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Association between objectively measured physical activity and longitudinal changes in body composition in adolescents: the Tromsø study fit futures cohort

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ABSTRACT

Objectives Physical activity may be important in deterring the obesity epidemic. This study aimed to determine whether objectively measured physical activity in first year of upper secondary high school predicted changes in body composition over 2 years of follow-up in a cohort of Norwegian adolescents (n=431).

Design A longitudinal study of adolescents (mean age of 16 (SD 0.4) at baseline, 60.3% girls) participating in the Fit Futures studies 1 (2010–2011) and 2 (2012–2013).

Setting All eight upper secondary high schools in two municipalities in Northern Norway.

Participants Students participating in both studies and under the age of 18 at baseline and with valid measurement of physical activity at baseline and body composition in both surveys.

Primary and secondary outcomes Change in objectively measured body mass index and waist circumference and change in dual-energy X-ray absorptiometry measured fat mass index, lean mass index (LMI) and appendicular LMI (aLMI) between baseline and follow-up.

Results At baseline, boys had significantly higher physical activity volume (p=0.01) and spent on average of 6.4 (95% CI 2.1 to 10.6) more minutes in moderate-to-vigorous physical activity (MVPA) than girls (p<0.01). In girls, multivariate regression analyses showed that more sedentary time was negatively associated with changes in LMI (p<0.01) and aLMI (p<0.05), whereas more light activity had opposite effects on these measures (p<0.01 and p<0.05, respectively). No significant associations between measures of baseline physical activity and changes in body composition parameters were observed in boys.

Conclusions In this cohort of Norwegian adolescents, sedentary and light physical activity was associated with changes in LMI and aLMI in girls, but not boys. Minutes spent in MVPA in first year of upper secondary high school was not associated with changes in measures of body composition in neither sex after 2 years.

Strengths and limitations of this study

- ► This study used objective measures of physical activity.
- ► The study included objectively measured weight, height and waist circumference and dual-energy X-ray absorptiometry measures of fat and lean mass.
- ► We were not able to fully adjust for nutrition and not for pubertal development.
- ► The 431 participants with complete data from both baseline and follow-up represent 41% of those attending Fit Futures 1, indicating a degree of selection.

BACKGROUND

The potential of physical activity to prevent or treat a number of diseases has been highlighted by the WHO,[1] with inactivity accounting for 9% of worldwide premature mortality.[2] Public health guidelines state that adolescents should engage in moderate-to-vigorous physical activity (MVPA) ≥60 min/day,[3] but in 2011, only 50% of Norwegian, 15-year olds, met these recommendations.[4] During adolescence, there is a decline in both total physical activity and MVPA,[5 6] and many quit or reduce participation in organised sports.[7] As of 2013, the prevalence of overweight and obesity (body mass index (BMI) ≥25 kg/m^2) in Norwegians aged <20 years appears to be stabilising at around 20% in boys and 16% in girls—comparable to the Nordic countries.[8] This is lower than in the USA (around 29% in boys and girls),[8] but the health effects for those concerned may still be substantial over the long term.[9]

While physical activity has many positive health effects, its relationship with adiposity is less clear and it has proven difficult to determine causality, direction and magnitude of this relationship.[10] Cross-sectional research typically shows a strong inverse association between physical activity and weight status,[11] but temporality cannot be ascertained using such study designs.[12] Longitudinal studies may ascertain if lower physical activity precedes excess weight gain, but a review found no evidence for a relationship between objectively measured physical activity and body fat gain in adolescents.[12] The lack of congruent results may in part be explained by the diverse and inadequate measures of both exposure and outcome used in research of the association between physical activity and body composition.[10 11]

Although many methods to measure physical activity are available, the most common and most feasible is self-report, which commonly overestimates the total amount of physical activity.[13] Body composition is most commonly assessed using BMI, but BMI does not distinguish between fat and muscle mass.[14] This has the potential to cause misclassification of overweight status and may attenuate a true association between physical activity and fat or muscle mass. Thus, in the current study, we sought to overcome these limitations by applying objective measures of both physical activity and specific measures of body composition. Our aim was to investigate the association between objectively measured physical activity and changes in five different measures of body composition (BMI, waist circumference, fat mass index (FMI), lean mass index (LMI) and appendicular LMI (aLMI)) over 2 years of follow-up in a cohort of Norwegian adolescents.

