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Physically active adults have lower body fat percentage, after adjusting for BMI: a cross-sectional analysis of UK Biobank

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Abstract

Objectives: The objective of this study was to examine if physically active adults have less body fat after taking BMI into account.

Design: A cross-sectional analysis of participants recruited into UK Biobank in 2006-2010. **Setting:** UK Biobank assessment centres throughout the UK.

Participants: 119,230 men and 140,578 women aged 40-69 years, with complete physical activity information, and without a self-reported long-term illness, disability or infirmity.
Exposures: Physical activity measured as excess MET-hours per week, estimated from a combination of walking, and moderate and vigorous physical activity. BMI from measured height and weight.

Main outcome measure: Body fat percentage estimated from bio-impedance.

Results: BMI and body fat percentage were highly correlated (r=0.85 in women; r=0.79 in men), and both were inversely associated with physical activity. Compared to <5 excess metabolic equivalent (MET)-hours per week at baseline, \geq 100 excess MET-hours per week was associated with a 1.1 kg/m² lower BMI (27.1 versus 28.2 kg/m²) and 2.8 percentage points lower body fat (23.4% versus 26.3%) in men, and 2.2 kg/m² lower BMI (25.6 versus 27.7 kg/m²) and 4.0 percentage points lower body fat (33.9% versus 37.9%) in women. For a given BMI, greater physical activity was associated with lower average body fat percentage (for a BMI of 22.5-24.99 kg/m²: 2.0 (95% CI: 1.8 to 2.2) percentage points lower body fat in men, and 1.8 (95% CI: 1.6 to 2.0) percentage points lower body fat in women, comparing \geq 100 excess MET-hours per week to <5 excess MET-hours per week).

Conclusions: Physical activity was inversely associated with BMI and body fat percentage. For people with the same BMI, those who were more active had a lower body fat percentage.

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Strengths and limitations of this study

- This study of older adults, drawn from the general population, is very large (n = 259,808) and height and weight (for the calculation of BMI) were measured by trained staff using standardised techniques.
- Body fat percentage (estimated via bio-impedance) was available for virtually all participants.
- Physical activity was self-reported and therefore there will be some measurement error associated with this variable.
- The study is cross-sectional and therefore we cannot infer cause and effect.

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Introduction

Body mass index (BMI) is a simple index calculated from height and weight, and is usually used as a proxy for body fatness in large epidemiological studies. Correlations between BMI and more direct measures of body fatness are generally strong (r > 0.70) (1, 2).

Observational studies have shown that people who do comparatively more physical activity have a lower BMI than less active people (3, 4). Few large epidemiological studies have directly estimated body fatness, and it is of interest to examine whether more comprehensive measures of body fatness provide additional information above and beyond that which is captured by BMI. Previous studies each of approximately 500 young adults have found that, for a given BMI, athletes have a lower body fat percentage than non-athletes (5, 6); however it is unclear whether in the general population, including older adults, those who do more physical activity have a lower body fat percentage than those who do minimal physical activity, after taking into account BMI.

UK Biobank is a population-based cohort of 500,000 UK men and women, aged 40-69 years at recruitment. Body mass index and body fat percentage were measured at recruitment for virtually all participants. For this analysis of data from UK Biobank we aimed firstly to describe the associations of physical activity with BMI and body fat percentage, and secondly to determine whether physical activity is associated with body fat percentage, independently of BMI. We also examined whether the associations were influenced by important lifestyle factors.

METHODS

Subjects

UK Biobank is a prospective cohort of approximately 500,000 people aged 40-69 years, recruited in 2006-2010 in the UK (7). People aged 40-69 years who lived within reasonable travelling distance of 22 assessment centres were identified from National Health Service patient registers and invited to participate in UK Biobank by attending an assessment centre. Permission for access to patient records for recruitment was approved by the National Information Governance Board for Health and Social Care in England and Wales, and the Community Health Index Advisory Group in Scotland. A sub-sample of approximately 20,000 participants completed a full repeat of the assessment centre visit between August 2012 and June 2013, approximately 5 years after recruitment (8). UK Biobank has ethical approval from the North West Multi-centre Research Ethics Committee. The UK Biobank protocol is available online (http://www.ukbiobank.ac.uk/wp-content/uploads/2011/11/UK-Biobank-Protocol.pdf). The touchscreen questionnaire and other resources are also available on the UK Biobank website (http://www.ukbiobank.ac.uk/resources/).

