Do declines in occupational physical activity contribute to population gains in body mass index? The Tromsø Study 1974-2016

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SUMMARY BOX

What is already known about this subject?

- The inconclusive results from observational studies on occupational physical activity change and BMI gain may be due to methodological issues

What are the new findings?

- Occupational physical activity declines were not prospectively associated with body mass index gains in this large population-based sample

How might this impact on policy or clinical practice in the foreseeable future?

- Public health initiatives aimed at weight gain prevention may have greater success if focusing on other aspects than occupational physical activity

ABSTRACT

Objective: To examine whether occupational physical activity changes predict future body mass index (BMI) changes.

Methods: This longitudinal cohort study included adult participants attending ≥3 consecutive Tromsø Study surveys (examination 1, 2, 3) from 1974-2016 (N=11308). If a participant attended >3 surveys, the three most recent surveys were included. Occupational physical activity change (assessed by the Saltin-Grimby Physical Activity Level Scale) was computed from the 1st to 2nd examination, categorized into persistently inactive (PI; n=3692), persistently active (PA; n=5560), active to inactive (AI; n=741) and inactive to active (IA; n=1315). BMI change was calculated from the 2nd to 3rd examination (height being fixed at the 2nd examination) and regressed on preceding occupational physical activity changes using ANCOVA adjusted for sex, birth year, smoking, education and BMI at examination 2.

Results: Overall, BMI increased by 0.84 kg/m^2 (95% CI: 0.82-0.89). Following adjustments as described above, we observed no differences in BMI increase between the occupational physical activity change groups (PI: 0.81 kg/m^2 (95% CI: 0.75-0.87), PA: 0.87 kg/m^2 (95% CI: 0.82-0.92), AI: 0.81 kg/m^2 (95% CI: 0.67-0.94), IA: 0.91 kg/m^2 (95% CI: 0.81-1.01), p=0.25).

Conclusion: We observed no prospective association between occupational physical activity changes and subsequent BMI changes. Our findings do not support the hypothesis that occupational physical activity declines contributed to population BMI gains over the past decades. Public health initiatives aimed at weight gain prevention may have greater success if focusing on other aspects than occupational physical activity.

Keywords; [1]leisure time physical activity, [2]obesity, [3]overweight, [4]adiposity, [5]longitudinal, [6]prospective, [7]energy expenditure, [8]energy balance

INTRODUCTION

Excessive adiposity and weight gain arise from an imbalance between energy- intake and expenditure[1]. Increased energy intake is likely the main driver for population weight gains[2], but declines in physical activity levels may also contribute[1, 3]. At the population level, it may be easier to prevent weight gain by increasing physical activity levels than changing food habits[1]. Although the evidence for a prospective association between physical activity and weight gain is limited by methodological challenges[4], higher levels of physical activity are reported to prevent weight gain at the population level[5].

Energy expenditure contribution from occupational physical activity is considered higher than that from leisure time physical activity[3, 6]. Since leisure time physical activity appears stable over the past decades and occupational physical activity has declined in western countries[3, 7-10], lower levels of occupational physical activity, rather than leisure time physical activity, may contribute to population gains in weight[3, 11, 12].

Studies assessing the association between occupational physical activity and body mass index (BMI) or weight show conflicting results[11-16]. Some studies reported no association between baseline occupational physical activity and future BMI change[11, 13-16], however, baseline physical activity does not take the reciprocal relationship of changing weight and physical activity into account (i.e. physical activity level at baseline may change over time to follow up, which may be related or unrelated to weight change)[4]. Some computed change scores for both occupational physical activity and BMI and reported conflicting results[12, 17], however, without adjusting for previous physical activity or BMI/weight at baseline, this represents a cross-sectional analysis of change scores(i.e. it is as likely that physical activity change leads to weight change as *vice versa*) and thus the direction of the association is unexamined[4].

To overcome these methodological challenges, the aim of this study was to assess whether changes in occupational physical activity predicted future changes in BMI over a 40-year period in a large cohort of Norwegian adults examined at three time points with ~6 years follow up between each time point.

