1994–1995 or in 2001.

baseline examination, men who reported eating breakfast every day would have an estimated BMI 0.76 kg/m^2 lower than that of men who reported not eating breakfast every day.

The association between lifestyle factors and baseline BMI or its slope in women differed from that in men (table 5). The majority of the associations were stronger in women. For

TABLE 4. Associations* between lifestyle and demographic factors and baseline BMI†,‡ (intercept) and BMI slope among men in multilevel analyses, The Tromsø Study, 1979–2001

Baseline variable	Baseline BMI		10-year BMI change	
	Coefficient	95% CI†	Coefficient	95% CI
Intercept (in 1979 at age 20 years)§	23.0	22.9, 23.2	1.75	1.68, 1.82
Baseline age (10 years)	0.71	0.63, 0.79	−0.37	−0.41, −0.34
Height (10 cm)	−0.24	−0.35, −0.13	0.08	0.03, 0.12
Total alcohol abstinence (yes/no)	0.11	−0.21, 0.43	0.01	−0.13, 0.15
Frequency of alcohol consumption (five categories)				
Beer	−0.17	−0.24, −0.09	0.01	−0.03, 0.04
Wine	−0.15	−0.26, −0.03	0.03	−0.02, 0.08
Liquor	0.14	0.06, 0.23	−0.03	−0.07, 0.01
Level of education in 1994–1995 (five categories)	−0.14	−0.19, −0.09	0.05	0.02, 0.07
Physical activity (four categories)				
During leisure time	−0.20	−0.29, −0.11	−0.0001	−0.04, 0.04
At work	0.07	0.01, 0.14	−0.003	−0.03, 0.03
Family economy during childhood¶ (four categories)	0.04	−0.09, 0.17	0.003	−0.00, 0.01
Smoking status				
Never smoker (reference group)				
Previous smoker	0.44	0.24, 0.64	−0.04	−0.13, 0.05
Current smoker	−0.19	−0.37, −0.01	−0.04	−0.12, 0.03
Coffee consumption (cups/day; four categories)	0.25	0.16, 0.35	−0.03	−0.08, 0.01
Drinking boiled coffee daily# (yes/no)	0.11	−0.05, 0.27	−0.13	−0.20, −0.06
Eating breakfast every day in 1986–1987# (yes/no)	−0.61	−0.80, −0.42	−0.15	−0.24, −0.07
Shift work or night work (yes/no)	0.50	0.31, 0.69	−0.02	−0.11, 0.06
Treatment for hypertension (yes/no)	1.99	1.49, 2.49	−0.01	−0.03, 0.01
Desired BMI reported in 1994–1995 (kg/m^2)	1.03	1.00, 1.06	0.20	0.18, 0.22

* Adjusted for age at baseline and smoking status.
† BMI, body mass index; CI, confidence interval.
‡ Weight (kg)/height (m)^2.
§ The multilevel model had two intercepts, one for baseline BMI at age 20 years and another for subsequent linear change in BMI over time.
¶ From the 1979–1980 questionnaire only.
\# From the 1986–1987 questionnaire only.

TABLE 5. Associations* between lifestyle and demographic factors and baseline BMI†,‡ (intercept) and BMI slope among women in multilevel analyses, The Tromsø Study, 1979–2001

Baseline variable	Baseline BMI		10-year BMI change	
	Coefficient	95% CI†	Coefficient	95% CI
Intercept (in 1979 at age 20 years)§	20.7**	20.6, 20.9	1.88**	1.80, 1.97
Baseline age (10 years)	1.17**	1.07, 1.27	−0.18**	−0.23, −0.13
Height (10 cm)	−0.54**	−0.68, −0.41	−0.03**	−0.10, 0.03
Total alcohol abstinence (yes/no)	0.88**	0.59, 1.17	0.26**	0.11, 0.40
Frequency of alcohol consumption (five categories)				
Beer	−0.35**	−0.47, −0.23	−0.07**	−0.13, −0.01
Wine	−0.47**	−0.59, −0.35	−0.06	−0.13, −0.00
Liquor	−0.17**	−0.30, −0.04	−0.03	−0.10, 0.03
Level of education in 1994–1995 (five categories)	−0.30**	−0.36, −0.24	−0.03**	−0.06, 0.00
Physical activity (four categories)				
During leisure time	−0.10	−0.23, 0.04	−0.05	−0.11, 0.02
At work	0.49**	0.37, 0.60	−0.02	−0.08, 0.04
Family economy during childhood¶ (four categories)	−0.22**	−0.36, −0.07	−0.004**	−0.01, 0.00
Smoking status				
Never smoker (reference group)				
Previous smoker	−0.15**	−0.38, 0.08	−0.12	−0.24, −0.01
Current smoker	−0.56**	−0.74, −0.37	−0.22**	−0.31, −0.13
Coffee consumption (cups/day; four categories)	0.50**	0.38, 0.62	−0.01	−0.07, 0.05
Drinking boiled coffee daily# (yes/no)	0.44**	0.26, 0.62	−0.13	−0.22, −0.04
Eating breakfast every day in 1986–1987# (yes/no)	−0.30	−0.55, −0.06	−0.05	−0.17, 0.08
Shift work or night work (yes/no)	0.34	0.09, 0.59	−0.08	−0.21, 0.04
Treatment for hypertension (yes/no)	2.20	1.48, 2.93	0.001	−0.04, 0.03
Desired BMI reported in 1994–1995 (kg/m^2)	1.04	1.01, 1.07	0.33**	0.30, 0.35
Housekeeping as main occupation (yes/no)	0.60	0.43, 0.76	0.02	−0.07, 0.10
Oral contraceptive use (yes/no)	−0.39	−0.71, −0.08	−0.16	−0.32, 0.01
Parity (≥4 children/0–3 children)	0.68	0.43, 0.93	0.04	−0.09, 0.16