METHODS AND MATERIALS

We used data from the first and second Fit Futures cohort studies, performed in 2010–2011 and 2012–2013, respectively. In the first study, we invited all students (n=1117) in their first year of upper secondary high school in the neighbouring municipalities of Tromsø and Balsfjord in Northern Norway, and 93% participated. The study was repeated 2 years later, when the students were in their last year of upper secondary high school or had started as apprentices if they studied vocational subjects. The second study included 868 participants, giving an attendance of 77%. All eight upper secondary high schools in the two municipalities participated in both studies. Altogether, 735 adolescents attended both surveys. For the present study, we excluded those aged ≥18 years of age at baseline (n=38). Some participants (n=240) did not have valid measurements of physical activity at baseline and were therefore not included in the study. We also excluded those with missing data on change in body composition parameters or variables included in the model (n=26). Thus, 431 participants were included in the present study (60.3% girls). Online supplemental appendix table 1 includes descriptive characteristics of the boys and girls with a valid baseline measurement of physical activity and variables included in the analyses, but who were missing follow-up data on body composition parameters (n=133).

Students were granted leave of absence from school to attend an examination at the Clinical Research Unit at the University Hospital of Northern Norway in both surveys. The participants attended a clinical examination where they also completed a questionnaire, which included questions on lifestyle, screen time, dietary habits and so on. The participants signed a letter of informed consent, and those under the age of 16 brought a letter of consent signed by their parent or guardian.

All measurements were performed by trained personnel. Height was measured to the nearest centimetre and weight to the nearest 100 g, wearing light clothing and using an automatic electronic scale/stadiometer (Jenix DS 102 stadiometer, Dong Sahn Jenix, Seoul, Korea). BMI was calculated as body weight in kilograms per height in meter square. Waist circumference was measured to the nearest 0.1 centimetre at the height of the umbilicus. Fat and soft tissue lean mass in grams was estimated by whole-body dual-energy X-ray absorptiometry (DXA) (GE Lunar Prodigy, Lunar Corporation, Madison, Wisconsin, USA). Fat mass comprises all fat, while soft tissue lean mass comprises all bodily tissue except fat and skeletal mass. These variables were used to calculate FMI, fat mass in kilograms per height in meter square and LMI, lean mass in kilograms/height in meter square. In addition, we calculated aLMI, which is the sum of soft tissue lean mass in kilograms in all four extremities divided by height in meter square. Although most commonly used in studies of sarcopenia in elderly,[15] this body composition parameter is arguably more specific to skeletal muscle mass than total LMI. The ability of DXA to detect changes in appendicular lean mass in young adolescents is good and has been validated against MRI.[16]

Physical activity was objectively measured using the ActiGraph GT3X accelerometer (ActiGraph, LLC, Pensacola, USA). Participants were instructed to wear the device on their right hip for 7 consecutive days and to remove it only when showering, swimming or sleeping. The ActiLife software was used to initialise the accelerometer and download data, which was imported into the Quality Control & Analysis Tool for data processing. This software was developed by the research group of professor Horsch in Matlab (The MathWorks, Massachusetts, USA) for processing of accelerometer data. The accelerometer was set in raw data mode, with a sampling frequency of 30 Hz and with normal filtering epochs of 10 s. Data collection was initiated at 14:00 hours the first day and concluded at 23:58 on the eighth day of measurement. We excluded data from the first day of measurement to reduce reactivity bias. The criteria for a valid measurement of physical activity was wear time of ≥4 consecutive days, with ≥10 hours wear time per day. This has been demonstrated as representative of activity over a full week.[17] The triaxial algorithm developed by Hecht *et al* was used to calculate wear time.[18] Minutes per day in sedentary (0–99 cpm), light (100–1951 cpm), moderate (1952–5723 cpm) and vigorous (≥5724 cpm) physical activity was determined using the cut-offs developed by Freedson.[19] The choice of these cut-offs enables direct comparisons as the cohort ages, although these cut-offs are not commonly used for adolescents, we consider the bodily proportions of an adolescent to resemble that of an adult in terms of measured acceleration. The device collected data in both uniaxial and triaxial modes, but in the present study, only the uniaxial data had been processed and therefore available. Studies have shown that uniaxial data recorded from the GT3X correlate well with uniaxial data recorded from previous ActiGraph models.[20] Data on objectively measured physical activity were only available from Fit Futures 1.