METHODS

Design

The Tromsø Study is an ongoing population-based cohort study in the municipality of Tromsø, Norway, which includes seven repeated surveys with high attendance (%): 1974 (Tromsø 1) (83%), 1979-80 (Tromsø 2) (85%), 1986-87 (Tromsø 3) (81%), 1994-95 (Tromsø 4) (77%), 2001 (Tromsø 5) (79%), 2007-08 (Tromsø 6) (66%) and 2015-16 (Tromsø 7) (65%). Our cohort includes invited participants from total birth cohorts and random samples of inhabitants in the Tromsø municipality [10, 18]. Tromsø 1 included only men while Tromsø 2-7 included both sexes (details described elsewhere (Tromsø 1-6[18], Tromsø 7[10]). In this study, we included participants attending at least three consecutive surveys (hereafter; examination 1-3). We computed change in physical activity from examination 1 to 2 followed by change in BMI and weight from examination 2 to 3. Consequently, the follow up period for physical activity change from examination 1 to 2 and BMI change from examination 2 to 3 were 6-7 years (mean: 6.5 years) for all included participants. Inclusion criteria were information on; 1) physical activity at examination 1 and 2, and height and weight at examination 2 and 3, 2) educational level and smoking habits at examination 2, and 3) not pregnant at examination 2 and/or 3. If participants attended more than three consecutive surveys, data from the three most recent surveys were included in the main analyses (overall cohort), while one participant could be included in multiple period-specific samples (Tromsø 1-3: 1974-1987, Tromsø 2-4: 1979-1995, Tromsø 3-5: 1986-2001, Tromsø 4-6: 1994-2008, Tromsø 5-7: 2001-2016). The layout for the analyses is illustrated in Figure 1.

Insert Figure 1 about here

Participants

A flow chart illustrates the selection of participants for our samples (Supplementary Figure 1). In short, the overall cohort comprised 11308 participants with their three most recent attendances. The period-specific sample sizes were as follows: Tromsø 1-3 (1974-1987): n=3570, Tromsø 2-4 (1979-1995): n=9679, Tromsø 3-5 (1986-2001): n=3827, Tromsø 4-6 (1994-2008): n=2212 and Tromsø 5-7 (2001-2016): n=1146). Each individual was eligible for inclusion in multiple period-specific samples. Some participants were excluded due to missing confounders; Tromsø 1-3 (1974-1987): n=512, Tromsø 2-4 (1979-1995): n=595, Tromsø 3-5 (1986-2001): n=15, Tromsø 4-6 (1994-2008): n=39, Tromsø 5-7 (2001-2016): n=20 (Supplementary Figure 1).

The descriptive characteristics at examination 2 for the overall cohort and period-specific samples are presented in Table 1. Tromsø 1 (1974) included only men, thus, the Tromsø 1-3 (1974-1987) sample only include men. All other cohorts are well balanced on sex distribution. Across period-specific samples, age distribution increases, current smokers decrease and educational level increase (Table1).

Table 1. Descriptive characteristics of the overall cohort and period-specific samples.

	The overall cohort	Period-specific samples*				
Cohort	**Tromsø 1-7 (1974-2016)**	**Tromsø 1-3 (1974-1986)**	**Tromsø 2-4 (1979-1995)**	**Tromsø 3-5 (1985-2001)**	**Tromsø 4-6 (1994-2008)**	**Tromsø 5-7 (2001-2016)**
Baseline	**Examination 2**	**Tromsø 2 (1979-80)**	**Tromsø 3 (1986-87)**	**Tromsø 4 (1994-95)**	**Tromsø 5 (2001)**	**Tromsø 6 (2007-08)**
Total N (%)	11308 (100%)	3570 (100%)	9679 (100%)	3827 (100%)	2212 (100%)	1146 (100%)
Sex n (%)						
Female	5482 (48.8%)	N/A	4820 (49.8%)	2023 (52.8%)	1183(53.5%)	611 (53.3%)
Male	5826 (51.2%)	3570 (100%)	4859 (50.2%)	1806 (47.2%)	1029 (46.5%)	535 (46.6%)
Age n (%)						
≤39 years	4072 (36.0%)	1819 (51%)	3831 (39.6%)	673 (17.6%)	102 (4.6%)	32 (2.8%)
40-49 years	2461 (21.8%)	1186 (33.2%)	3509 (36.3%)	342 (8.9%)	341 (15.4%)	251 (21.9%)
50-59 years	2561 (22.6%)	565 (15.8%)	2107 (21.8%)	1977 (51.7%)	689 (31.1%)	291 (25.4%)
60-69 years	1981 (17.5%)	N/A	232 (2.4%)	831 (21.7%)	944 (42.7%)	465 (40.6%)
≥70 years	233 (2.0%)	N/A	N/A	4 (0.1%)	136 (6.1%)	107 (9.3%)
Smoking n (%)						
Current smoker	4480 (39.6%)	1705 (47.8%)	4221 (43.6%)	1263 (33.0%)	579 (26.2%)	196 (17.1%)
Previous smoker	1790 (15.8%)	503 (14.1%)	754 (7.8%)	390 (10.2%)	843 (38.1%)	517 (45.1%)
Never smoker	5038 (44.6%)	1362 (38.2%)	4704 (48.6%)	2174 (56.8%)	790 (35.7%)	433 (37.8%)
Education n (%)						
Primary School	4698 (41.5%)	1842 (51.6%)	4324 (44.7%)	1456 (38.0%)	782 (35.3%)	299 (26.1%)
High School	3610 (31.9%)	1002 (28.1%)	2936 (30.3%)	1408 (36.8%)	665 (30.0%)	419 (36.6%)
University <4 years	1641 (14.5%)	423 (11.8%)	1380 (14.3%)	551 (14.4%)	364 (16.5%)	209 (18.2%)
University ≥4 years	1359 (12.0%)	303 (8.5%)	1039 (10.7%)	412 (10.8%)	401 (18.1%)	219 (19.1%)