Anthropometric measurements

At the UK Biobank assessment centres, a touchscreen questionnaire was used to collect information on socio-demographic characteristics and lifestyle exposures. Socks and shoes were removed and height was measured using the Seca 202 height measure (Seca, Hamburg, Germany). Weight and estimated percentage fat were measured with the Tanita BC418ma bio-impedance device (Tanita, Tokyo, Japan).

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Physical activity assessment

Questions on the touchscreen about walking, moderate physical activity, and vigorous physical activity, which were similar to those used in the short form of the International Physical Activity Questionnaire (9), were used to estimate excess metabolic equivalents (MET)-hours per week of physical activity during work and leisure time. For each of the three activity categories (walking, moderate physical activity, and vigorous physical activity) participants were asked how many days in a typical week they did each of the activities for 10 minutes or more (for walking: touchscreen question number WP1, UK Biobank variable n_864_0_0; for moderate physical activity: touchscreen question number WP2, UK Biobank variable n_884_0_0; for vigorous physical activity: touchscreen question number WP3, UK Biobank variable n_904_0_0). For each category, participants who entered one or more days were then asked how many minutes they spent doing those activities on a typical day (for walking: WP1A, n_874_0_0; for moderate physical activity: WP2A, n_894_0_0; for vigorous physical activity: WP3A, n_914_0_0). For each activity category, the number of reported days was multiplied by the number of reported minutes on a typical day to generate duration of activity in minutes per week.

Activity on a typical day of less than 10 minutes was recoded to 0 for any of the three categories of activity. For each of the three categories of activity, values of more than 1260 minutes per week (equivalent to an average of 3 hours per day) were truncated at 1260 (9).

Total MET values for each category from the International Physical Activity Questionnaire short form were: 3.3 for walking, 4.0 for moderate physical activity, and 8.0 for vigorous

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physical activity (9). We report excess METs, which are calculated by subtracting 1 MET from the value for each activity, and represent the energy expenditure above that of an inactive person (10). Excess MET values were therefore 2.3 for walking, 3.0 for moderate physical activity, and 7.0 for vigorous physical activity. Excess MET-hours per week were calculated by multiplying the excess MET value for each activity by the duration of activity in hours per week (9).

Exclusions

The UK Biobank dataset used for this analysis included 502,640 participants. Participants were excluded from this analysis if they selected 'Prefer not to answer' or 'Do not know' to any of the possible six questions on physical activity (WP1, WP1A, WP2, WP2A, WP3, WP3A) (n = 66,625). Participants were also excluded from this analysis if they responded to the question: "Do you have a long-term illness, disability or infirmity?" with 'Yes' (n = 159,941), 'Prefer not to answer' (n = 1,052) or 'Do not know' (n = 11,391), or if they had a missing value for this variable (n = 919) (touchscreen question number H4, UK Biobank variable $n_2188_0_0$). In addition, the questions used in the pilot study on the duration of physical activity differed from those in the main study, and participants who answered the pilot version of these questions were excluded (n = 2,253). Based on the International Physical Activity Questionnaire recommendations for data cleaning and processing (9), participants were also excluded from the analysis if the sum of walking, moderate physical activity, and vigorous physical activity was greater than 112 hours per week (n = 651), leaving a total of 259,808 participants in the present study.

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Statistics

STATA version 14.0 (Stata Corp LP, College Station, TX) was used for all statistical analyses. All analyses were done for men and women separately. Participant characteristics were described by level of physical activity (low, < 10.0; moderate, 10.0-49.9; high, ≥ 50 excess MET-hours per week). Pearson's correlation coefficients between BMI and body fat percentage were calculated. Multiple linear regression was used to calculate the mean body fat % in single units of BMI (e.g. 17.00-17.99, 18.00-18.99, 19.00-19.99 kg/m², etc), adjusted for age (5 year categories: < 45 years, 45-49.99 years, 50-54.99 years, 55-59.99 years, 60-64.99 years, \geq 65.00 years). Groups with 200 or more participants are shown in the Figure. Multiple linear regression was also used to calculate mean BMI and body fat percentage in categories of excess MET-hours per week (< 5, 5-9.9, 10-14.9, 15-24.9, 25-34.9, 35-49.9, 50-74.9, 75-99.9, \geq 100 excess MET-hours per week), adjusted for age (5 year categories, as above). For the final analysis, we used multiple linear regression to examine the association between physical activity (in excess MET-hours per week: < 5, 5-9.9, 10-14.9, 15-24.9, 25-34.9, 35-49.9, 50-74.9, 75-99.9, > 100) and body fat percentage (continuous variable). Body mass index (in 2.5 unit categories, e.g. < 18.50, 18.50-19.99, 20.00-22.49, 22.50-24.99, 25.00-27.49...,42.50-44.99, $\geq 45.00 \text{ kg/m}^2$, etc) and age (5 year categories) were included as covariates. We included a product term of excess MET-hours per week (categories, as above) and BMI (in 2.5 unit categories as above) in the model to calculate mean body fat percentage in categories of physical activity within strata of BMI. In additional sensitivity analyses, we adjusted for reported intakes of fruit and vegetables (< 3.00 servings/week, 3.00-3.99, 4.00- $4.99, 5.00-5.99, \ge 6.00$ servings/week, unknown), and red and processed meat (< 2.00) servings/week, 2.00-2.99, 3.00-3.99, 4.00-4.99, \geq 5.00 servings/week, unknown). We also restricted the analysis to those with a university or college degree, and separately, to those that do not have a job that usually or always involves standing or walking or manual work.