Baseline characteristics were presented as means with SD or prevalence in percentages with number of subjects (n). Sex-specific difference in body composition between baseline and follow-up was tested using a paired samples t-test. The difference in physical activity between sexes was tested using a two-sample t-test, while sex differences in categories of minutes spent in MVPA was tested using a χ^2 test. Difference in linear trend across categories of minutes spent in MVPA was tested using STATA's non-parametric test for trend, developed by Cuzick.[21] Linear regression was used to determine the effect of baseline physical activity on change in body composition, that is, the change in BMI, waist circumference, FMI, LMI and aLMI from the first to the second Fit Futures Study.

We used three different predictors of change in body composition, performing three sets of analyses, with first; minutes per day spent in sedentary activity second; minutes per day spent in light activity and third; minutes per day spent in MVPA . We divided the continuous variables sedentary and light activity by 30 and the continuous variable MVPA by 15 before inclusion in the models, thus presenting the beta coefficient for change in body composition parameter per 30 minof sedentary or light activity, or per 15 min of MVPA, with 95% CIs and a p value. In model 1, we adjusted for the baseline measurement of the body composition parameter. In the adjusted models (model 2), we also included time between measurements (mean (SD): 730 (74) days) and baseline values of device wear time, age in half years and questionnaire data on screen time on weekdays (how many hours per weekday the students spent in front of a computer or television—answers ranged from none to more than 10 hours per weekday) and regularity of eating breakfast as an indicator of healthy meal patterns (answers ranging from rarely/never to everyday). In the analyses of sedentary and light activity, we also adjusted for minutes spent in MVPA (model 3). In a subset of analyses (online supplemental appendix tables 2–4), we repeated the analyses performed in tables 2 and 3, adjusting also for self-reported pubertal status measured by either pubertal development scale (boys) or age at menarche (girls). These analyses included the 143 boys and 256 girls with valid data on pubertal status. In all the analyses, a p value of <0.05 was considered statistically significant.

All analyses were performed sex specific as decided a priori, using STATA V.14 (StataCorp. 2015. Stata Statistical Software: Release 14. College Station, Texas, USA: StataCorp LP.).

Patient and public involvement

Participating schools were consulted and included in the design phase of the study.

RESULTS

Table 1 displays the participants' body composition measurements at baseline and follow-up as well as physical activity measurements at baseline. Boys had a statistically significant increase in all measures of body composition. Girls had a statistically significant increase in body weight, BMI, fat mass in kilogram and FMI, but not in LMI and appendicular lean mass. Boys were statistically significantly more physically active than girls in some aspects, with higher mean counts per minute (p=0.01) and more minutes in MVPA (p<0.01). Time spent in sedentary or light intensities did not differ significantly between sexes. Twenty-seven per cent of boys and 17% of girls complied with the recommendations of 60 min/day MVPA.

Table 2 displays the association between minutes spent in sedentary activity at baseline and changes in body composition between baseline and follow-up. There was no association between sedentary activity and changes in BMI, waist circumference and FMI in neither boys nor girls. In girls, but not in boys, more minutes spent in sedentary activity at baseline was associated with lower LMI (p<0.01) and aLMI (p=0.02). Adjustment for covariates and MVPA slightly attenuated the association with aLMI (p=0.05).