**Period specific samples include all participants meeting our inclusion criteria for that period (i.e. these samples do not add up to the overall cohort (Tromsø 1-7), which includes participants with their three most recent attendances)*

Patient and public involvement

All participants in Tromsø 4-7 provided written informed consent and the present study was approved by the Regional Ethics Committee for Medical Research (ref. 2016/758410). There was no public involvement in the design or implementation of this study. The Tromsø 7 advisory board included patient (University hospital of Northern Norway) and public (Norwegian Health Association, Tromsø municipality) representatives, and some participants were invited as ambassadors during data collection where they actively contributed to participant recruitment.

Physical activity

Physical activity was measured using the Saltin-Grimby Physical Activity Level Scale (SGPALS) questionnaire[19, 20] for occupational- and leisure-time physical activity (leisure-time during the last twelve months) (four hierarchical levels), slightly modified compared to the original SGPALS from 1968[19] (differences described in Supplementary File 1, the SGPALS layout presented in Supplementary Table 1). For the occupational SGPALS, those reporting rank 1) *predominantly sedentary work*, were considered inactive, while those reporting rank 2) *sitting or standing work with some walking*, 3) *walking, some handling of material* or 4) *heavy manual work*, where considered active (Supplementary Table 1). Similar inactive/active categorization were used for the leisure time SGPALS (Supplementary Table 1). The occupational SGPALS have shown acceptable reliability[21] and an ability to rank participants compared with accelerometry[22].

Change in occupational and leisure time SGPALS was computed as 1) *persistently inactive* (reporting rank 1 at examination 1 and 2), 2) *persistently active* (rank ≥2 at examination 1 and 2), 3) *active to inactive* (rank ≥2 at examination 1 and rank 1 at examination 2) and 4) *inactive to active* (rank 1 at examination 1 and rank ≥2 at examination 2).

The occupational time SGPALS was used in all surveys of the Tromsø study, while the leisure time SGPALS was used in all except Tromsø 4 (1994-95). In Tromsø 5 (2001), the leisure time SGPALS was answered by those under 70 years.

Body mass index and weight

Weight and height were measured in light clothing and expressed as kilograms (kg) and meters (m). Body mass index at examination 2 was calculated as weight divided by the square height (kg/m^2). To eliminate the effect of possible height loss between examination 2 and 3, change in BMI at examination 3 was calculated as weight at examination 3 divided by the square height at examination 2. Body max index change is our primary outcome, while weight change results are secondary outcomes (Supplementary Tables 2-3 and 5-9).

Confounders and effect modifiers

Our selected confounders were sex, birth year, smoking and education and baseline BMI/weight (at examination 2). Effect modifiers included the abovementioned confounders in addition to leisure time physical activity change. Smoking (from questionnaire) was categorized into; 1) Current smoker, 2) Previous smoker, 3) Never smoker. Years of education (from questionnaire) were reported in Tromsø 2 (1979-80), Tromsø 3 (1986-87) and Tromsø 5 (2001), which we categorized into; 1) Primary school (<10 years), 2) High school (10-12 years), 3) University <4 years (13-15 years) and 4) University ≥4 years (≥16 years). A five group alternative for education was reported in Tromsø 4 (1994-95) and Tromsø 6 (2007-08), including the four abovementioned groups and a fifth named "technical school 2 years senior high" (e.g. craftsman; plumber, electrician, carpenter etc.), which we categorized as 2) High school. All confounders included in the models were retrieved from examination 2.