* Adjusted for age at baseline and smoking status.
† BMI, body mass index; CI, confidence interval.
‡ Weight (kg)/height (m)^2.
§ The multilevel model had two intercepts, one for baseline BMI at age 20 years and another for subsequent linear change in BMI over time.
¶ From the 1979–1980 questionnaire only.
\# From the 1986–1987 questionnaire only.
** Coefficient significantly different from that for men ($p < 0.01$).

baseline BMI, significantly higher regression coefficients were observed in women for baseline age, height, being a teetotaler, consumption of beer, wine, and liquor, education, physical activity at work, family economy during childhood, current smoking, coffee consumption (cups/day), and drinking boiled coffee daily. No significant sex differences in the association with baseline BMI were observed for leisure-time physical activity, eating breakfast every day, shift or night work, treatment for hypertension, or self-reported desired BMI. The variables ''housekeeping as main occupation,'' ''oral contraceptive use,'' and ''parity'' were assessed only in women. All were significantly associated with baseline BMI.

The impression of stronger associations in women than in men that was observed for the baseline data was further strengthened by the observation of stronger associations between lifestyle factors and BMI change in women than in men. This was significantly evident for baseline age, height, being a teetotaler, beer intake, family economy during childhood, education, current smoking, and desired BMI. However, there were no significant sex differences for intakes of wine and liquor, physical activity at leisure and at work, coffee consumption (cups/day), drinking boiled coffee daily, eating breakfast every day, shift or night work, or treatment for hypertension.

Although the majority of significant associations in this study were strong, as measured by the *t* statistic, the magnitude of associations may be assessed by effect sizes. A difference of 0.20 kg/m^2 between categories of a predictor on an ordinal scale may not be clinically relevant for individual prediction. However, in a general population perspective, the effect size is substantial. Thus, most of the significant associations shown in tables 4 and 5 may be considered clinically meaningful.

The associations between lifestyle factors and BMI intercept or BMI slope could have been modified by increasing age in men and women. Therefore, in a separate set of analyses, we assessed interactions by age. Although some age interaction terms were significant, we have chosen not to report the results in tabular form because of their high degree of complexity. However, some results are worth noting: The BMI difference between current smokers and never smokers was significantly strengthened by age in both sexes. The association between the alcohol variables and baseline BMI was most apparent for older women.

DISCUSSION

In this population-based cohort study with serial examinations conducted three or four times between 1979–1980 and 2001, we assessed associations between lifestyle factors and BMI intercept and BMI slope in men and women. The majority of the factors were associated with BMI. Women had lower baseline BMI values estimated at age 20 years than did men. However, the associations with lifestyle factors were stronger in women than in men, and the 10-year BMI increase was significantly higher in women.

It is interesting that the associations were stronger in women than in men. Women had lower baseline BMI values and an increasing variation in baseline BMI with age compared with men. In addition, longitudinal increase in BMI was clearly higher in women than in men, especially for those over 30 years of age. This difference in BMI may have contributed to the stronger associations observed in women. However, the mechanisms are not understood. Sex differences in lifestyle and demographic characteristics were also observed (table 2). However, patterns that could explain stronger associations in women were not detected.

Our study had several strengths. It was based on an entire general population aged 20–61 years at baseline, with a high baseline participation rate (>75 percent), and the design was longitudinal. Height and weight were actually measured rather than self-reported.

Since the study included all inhabitants of Tromsø, apart from temporary residents, the results are probably representative of the population of any small Scandinavian city. However, it should be kept in mind that the municipality of Tromsø is located at 69°N, and the harsh climate may have some impact on lifestyle there, as well as on BMI. The variation in daylight exposure is extreme, with polar nights for 2 months during the winter and midnight sun for 2 months during the summer. On the other hand, despite its location far beyond the Arctic circle, the temperature in Tromsø varies only between −15°C and 25°C because of the effect of the Gulf Stream, which carries warm water from the Straits of Florida to the Norwegian Sea.