Table 3 displays the association between minutes spent in light activity at baseline and changes in body composition between baseline and follow-up. There was no association between the exposure and either body composition parameter in boys. In girls, there was some evidence to suggest an association with change in waist circumference (p=0.05), but the association was attenuated after adjustments (p=0.17). More minutes spent in light physical activity was associated with higher LMI (p<0.01 (models 2 and 3)) and aLMI (p=0.04 (model 2) and 0.05 (model 3)).

Table 4 displays the association between minutes in MVPA at baseline and changes in body composition between baseline and follow-up. There was no association between time spent in MVPA and changes in either measure of body composition for either sex.

Online supplemental appendix table 1 shows the descriptive characteristics of the participants with valid baseline measurements of physical activity and adjustment variables, but who were lost to follow-up. Both boys and girls lost to follow-up had significantly higher mean BMI, waist circumference, fat mass and FMI at baseline as well as significantly less minutes per day spent in light-to-vigorous and moderate-to-vigorous (girls only) physical activities. In online supplemental appendix tables 2–4, we present subanalyses restricted to those with complete data on pubertal development, confirming the results displayed in tables 2–4 also after adjustments for pubertal development. Overall, adjustment for pubertal

Table 1 Characteristics of the longitudinal cohort of the Tromsø study; Fit Futures 2010–2011 and 2012–2013*

	Boys (n=171)		Girls (n=260)	
	FF1	FF2	FF1	FF2
Age (years)	16.0 (0.4)	18.2 (0.4)	16.1 (0.4)	18.1 (0.4)
Height (cm)	177.1 (6.6)	179.0 (6.5)*	165.4 (6.6)	166.1 (6.6)*
Body weight (kg)	69.0 (12.3)	74.3 (13.0)*	60.8 (10.8)	63.4 (11.6)*
Body mass index (BMI kg/m2)	22.0 (3.5)	23.2 (3.7)*	22.2 (3.7)	23.0 (4.0)*
Waist circumference (cm)	81.0 (10.3)	83.9 (10.9)*	76.7 (9.8)	78.0 (10.8)*
Total body fat mass (kg)	13.3 (9.4)	15.6 (10.4)*	19.9 (8.3)	21.7 (9.1)*
FMI (kg/m^2)	4.2 (3.0)	4.9 (3.2)*	7.3 (3.0)	7.9 (3.3)*
Total body lean mass (kg)	54.0 (6.5)	56.4 (6.9)*	38.9 (4.5)	39.3 (4.7)*
LMI (kg/m^2)	17.2 (1.6)	17.6 (1.8)*	14.2 (1.3)	14.2 (1.4)
Appendicular lean mass (kg)	25.3 (3.4)	26.2 (3.6)*	17.4 (2.3)	17.4 (2.3)
aLMI (kg/m^2)	8.1 (0.9)	8.2 (0.9)*	6.4 (0.7)	6.3 (0.7)*
Accelerometer variables				
Wear time per valid day	14.2 (1.2)		14.1 (1.1)	
Counts per minute	362.9 (137.5)		334.0 (111.9)‡	
Minutes per day in different intensities				
Sedentary (cpm 0–99)	573.3 (77.3)		565.3 (63.2)	
Light (cpm 100–1951)	230.5 (58.8)		236.2 (48.4)	
Moderate (cpm 1952–5723)	45.8 (20.6)		40.2 (17.7)‡	
Vigorous (cpm ≥5724)	3.7 (5.8)		2.9 (4.1)‡	
MVPA§ (cpm ≥1952)	49.5 (23.4)		43.1 (19.6)‡	
Meeting MVPA guidelines per day				
0–29 min	35 (20.5)		69 (26.5)	
30–59 min	90 (52.6)		146 (56.2)	
≥60 min	46 (26.9)		45 (17.3)¶	