Statistical Analyses

We used paired t-tests to assess whether participants changed BMI and weight from examination 2 to 3. We used analyses of covariance (ANCOVA) to assess whether physical activity changes from examination 1 to 2 predicted BMI or weight changes from examination 2 to 3 as overall and in strata of sex, birth year, smoking, education and leisure time physical activity change, with adjustment for sex, birth year, smoking, education and BMI or weight at examination 2. Q-Q plots confirmed change in BMI and weight from examination 2 to 3 to not deviate from normal distribution. The Levene´s test of equality variance confirmed homogeneity of variance across occupational physical activity change groups (all p>0.07). We assessed interaction effects between occupational physical activity change and potential effect modifiers (sex, birth year, smoking, education and leisure time physical activity change from examination 1 to 2) in the overall cohort. For sensitivity analyses, we computed occupational physical activity change into 6 groups; 1) *Persistently inactive*, 2) *Persistently active*, 3) *Active but decreasing* (rank 4 or 3 → 3 or 2), 4) *Active and increasing* (rank 2 or 3 → 3 or 4), 5) *Active to Inactive* and 6) *Inactive to Active*. Data are shown as mean and 95% confidence intervals (CI) unless otherwise stated. We used the Statistical Package for Social Sciences (SPSS, Version 26, IBM, Armonk, NY, United States) for all statistical analyses.

RESULTS

The participants in the overall cohort and period-specific samples increased their BMI from examination 2 to 3 (all p<0.01) (Table 2). Weight change results are found in Supplementary Table 2.

Table 2. Body mass index at examination 2 and 3 and BMI change in the overall cohort and period-specific samples.

Overall Cohort	**N=11308**	**Examination 2**	**Examination 3**	**Change**
Examination 2-3	Mean	24.96	25.80	0.84
BMI (kg/m^2)	95%CI	24.89 to 25.03	25.73 to 25.87	0.82 to 0.89
Period-specific samples*				
Tromsø 1-3 (1974-87)#	N=3570			
Tromsø 2-3 (1979-87)	Mean	24.65	25.14	0.49
BMI (kg/m^2)	95%CI	24.56 to 24.74	25.04 to 25.24	0.44 to 0.54
Tromsø 2-4 (1979-95)	N=9679			
Tromsø 3-4 (1986-95)	Mean	24.25	25.38	1.13
BMI (kg/m^2)	95%CI	24.18 to 24.32	25.31 to 25.45	1.09 to 1.17
Tromsø 3-5 (1986-2001)	N=3827			
Tromsø 4-5 (1994-2001)	Mean	25.53	26.49	0.95
BMI (kg/m^2)	95%CI	25.42 to 25.64	26.36 to 26.62	0.90 to 1.01
Tromsø 4-6 (1994-2008)	N=2212			
Tromsø-5-6 (2001-08)	Mean	26.66	26.78	0.12
BMI (kg/m^2)	95%CI	26.50 to 26.82	26.61 to 26.95	0.04 to 0.20
Tromsø 5-7 (2001-2016)	N=1146			
Tromsø 6-7 (2007-16)	Mean	27.01	27.22	0.21
BMI (kg/m^2)	95%CI	26.76 to 27.26	26.96 to 27.48	0.09 to 0.33

*Data are shown as unadjusted mean and 95% CI. CI=confidence interval, BMI=body mass index, Examination 2=second survey of the three attended surveys, Examination 3=third survey of the three attended surveys. *Period specific samples include all participants meeting our inclusion criteria for that period (i.e. these samples do not add up to the overall cohort (Tromsø 1-7), which includes participants with their three most recent attendances), #Tromsø 1 included only men.*

Change in BMI by change in occupational physical activity

Changes in BMI by occupational physical activity change, overall and by strata of sex, birth year, smoking, education, and leisure time physical activity changes are presented in Table 3. We observed no differences in BMI change from examination 2 to 3 by occupational physical activity changes from examination 1 to 2 (*Persistently Inactive*: 0.81 kg/m^2 (95% CI: 0.75-0.87), *Persistently Active*: 0.87 kg/m^2 (95% CI: 0.82-0.92), *Active to Inactive*: 0.81 kg/m^2 (95% CI: 0.67-0.94), *Inactive to Active*: 0.91 kg/m^2 (95% CI: 0.81-1.01), $p=0.25$), which was consistent in stratified analyses (all $p \geq 0.054$) (Table 3).

Table 3. Body mass index change by occupational physical activity change for the overall cohort and in strata of sex, birth year, smoking, education and leisure time physical activity change.