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We also examined mean BMI and body fat percentage in 5 year age categories. For each age decade separately (i.e. participants < 50 years, 50-59 years, and \geq 60 years) linear regression was used to calculate mean body fat percentage in single units of BMI, and to calculate mean BMI and body fat percentage in each category of physical activity (< 5, 5-9.9, 10-14.9, 15-24.9, 25-34.9, 35-49.9, 50-74.9, 75-99.9, \geq 100 excess MET-hours per week).

To explore the repeatability of self-reported physical activity, including effects of measurement error and possible changes in activity over time, we used a sub-sample of 10,225 UK Biobank participants who were eligible for the current study and who completed a repeat assessment visit approximately 5 years after recruitment (Supplementary Tables S1 and S2). For these participants, we calculated excess MET-hours per week from their answers to the touchscreen questionnaire completed at the repeat assessment centre visit, as described above. Then for each category of excess MET-hours per week defined at baseline, we calculated both the mean excess MET-hours per week at their baseline visit (to assess comparability of the sub-sample to the full cohort) and the mean excess MET-hours per week at the repeat visit (to assess measurement error in reporting physical activity and change over time). The sub-sample of participants who completed a repeat assessment centre visit approximately 5 years after recruitment was similar at baseline to the full cohort with regard to reported physical activity. However, at the repeat assessment, for participants in the highest category of physical activity defined at baseline (≥ 100 excess MET-hours per week), the mean excess MET-hours per week was much lower than at baseline (80 compared to 130) for both men and women). For the lowest category of physical activity defined at baseline, the mean excess MET-hours per week was somewhat higher at the repeat assessment than at

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baseline (12 compared to 2.6 for both men and women). Overall, this represents regression to the mean of almost 50% (calculated from the ratio of the range of mean values at the repeat assessment to the range of mean values at baseline). The Pearson's correlation coefficients between recruitment and repeat measurements of BMI and body fat percentage in the sub-sample of participants who completed a repeat assessment centre visit were 0.92 for both BMI and body fat percentage.

All *p* values were two-sided and *P* < 0.05 was considered statistically significant.

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RESULTS

Participant flow is shown in Figure 1. Participants who had a high level of physical activity were older, had a lower BMI, a lower body fat percentage, and a higher intake of fruit and vegetables than participants with a low level of physical activity (Table 1 and Table 2). They were also less likely to have a college or university degree, and much more likely to have a standing or manual job than those with a moderate or low level of physical activity. Participants with a moderate activity level were the least likely to be current smokers.

Body fat percentage was positively related to BMI (Figure 2). The correlation between BMI and body fat percentage was 0.85 in women, and 0.79 in men. At the same BMI, women had a much higher body fat percentage than men; for example, women with a BMI of 30.00-30.99 kg/m² had on average 41% body fat, whereas men with the same BMI had on average 28% body fat.

Body fat percentage and BMI were inversely related to physical activity (Figure 3). Men who did < 5 excess MET-hours of physical activity per week had, on average, a BMI of 28.2 kg/m² (95% Confidence Interval (CI): 28.2 to 28.3 kg/m²) and 26.3% (95% CI: 26.2 to 26.4 kg/m²) body fat. Men who did \geq 100 excess MET-hours per week of physical activity per week had, on average, a BMI of 27.1 kg/m² (95% CI: 27.0 to 27.2 kg/m²) and 23.4% (95% CI: 23.3 to 23.5%) body fat. Women who did < 5 excess MET-hours per week of physical activity per week had, on average, a BMI of 27.7 kg/m² (95% CI: 27.7 to 27.8 kg/m²) and 37.9% (95% CI: 37.8 to 38.0%) body fat. Women who did \geq 100 excess MET-hours per week of physical activity per week had, on average, a BMI of 27.7 kg/m² (95% CI: 27.7 to 27.8 kg/m²) and 37.9% (95% CI: 37.8 to 38.0%) body fat. Women who did \geq 100 excess MET-hours per week of physical activity per week had, on average, a BMI of 25.6 kg/m² (95% CI: 25.5 to 25.7 kg/m²) and a 33.9% (95% CI: 33.7 to 34.0%) body fat. For both men and women, as shown by the r² values, age and physical activity explained more of the variation in body fat