*Values are means with SD or n (prevalence in percentages). BMI: body weight in kg/height in meters^2, FMI: fat mass in kg/height in meters^2, LMI: lean mass in kg/height in meters^2, aLMI: appendicular lean mass in kg/height in meters^2. Data on physical activity in FF2 was not available.
†Significantly different from baseline measurement (p<0.05).
‡Significantly different from boys (mean).
§MVPA: moderate to vigorous physical activity, using cut-offs suggested by Freedson.[19]
¶Significantly different linear trend from boys (p<0.05).

development had no substantial impact on an association between sedentary, light and MVPA and changes in body composition for either sex in complete case analyses. However, the association between minutes spent in sedentary activity and light activity and changes in aLMI were no longer significant for girls in model 3. The point estimates did not differ from those from analyses without adjustments for pubertal development, however.

DISCUSSION

In this longitudinal population-based study of Norwegian adolescents, there were in both boys and girls no associations between objectively measured physical activity at baseline and 2-year changes in BMI, waist circumference and FMI. Both boys and girls had statistically significant increases in the measures of body composition (except LMI and appendicular lean mass in girls). Objectively measured physical activity did not predict changes in boys. In girls, there was a significant association between minutes spent in sedentary and light physical activity and changes in indices of lean mass.

Although the magnitude of change differed, both sexes experienced increases in measures of body composition. In boys, FMI increased by 0.7 units (+16.7%), whereas LMI increased by 0.4 units (+2.3 %) from baseline. Similar relative changes were observed in girls, (FMI+8.2 %) and (LMI+0.7%), indicating that FMI increases relatively more than LMI during late adolescence. We observed statistically significant differences in minutes spent in moderate (p<0.01) and vigorous (p=0.04) intensity between boys and girls, but time spent in other intensity levels did not differ. Differences in physical activity by sex are consistent

Table 2 Association between minutes per day spent in sedentary activity (cpm 0–99) at baseline and changes in body composition*

	Boys (n=171)			Girls (n=260)		
	Beta	95% CI	P value	Beta	95% CI	P value
Δ BMI						
Model 1	−0.02	−0.13 to 0.09	0.76	−0.05	−0.15 to 0.05	0.33
Model 2	−0.02	−0.17 to 0.12	0.75	−0.11	−0.24 to 0.03	0.12
Model 3	0.01	−0.17 to 0.20	0.88	−0.11	−0.27 to 0.05	0.16
Δ waist circumference						
Model 1	0.17	−0.21 to 0.56	0.37	−0.01	−0.41 to 0.40	0.96
Model 2	0.27	−0.24 to 0.78	0.30	−0.33	−0.87 to 0.20	0.22
Model 3	0.42	−0.23 to 1.07	0.20	−0.44	−1.06 to 0.18	0.17
Δ FMI						
Model 1	0.00	−0.10 to 0.10	0.99	−0.01	−0.11 to 0.08	0.83
Model 2	−0.02	−0.16 to 0.11	0.74	−0.06	−0.18 to 0.07	0.36
Model 3	0.00	−0.17 to 0.17	0.98	−0.05	−0.20 to 0.09	0.48
Δ LMI						
Model 1	0.00	−0.05 to 0.05	0.88	−0.06	-0.09, to 0.02	<0.01
Model 2	0.01	−0.06 to 0.07	0.77	−0.07	-0.12, to 0.02	<0.01
Model 3	0.02	−0.06 to 0.10	0.63	−0.08	-0.13, to 0.03	<0.01
Δ aLMI						
Model 1	0.00	−0.03 to 0.03	0.84	−0.02	-0.04, to 0.00	0.02
Model 2	0.00	−0.03 to 0.04	0.81	−0.03	-0.05, to 0.01	0.02
Model 3	0.01	−0.04 to 0.05	0.71	−0.03	−0.06 to 0.00	0.05