Tromsø 1-7 (1974-2016)	**Change occupational physical activity examination 1 to 2**					
	Total	**Persistently inactive**	**Persistently Active**	**Active to inactive**	**Inactive to active**	**$P_{equality}$**
	BMI change examination 2 to 3					
Total (N)	*11308*	*3692*	*5560*	*741*	*1315*	
BMI (kg/m^2)	Mean	0.81	0.87	0.81	0.91	0.25
	95% CI	0.75 to 0.87	0.82 to 0.92	0.67 to 0.94	0.81 to 1.01	
Sex						
Women (n)	*5482*	*1638*	*2925*	*319*	*600*	
BMI (kg/m^2)	Mean	1.06	1.09	1.10	1.18	0.74
	95% CI	0.96 to 1.17	1.02 to 1.17	0.87 to 1.33	1.01 to 1.34	
Men (n)	*5826*	*2054*	*2635*	*422*	*715*	
BMI (kg/m^2)	Mean	0.56	0.67	0.55	0.66	0.11
	95% CI	0.49 to 0.63	0.61 to 0.74	0.39 to 0.71	0.54 to 0.78	
Birth year						
≤1929 (n)	*748*	*239*	*350*	*60*	*99*	
BMI (kg/m^2)	Mean	-0.09	0.15	0.20	-0.31	0.054
	95% CI	-0.31 to 0.14	-0.03 to 0.33	-0.22 to 0.62	-0.64 to 0.01	
1930-1939 (n)	*2974*	*856*	*1580*	*189*	*349*	
BMI (kg/m^2)	Mean	0.43	0.53	0.55	0.36	0.39
	95% CI	0.30 to 0.57	0.43 to 0.62	0.28 to 0.82	0.16 to 0.56	
1940-1949 (n)	*4192*	*1483*	*2020*	*260*	*429*	
BMI (kg/m^2)	Mean	0.85	0.92	0.73	1.06	0.10
	95% CI	0.75 to 0.95	0.84 to 1.00	0.50 to 0.96	0.88 to 1.24	
1950-1959 (n)	*3947*	*932*	*1430*	*205*	*380*	
BMI (kg/m^2)	Mean	1.34	1.28	1.28	1.52	0.12
	95% CI	1.22 to 1.45	1.19 to 1.37	1.04 to 1.52	1.34 to 1.70	
≥1960 (n)	*447*	*182*	*180*	*27*	*58*	
BMI (kg/m^2)	Mean	1.04	1.11	1.13	1.34	0.88
	95% CI	0.69 to 1.39	0.75 to 1.46	0.24 to 2.02	0.72 to 1.95	
Smoking						
Current Smoker (n)	*4480*	*1250*	*2343*	*306*	*581*	
BMI (kg/m^2)	Mean	0.96	1.00	0.82	1.02	0.44
	95% CI	0.85 to 1.07	0.92 to 1.08	0.60 to 1.03	0.86 to 1.17	
Previous smoker (n)	*1790*	*703*	*782*	*126*	*179*	
BMI (kg/m^2)	Mean	0.34	0.42	0.52	0.43	0.71
	95% CI	0.19 to 0.48	0.28 to 0.55	0.19 to 0.85	0.16 to 0.71	
Never smoker (n)	*5038*	*1739*	*2435*	*309*	*555*	
BMI (kg/m^2)	Mean	0.87	0.91	0.91	0.95	0.79
	95% CI	0.78 to 0.95	0.83 to 0.98	0.71 to 1.10	0.81 to 1.10	
Education						
Primary school (n)	*4698*	*878*	*3010*	*265*	*545*	
BMI (kg/m^2)	Mean	0.75	0.83	0.68	0.79	0.52
	95% CI	0.62 to 0.88	0.76 to 0.90	0.45 to 0.92	0.63 to 0.95	
High School (n)	*3610*	*1361*	*1566*	*271*	*412*	
BMI (kg/m^2)	Mean	0.87	0.95	0.82	1.11	0.09
	95% CI	0.77 to 0.97	0.86 to 1.04	0.60 to 1.03	0.93 to 1.29	
University <4 years (n)	*1641*	*787*	*539*	*117*	*198*	
BMI (kg/m^2)	Mean	0.85	0.90	0.88	0.97	0.85
	95% CI	0.72 to 0.98	0.75 to 1.06	0.55 to 1.21	0.71 to 1.22	
University >4 years (n)	*1359*	*666*	*445*	*88*	*160*	
BMI (kg/m^2)	Mean	0.72	0.80	1.16	0.75	0.14
	95% CI	0.59 to 0.85	0.64 to 0.96	0.81 to 1.50	0.49 to 1.01	
Leisure time physical activity change examination 1 to 2*						
Persistently inactive (n)	*813*	*332*	*317*	*63*	*101*	
BMI (kg/m^2)	Mean	0.81	0.98	1.25	0.94	0.42
	95% CI	0.60 to 1.03	0.76 to 1.20	0.76 to 1.73	0.55 to 1.33	
Persistently active (n)	*5368*	*1599*	*2798*	*328*	*643*	
BMI (kg/m^2)	Mean	1.00	1.02	0.82	1.13	0.08
	95% CI	0.91 to 1.08	0.95 to 1.08	0.63 to 1.02	1.00 to 1.27	
Active to inactive (n)	*974*	*291*	*469*	*71*	*143*	
BMI (kg/m^2)	Mean	0.82	1.03	1.24	1.11	0.23
	95% CI	0.60 to 1.04	0.86 to 1.21	0.80 to 1.68	0.80 to 1.42	
Inactive to active (n)	*999*	*348*	*451*	*66*	*134*	
BMI (kg/m^2)	Mean	0.90	1.09	0.89	0.77	0.31
	95% CI	0.69 to 1.11	0.91 to 1.28	0.42 to 1.37	0.43 to 1.10	