The association between lifestyle factors and BMI change in adults is sparsely documented in the literature (19–22). It is not a straightforward matter to compare those results with ours, because of the different study designs, time spans, and methods of analysis. The associations between BMI change and physical activity, education, and smoking have differed with regard to the significance of estimates and the direction of association. The Nord-Trøndelag Health Study showed that education was not significantly associated with BMI change in men, and men who were physically active and nonsmokers had significantly lower BMI increases (21). These results differ from ours somewhat. We observed no association between leisure-time physical activity or smoking status and BMI slope, but we observed a direct association with education. The differences may be explained by several factors. The Nord-Trøndelag Health Study included only men with normal BMIs; educational level was dichotomized; and there were differences in the questions about physical activity.

Our results are consistent with those of the Copenhagen City Heart Study, which showed no association between physical activity and BMI change (22). The Whitehall II Study addressed the association between BMI change and socioeconomic status (19). Persons of lower socioeconomic status gained weight more rapidly than did persons of higher status. In our study, there was a significant inverse association between education and baseline BMI in both men and women. In men, this association was attenuated over time, whereas it was further strengthened by time in women. The Swedish Annual Level-of-Living Survey found relations for smoking, exercise, and education that were in accordance with our results (20).

Cross-sectional results have been in agreement with those of our study in that socioeconomic status and leisure-time physical activity have been inversely associated with BMI (11–13, 17, 22, 33). However, in our study, the relation between physical activity and BMI in women did not reach statistical significance. This could be explained by the small variation in answers to the physical activity question among women (table 2). Studies on the impact of alcohol consumption on BMI have shown some diverging results, especially with regard to type of alcohol consumed (liquor, wine, or beer) (18, 34–37). We observed significant inverse associations between all three types of alcohol and baseline BMI (except for liquor consumption in men), and the associations were stronger in women than in men.

In most studies, nonsmokers have a significantly higher average BMI than smokers (13, 14, 18, 38–40). However, heavy smoking has been linked to higher BMI (39).

An inverse association has been observed between breakfast consumption and BMI in cross-sectional studies (15). According to our findings, regular breakfast eaters have a significantly lower baseline BMI than persons who do not eat breakfast every day. Comparable results from longitudinal studies have not been found.

An interesting finding of our study is the strong association between the desired BMI reported in 1994–1995 and BMI intercept and BMI slope. Results from ordinary least-squares regression show that desired BMI could explain over 50 percent of the total variation in BMI intercept and approximately 20 percent of the variation in BMI slope in both men and women. The relatively high degree of explained variation implies that a desired BMI reported at some point in time is highly predictive of a subject's BMI 15–16 years earlier.

Our tests of interaction by age showed that the associations between several lifestyle factors and BMI were modified by age, but without any distinct direction. However, more associations were weakened rather than strengthened by age (nine significant associations vs. five). Four of the associations that were strengthened by age were for the variables "current smoking" (vs. nonsmoking) and "desired BMI" in both men and women. Smokers in older age groups had a lower baseline BMI than nonsmokers, and older men and women reported a higher desired BMI than younger subjects.

Loss to follow-up is a major source of bias in longitudinal studies. Thirty-six percent of subjects who participated in the 1979–1980 survey were not included in our analyses because they did not attend two or three of the later examinations. This may have had some impact on our findings. Examination of the baseline characteristics of this group gave us no reason to suspect bias. However, some differences were detected. Subjects who were not included in the longitudinal analyses were, on average, 3 years younger than those who were included. There were no changes in examination procedures between the surveys, which were made within the time span of 1 year.

Information biases could have been present because of errors or misclassifications. Nondifferential misclassification undoubtedly took place, since most habits are reported with some error. In longitudinal studies this is generally not considered a large problem, since it usually contributes to underestimation of the true associations (41). However, nondifferential misclassification of a confounder may cause bias in either direction. Age and smoking were the only confounders included in all models. Age data could not have been misclassified, and we have no reason to suspect a high degree of misclassification for smoking status.

It is also possible that misclassification depends on BMI. The variables "normally eating breakfast every day (yes/no)" and "leisure-time physical activity" are two obvious candidates for differential misclassification. Obese subjects could wrongly answer that they eat breakfast every day because of public health advice to do so. It is also possible that obese subjects could provide a "healthier" answer to the physical activity question. In this case, the association between breakfast-eating or physical activity and BMI would be underestimated. It is not obvious that misclassification in other variables could depend on subjects' current BMIs.

In cross-sectional studies, subjects who are overweight or consider themselves to be so may have changed their habits (e.g., reduced alcohol consumption) in order to reduce their weight (18). This is not a problem to the same extent for the longitudinal part of our study. Confounding by variables not measured may also influence our results; for example, being a teetotaler is a marker for more than alcohol abstinence. Thus, we believe that prudence ought to be exercised when these results are applied in the prevention of obesity. While the beneficial effect of daily breakfast-eating and leisure-time physical activity (in men) seems to be confirmed by our multilevel analysis, there is a need for more comprehensive prospective studies.

In summary, the present study has suggested an association between several lifestyle factors and BMI and its change. The two most important predictors for baseline BMI and BMI change were age and desired BMI. However, increased alcohol consumption, higher educational level, being a smoker, reduced coffee intake, eating breakfast every day, and shift or night work, as well as physical activity in men, were also clearly associated with lower BMI values. In general, the associations were stronger in women than in men.

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