*The table displays the association between minutes spent in sedentary activity and difference in BMI (kg/m^2), waist circumference, FMI (fat mass in kg/m^2), LMI (lean mass in kg/m^2) and aLMI (appendicular lean mass in kg/m^2) between Fit Futures 1 (2010–2011) and Fit Futures 2 (2012–2013). The models give the beta coefficient for 30 min increase in sedentary activity. All models were adjusted for baseline values of the body composition parameter. In model 2 also adjusted for time between measurements and baseline values of screen time on weekdays, study specialisation, age in half-years, regularity of eating breakfast and device wear time. In model 3 adjusted also for minutes spent in moderate-to-vigorous physical activity (cpm≥1952).
aLMI, appendicular LMI; BMI, body mass index; FMI, fat mass index; LMI, lean mass index .

with the previous research.[22 23] Differences in changes in body composition by sex are biologically determined during adolescence, with sex hormones resulting in fat mass accrual in girls and lean mass accrual in boys.[24 25] The observation that sedentary and light activity-predicted changes in indices of lean mass in girls, but not boys, may be explained by these expected biological differences. Physical activity may have somewhat greater potential to influence lean mass accrual in girls than in boys during this period, as fat-free mass is relatively stable in girls in late adolescence, whereas it increases up to 18 years of age in boys.[26]

In the present study, sedentary and light activity had opposing effects on lean mass in girls. In a study using isotemporal substitution models, positive prospective effects on fat mass were found when substituting 30 min of sedentary activity with MVPA, but not when substituted with light activity.[27] It is reasonable that sedentary and light physical activity has opposing effects on lean mass.[28] In the present study, sedentary and light activity was inversely correlated (r=−0.39), but minutes spent in different intensity levels is not directly a function of each other as wear time in the participants varies between individuals. Based on wear time inclusion criteria, the theoretical time span for wear time lies between 10 and 24 hours. Thus, minutes spent in sedentary activity may not be deduced from the sum of minutes spent in other intensities and vice versa, but it is plausible that higher wear time results in more sedentary time. This was evident in an exploratory analyses on the same cohort (not included in the present study), where higher wear time was significantly associated with more sedentary activity and less light activity (p<0.01). Adjusting for wear time (model 2) did not change the associations substantially for sedentary activity (table 2), but had some effect on the associations with light physical activity (table 3). Because of the inverse relationship between minutes spent sedentary and in light activity, it is not possible to determine whether it is sedentary time or light activity time that is associated with change in LMI. The practical consequences are nevertheless that being active increases lean mass in girls.

Table 3 Association between minutes per day spent in light activity (cpm 100–1951) at baseline and changes in body composition*

	Boys (n=171)			Girls (n=260)		
	Beta	95% CI	P value	Beta	95% CI	P value
Δ BMI						
Model 1	0.04	−0.11 to 0.18	0.60	0.05	−0.09 to 0.19	0.47
Model 2	0.01	−0.17 to 0.18	0.93	0.12	−0.04 to 0.27	0.13
Model 3	−0.01	−0.20 to 0.17	0.88	0.11	−0.05 to 0.27	0.16
Δ waist circumference						
Model 1	−0.11	−0.62 to 0.40	0.68	0.54	0.01 to 1.07	0.05
Model 2	−0.38	−1.00 to 0.23	0.22	0.43	−0.19 to 1.05	0.17
Model 3	−0.42	−1.07 to 0.23	0.20	0.44	−0.19 to 1.06	0.17
Δ FMI						
Model 1	0.03	−0.10 to 0.16	0.67	0.02	−0.10 to 0.15	0.71
Model 2	0.01	−0.15 to 0.18	0.87	0.06	−0.09 to 0.20	0.43
Model 3	−0.00	−0.17 to 0.17	0.98	0.05	−0.09 to 0.20	0.49
Δ LMI						
Model 1	−0.01	−0.07 to 0.06	0.84	0.04	−0.01 to 0.09	0.08
Model 2	−0.02	−0.09 to 0.06	0.67	0.08	0.03 to 0.13	<0.01
Model 3	−0.02	−0.10 to 0.06	0.63	0.08	0.03 to 0.13	<0.01
Δ aLMI						
Model 1	0.00	−0.03 to 0.04	0.87	0.02	−0.01 to 0.04	0.16
Model 2	−0.01	−0.05 to 0.04	0.73	0.03	0.00 to 0.06	0.04
Model 3	−0.01	−0.05 to 0.04	0.70	0.03	−0.00 to 0.06	0.05