Data are adjusted for sex, birth year, smoking, education and BMI at examination 2, and shown as adjusted mean and 95% CI. CI=confidence interval, BMI=body mass index, Examination 1=first survey of the three attended surveys, Examination 2=second survey of the three attended surveys, Examination 3=third survey of *the three attended surveys, $P_{equality}$=main differences between groups. *The leisure time Saltin-Grimby Physcial Activity Scale was not included in Tromsø 4 (1994-95).*

We found no interaction effects of potential effect modifiers for the association between occupational physical activity changes and BMI changes (sex: p=0.87, smoking status: p=0.64, education: p=0.25, leisure time physical activity changes: p=0.24), except by birth year (p=0.01).

Overall and stratified weight change results for the overall cohort are found in Supplementary Table 3; we found no differences in weight change from examination 2 to 3 by occupational physical activity change from examination 1 to 2 (all p≥0.049).

In the sensitivity analyses where we computed occupational physical activity change into 6 groups; 1) *Persistently Inactive*, 2) *Persistently Active*, 3) *Active but decreasing* (rank 4 or 3 to 3 or 2), 4) *Active and increasing* (rank 2 or 3 to 3 or 4), 5) *Active to Inactive* and 6) *Inactive to Active*, the results generally remained unchanged (overall analysis: p=0.15), however, some differences were observed in some strata analyses (birth year; born ≤1929: p=0.03, education; High School: p=0.04, University ≥4 years: p=0.049, and leisure time physical activity changes; *Persistently Active*: p=0.003) (Supplementary Table 4). We found no interaction in the association between occupational physical activity change and BMI change (sex: p=0.21, smoking: p=0.59, education: p=0.88, leisure time physical activity change (p=0.12), except by birth year (p=0.04).

We observed no differences in BMI change by occupational physical activity change in any period-specific sample (Table 4); 1) There were no differences in BMI change from Tromsø 2 (1979-80) to Tromsø 3 (1986-87) between the physical activity change groups from Tromsø

1 (1974) to Tromsø 2 (1979-80) (p=0.68), 2) BMI change from Tromsø 3 (1986-87) to Tromsø 4 (1994-95) between the physical activity change groups from Tromsø 2 (1979-80) to Tromsø 3 (1986-87) (p=0.50), 3) BMI change Tromsø 4 (1994-95) to Tromsø 5 (2001) between the physical activity change groups from Tromsø 3 (1986-87) to Tromsø 4 (1994-95) (p=0.90), 4) BMI change Tromsø 5 (2001) to Tromsø 6 (2007-08) between the physical activity change groups from Tromsø 4 (1994-95) to Tromsø 5 (2001) (p=0.98), 5) BMI change from Tromsø 6 (2007-08) to Tromsø 7 (2015-16) between the physical activity change groups from Tromsø 5 (2001) to Tromsø 6 (2007-08) (p=20). Stratified analyses for the period-specific samples are presented in Supplementary Tables 5-9. We observed no differences in BMI or weight change by occupational physical activity change in any strata analysis (all p≥0.13; except Tromsø 2-4 (1979-1995) sample, ≥4 years University education: p≤0.04 Supplementary Table 8).

Table 4. Body mass index change by occupational physical activity change in period-specific samples.

Period-specific samples*	Change occupational physical activity Examination 1 to 2					$P_{equality}$
	Total	**Persistently inactive**	**Persistently Active**	**Active to inactive**	**Inactive to active**	
Tromsø 1-3 (1974-87)#	*n*					
Tromsø 2-3 (1979-87)	*3570*	*1033*	*1805*	*366*	*366*	
BMI (kg/m^2)	Mean	0.48	0.48	0.49	0.57	0.68
	95%CI	0.39 to 0.57	0.41 to 0.54	0.35 to 0.64	0.43 to 0.71	
Tromsø 2-4 (1979-95)	*n*					
Tromsø 3-4 (1986-95)	*9679*	*2512*	*5179*	*665*	*1323*	
BMI (kg/m^2)	Mean	1.12	1.15	1.12	1.07	0.50
	95% CI	1.05 to 1.19	1.10 to 1.20	0.99 to 1.26	0.98 to 1.17	
Tromsø 3-5 (1986-2002)	*n*					
Tromsø 4-5 (1994-2001)	*3827*	*1315*	*1915*	*223*	*374*	
BMI (kg/m^2)	Mean	0.96	0.96	1.02	0.91	0.90
	95% CI	0.86 to 1.05	0.87 to 1.04	0.79 to 1.25	0.73 to 1.09	
Tromsø 4-6 (1994-2008)	*n*					
Tromsø 5-6 (2001-08)	*2212*	*884*	*985*	*166*	*177*	
BMI (kg/m^2)	Mean	0.12	0.12	0.15	0.07	0.98
	95% CI	-0.004 to 0.24	0.01 to 0.24	-0.13 to 0.43	-0.20 to 0.35	
Tromsø 5-7 (2001-16)	*n*					
Tromsø 6-7 (2007-16)	*1146*	*481*	*501*	*60*	*104*	
BMI (kg/m^2)	Mean	0.07	0.35	0.14	0.21	0.20
	95%CI	-0.11 to 0.25	0.17 to 0.53	-0.36 to 0.64	-0.17 to 0.60	