*The table displays the association between minutes spent in light activity and difference in BMI (kg/m^2), waist circumference, FMI (fat mass in kg/m^2), LMI (lean mass in kg/m^2) and aLMI (appendicular lean mass in kg/m^2) between Fit Futures 1 (2010–2011) and Fit Futures 2 (2012–2013). The models give the beta coefficient for 30 min increase in light activity. All models were adjusted for baseline values of the body composition parameter. In model 2 also adjusted for time between measurements and baseline values of screen time on weekdays, study specialisation, age in half-years, regularity of eating breakfast and device wear time. In Model 3 adjusted also for minutes spent in moderate-to-vigorous physical activity (cpm≥1952).
aLMI, appendicular LMI; BMI, body weight index; FMI, fat mass index; LMI, lean mass index.

When interpreting results, we must acknowledge the limitations of DXA in the estimation of lean mass, which can be affected by both biological factors and measurement error.[29] Because the relative increase in lean mass was small, only slight differences in, for instance, individual hydration status at the two time points may influence estimates and thus the association.

There were no associations between objectively measured physical activity and change in BMI, waist circumference and FMI for either sex. It may be that the negative effects of less physical activity have not yet had time to manifest themselves in a population still undergoing physiological changes as a result of natural growth, especially considering the relatively short 2-year follow-up. Our results are in line with a systematic review suggesting that objectively measured physical activity (PA) is not an important predictor of change in adiposity in children, adolescents and adults.[12] In contrast, another systematic review found a protective effect of physical activity on adiposity in adolescents.[10] There were however several methodological weaknesses in the studies included in this review, particularly regarding the validity of the measurement of both physical activity and body composition. In contrast, our study employed robust measures of both these exposures and outcomes, a combination of which is lacking in much past research on the association between the two.[10–12]

In adolescents, physical activity is influenced by friends, family and other social support[30] and is less stable than in adults.[31–33] Follow-up data on objectively measured physical activity were not available in the present study, but some evidence suggest that the decline in physical activity is steeper prior to the onset of adolescence.[34] Reductions in level of physical activity during the transition from adolescence to young adulthood nevertheless often occur.[35] Prior observations from the same cohort showed that change in self-reported physical activity between baseline and follow-up was a stronger predictor of change in body composition than self-reported baseline physical activity.[36] Other studies have suggested that change in activity during follow-up might obscure an association with body composition.[37 38] In a subanalyses,

Table 4 Association between minutes per day spent in MVPA (cpm≥1952) at baseline and changes in body composition*

	Boys (n=171)			Girls (n=260)		
	Beta	95% CI	P value	Beta	95% CI	P value
Δ BMI						
Model 1	0.11	–0.07 to 0.30	0.22	–0.00	–0.17 to 0.16	0.97
Model 2	0.08	–0.13 to 0.29	0.47	0.07	–0.11 to 0.25	0.47
Δ waist circumference						
Model 1	0.25	–0.39 to 0.89	0.44	–0.03	–0.68 to 0.63	0.94
Model 2	–0.02	–0.75 to 0.71	0.95	0.02	–0.70 to 0.74	0.96
Δ FMI						
Model 1	0.02	–0.15 to 0.19	0.83	–0.01	–0.17 to 0.14	0.86
Model 2	0.06	–0.14 to 0.25	0.57	0.05	–0.12 to 0.22	0.54
Δ LMI						
Model 1	0.07	–0.02 to 0.15	0.11	0.03	–0.03 to 0.09	0.33
Model 2	0.01	–0.08 to 0.10	0.86	0.02	–0.04 to 0.09	0.44
Δ aLMI						
Model 1	0.03	–0.02 to 0.08	0.19	0.02	–0.01 to 0.05	0.13
Model 2	0.00	–0.05 to 0.05	0.92	0.02	–0.01 to 0.05	0.18

*The table displays the association between minutes spent in moderate-to-vigorous physical activity (MVPA) and difference in BMI (kg/m^2), waist circumference, FMI (fat mass in kg/m^2), LMI (lean mass in kg/m^2) and aLMI (appendicular lean mass in kg/m^2) between Fit Futures 1 (2010–2011) and Fit Futures 2 (2012–2013). The models give the beta coefficient for 15 min increase in MVPA. Both models were adjusted for baseline values of the body composition parameter. In model 2 also adjusted for time between measurements and baseline values of screen time on weekdays, study specialisation, age in half-years, regularity of eating breakfast and device wear time.
aLMI, appendicular LMI ; BMI, body mass index; FMI, fat mass index ; LMI, lean mass index .

one of four in both the highest and lowest categories of MVPA at baseline reported decreased (high MVPA at baseline) and increased (low MVPA at baseline) self-reported physical activity at follow-up, thus indicating that physical activity in adolescents is fluctuant. These two observations, assuming that measurement of both MVPA and self-reported hours per week of physical activity, are representative of actual physical activity behaviour at the time, work in opposing directions with regards to the effect of physical activity on changes in adiposity. This phenomenon is known as regression dilution bias and may flatten the regression slope and cause an underestimate of the actual association.[39] With an annual decline in total physical activity of 7% in adolescents, researchers must consider the possibility that measured physical activity has a 'best before-date'. It remains questionable whether baseline measurements of a fluctuant behaviour such as physical activity is representative of actual habits during the period of follow-up. It may be that the measurement represents current, but not future (or even prior) habits.[12 40] This has implications for longitudinal studies of the relationship between physical activity and body composition.[38]

Strengths and limitations

The primary strength of this study is objective measures of both physical activity and body composition parameters and the inclusion of tissue-specific measures of body composition. Some limitations have to be considered. As the Fit Futures study did not include a validated food frequency questionnaire or similar instrument for nutritional assessment, we were not able to fully adjust for the potential confounding effects of nutrition and changes in food habits of adolescents on changes in body composition. Accelerometer-measured physical activity has limitations. A hip worn accelerometer such as the ActiGraph GT3X is not able to correctly measure cycling and swimming.[41] Furthermore, accelerometers are dependent on user compliance, and non-wear time therefore affects the amount of activity that is actually measured. Subjective judgement determines data management and analyses, for example, the decision to exclude participants with wear time <10 hours and <4 consecutive days is a trade-off between quality of data and the number of participants with valid data. We lacked complete data on physical activity and adjustment variables in 212 participants, but changes in BMI, waist circumference, FMI, LMI (except in girls, p=0.04) and aLMI were not significantly different between those with and without complete exposure data. Furthermore, of those with valid data concerning both physical activity and body composition parameters at baseline, close to 25% did not attend the follow-up (online supplemental appendix table 1). This group differed significantly from those included in the main analyses with respect to both physical activity and body composition parameters. The prospective associations between physical activity and changes in body composition parameters in this group (n=133) may be different from those observed in the group of participants included in the main analyses (n=431), and the associations in all the 564 participants with valid baseline data may therefore be different from what we find in the main analyses. This is however not possible to determine given the lack of follow-up data.

Although longitudinal observational studies are superior to cross-sectional studies to examine causation, they are also susceptible to directional bias, since participants may avoid physical activity because they are overweight, and not be overweight because they are inactive.[42–44] Finally, as the participants were 16 years old, much may already have happened both to the level of physical activity and the different measures of body composition prior to participation. In light of this, 2 years of follow-up may be a short time frame to determine the potential effects of physical activity on changes in the different body composition parameters.

CONCLUSION

Objectively measured physical activity was not significantly associated with change in objectively measured BMI, waist circumference or FMI after 2 years in this cohort of Norwegian adolescents. There was evidence to suggest that sedentary and light activity affected indices of lean mass in girls, but not boys.

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