Data are adjusted for sex, birth year, smoking, education and BMI at examination 2, and shown as adjusted mean and 95% CI. CI=confidence interval, BMI=body mass index, $P_{equality}$=main differences between groups,

**Period specific samples include all participants for that period (i.e. these samples do not add up to the overall cohort (Tromsø 1-7), which includes participants with their three most recent attendances), #Tromsø 1 included only men.*

DISCUSSION

In this large Norwegian population-based prospective study over four decades, we found no association between occupational physical activity changes and future BMI and weight changes.

Most previous longitudinal studies examined the association between baseline occupational physical activity and future BMI change[13-16], which do not account for the reciprocal temporal changes in physical activity and BMI[4]. Two studies assessed changes in both occupational physical activity and BMI where one found lower occupational physical activity to be associated with weight gain[12], while one found no association[17]. Without adjustment for previous physical activity levels, the direction of association and thus indication of causality, remains uncertain[4]. Our study corroborate the findings of a recent study by Dobson et al[23], which regressed trajectories of self-reported BMI (i.e. weight and height) on physical work exertion trajectories over nine time points in Canadian adults and showed that physical work exertion change was not associated with BMI trajectories, except for a higher odds of being in a very obese trajectory (from 36 to 40 kg/m^2 at follow up) compared with a reference normal weight trajectory (22 to 24 km/m^2) with no higher odds of other BMI trajectories among those who decreased their physical work exertion compared with those who sustained low physical work exertion[23]. Our study expands the work by Dobson et al[23] by using measured weight and height on both examinations and non-dichotomized BMI change as the outcome. Consequently, with higher accuracy in the outcome[24], the observed magnitudes in the association between occupational physical activity change and BMI change can be interpreted with higher confidence[4].

As we did not adjust for energy intake due to unavailable data, our results may be influenced by residual confounding. Nevertheless, a previous study estimated that increasing physical activity energy expenditures of about 100 kilocalories (kcal) a day would be sufficient for weight gain prevention at the population level[25], indicating that equivalent decreases would result in weight gain. This is similar to the estimated lower energy expenditure deriving from declines in occupational physical activity[3]. As leisure time physical activity influence energy expenditure, one could hypothesize that occupational physical activity decline is only hazardous for those being physically inactive in leisure time. However, we observed no effect modification by leisure time physical activity changes.

It has been suggested that achieving energy balance and weight stability is easier at higher energy turnover[1]. For example, energy intake increased by 500 kilocalories (kcal) per day from the 1970s to 2000s in the United States, and 110-150 minutes of walking per day is needed to compensate for this increase[26]. Consequently, as 150 minutes of walking per day is up to seven times higher than the current recommendations for physical activity (150 minutes per week)[27] and considering that 1 out of 3 adults in western high income countries fail to meet the recommendations[28], it is unlikely that the physical activity volume performed by the general population is sufficiently high to prevent weight gain [29].

As occupational physical activity energy expenditure is dependent on activity duration, the effect of occupational physical activity on weight gain prevention may be influenced by whether individuals work full or part time. Thus, as we did not adjust for full and part time work due to unavailable data, this may also have introduced residual confounding. However, these energy expenditure differences may in reality be small. For example, heavy manual labour workers are estimated to work at ~30-35 % of maximal oxygen uptake over an 8 hours work day[30], which can be a sufficient volume to compensate the 500 kcal per day energy intake increase[26]. However, few individuals in the Tromsø Study report heavy manual labour (~8% in 1979-80, ~2% in 2015-16[10]). In contrast, most occupational physical activities in the Tromsø Study changed from standing and walking to sitting[10], which is consistent with some cohorts[3, 11, 12]. The energy expenditure difference while sitting compared with standing is estimated to be 54 kcals over 6 hours (i.e. 72 kcals over 8 hours)[31], which is unlikely to have any apparent effect on weight gain.

Some cohorts in Southern Europe include a substantially larger proportion of heavy manual labour workers (Portugal, 37 %[32], Spain, Barcelona, 68 %[17]), however, this is not consistent (Madrid, Spain: 2%[33], Italy: 8%[34]). Consequently, the generalizability of our findings may be limited to Northern/Central European[8-10] and North American[3, 11] high income countries. Potential weight gain prevention in heavy manual labour workers could be a future research target.

In our study, 741 (7%) participants are categorized as "*Active to Inactive*", while 1315 (12%) participants were categorized as "*Inactive to Active*" (Table 3), indicating that more individuals increased their occupational physical activity level in our cohort. However, this is due to our crude categorization of physical activity change; in our sensitivity analysis, 1315 (12%) are categorized as "*Active but decreasing*" (rank 4 or 3 → rank 3 or 2) (Supplementary Table 4), where these are categorized as "*Persistently Active*" in our main analysis (rank ≥2

→ rank ≥2) (Table 3). Thus, the consistent pattern of declining occupational physical activity levels as in previous studies[3, 7-10] is confirmed in our study.

Our results indicate that occupational physical activity declines play a minor, if any, role in the observed population gain in BMI and weight. Consequently, public health initiatives aimed at weight gain prevention may have greater success by focusing on other aspects than occupational physical activity, for example intake of energy dense food[2, 26].

The association between physical activity and BMI gain may also be reversed and/or bidirectional[4]. High body weight appears causally associated with lower levels of physical activity when examining these associations using a Mendelian randomization approach[35]. However, intuitively, leisure time physical activity is self-regulated while occupational physical activity is less controllable by the individual. Whether individuals regulate their occupational physical activity level depending on their BMI gain is questionable.

Strengths

First, as population gains in BMI have gradually increased over decades[36], the long follow-up time (~6 years) between each examination allowed us to examine whether occupational physical activity has contributed to BMI gain in this cohort[4]. Second, by computing change in physical activity followed by change in BMI (accounting for previous physical activity level), we are able to interpret the direction of the association with more certainty[4]. Third, by merging our period-specific samples to an overall cohort, we had higher power to examine multiple potential effect modifiers (Table 4). For example, one warranted effect modification to be elucidated in associations between occupational physical activity and health outcomes is sex[37]. Although we found differences in BMI gain by sex, we observed no effect modification of the associations by sex. Fourth, we used measured weight and height to calculate BMI as our outcome, which are more valid than self-reported weight and height[24], likely explained by social desirability bias. Finally, the efforts to recruit representative samples and the high attendance in the Tromsø Study surveys indicate high representability of the population[18].

Limitations

We categorized self-reported physical activity into crude groups, which have introduced misclassification, as described above. Thus, we may have missed potential energy expenditure changes deriving from physical activity that could influence energy balance. However, crude groups of self-reported physical activity are valuable for categorization of population levels of physical activity[38] and the SGPALS categorisations have previously shown associations with multiple health outcomes suggesting predictive validity of the instrument[20]. Moreover, our findings were unaltered when occupational physical activity change was categorised into six groups.

The recall and social desirability bias associated with self-reported physical activity likely results in over-reporting of physical activity levels[39], which is also demonstrated in office workers[40]. Over-reporting of physical activity under- or overestimates the effect magnitude between physical activity and health outcomes[4]. However, self-reported physical activity is currently the only instrument available in long term ongoing cohort studies[4]. Finally, as we did not adjust our models for energy intake and full/part time work due to unavailable data, our results may be influenced by residual confounding.

CONCLUSION

We observed no association between changes in occupational physical activity and subsequent changes in BMI. Our findings do not support the hypothesis that occupational physical activity declines contributed to population gains in BMI over the past decades. Public health initiatives aimed at weight gain prevention may have greater success if focusing on other aspects than occupational physical activity.

FIGURE LEGEND

Figure 1: The layout for the analyses assessing the association between physical activity changes and future BMI change. BMI=body mass index.

COMPETING INTERESTS

The authors confirm to have no competing interests.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the Tromsø Study but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. The data can be made available from the Tromsø Study upon application to the Data and Publication Committee for the Tromsø Study, see www.tromsostudy.com.

CONTRIBUTORS

EHS, BM, UE, LAH designed the study, EHS carried out data acquisition and analysis, OL and TW provided statistical expertise, all authors interpreted the study results, EHS drafted the manuscript, and all authors contributed with manuscript revisions and approved the final version of the manuscript.

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ETHICS APPROVAL

All participants in Tromsø 4-7 provided written informed consent and the present study was approved by the Regional Ethics Committee for Medical Research (ref. 2016/758410).

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