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percentage than the variation in BMI in this study population; however, age and physical activity only explained a small proportion of the variation in both BMI and body fat percentage in this study population, with all r^2 values less than 0.06 (Figure 3).

Overall, in males, those doing \geq 100 or more excess MET-hours per week compared with < 5 excess MET-hours per week had a 1.7 (95% CI: 1.6 to 1.7) percentage points lower body fat percentage, on average, after adjustment for BMI and age; in females it was on average 1.5 (95% CI: 1.4 to 1.6) percentage points lower. For both men and women, within each stratum of BMI, a higher physical activity level was associated with a lower body fat percentage, and the difference in body fat percentage between physical activity categories appeared to be slightly larger at lower BMIs (*p* for interaction using likelihood ratio test < 0.001, for both sexes) (Figure 4, Supplementary Tables S3 and S4). For a BMI of 22.5-24.99 kg/m², \geq 100 excess MET-hours per week vs < 5 excess MET-hours per week was associated with 2.0 (95% CI: 1.8 to 2.2) percentage points lower body fat in men and 1.9 (95% CI: 1.6 to 2.0) percentage points lower body fat in women. For both men and women, within each stratum of BMI, the mean BMI was very similar across the categories of physical activity.

When we further adjusted for reported intakes of fruit and vegetables, and red and processed meats, or restricted the analysis to those who did not have an active job or those who had a university or college degree, the results were not materially altered. Comparing those doing \geq 100 excess MET-hours per week to those doing < 5 excess MET-hours per week, body fat percentage was, on average 1.6 (95% CI: 1.5 to 1.7) percentage points lower for men and 1.4 (95% CI: 1.3 to 1.5) percentage points lower for women after adjustment for diet quality; 1.7 (95% CI: 1.6 to 1.9) percentage points lower for men and 1.6 (95% CI: 1.4 to 1.8) percentage points lower for women when restricting analyses to those who had a university or college

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degree; and 1.6 (95% CI: 1.5 to 1.7) percentage points lower for men and 1.4 (95% CI: 1.3 to 1.5) percentage points lower for women when we restricted analyses to those who did not have a standing or manual job.

In men, the mean BMI was similar across 5-year age categories however the mean body fat percentage was higher in older age groups. In women, the mean BMI by 5-year age categories was slightly higher in older age groups, and the mean body fat percentage was also higher in older age groups (Supplementary Table S5). The association between BMI and body fat percentage was similar in each age decade (Supplementary Figures S1, S2, and S3). The differences in BMI between the extreme categories of physical activity were slightly larger and the differences in body fat percentage were slightly smaller with older age (Supplementary Figures S4, S5 and S6).

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DISCUSSION

In this large sample of middle-aged British men and women, more physical activity was associated with both a lower BMI and a lower body fat percentage, although even men and women who did the most physical activity were, on average, overweight. More physical activity was also associated with a lower body fat percentage within each category of BMI, with an average 1-2 percentage points lower body fat in the most active, compared to the least active individuals. Most of the difference in body fat percentage with physical activity was between the very low and moderately-high levels of physical activity (<5 and 35-49.9 excess MET-hours per week, respectively); there was relatively little difference in body fat percentage between moderately-high and very high levels of physical activity (35-49.9 and ≥100 excess MET-hours per week, respectively).

The current study is large, and height and weight were measured by trained staff using standardised techniques. We examined whether important lifestyle factors (diet quality, education, and job type) which varied by physical activity level might modify the associations between physical activity, BMI and body fat percentage. In each of these sensitivity analyses, the results were essentially unchanged, although because this is an observational study we cannot rule out confounding by other factors. A limitation of the study is that physical activity approximately 5 years after baseline indicates approximately 50% regression to the mean, which represents both the error in reporting physical activity and true changes in physical activity over time. The likely consequence of regression to the mean in physical activity levels over time is bias of associations towards the null, so that the true association between physical activity and body composition measures is likely to be stronger than that observed in this study. The study is cross-sectional, and

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therefore we can only show associations between reported physical activity and contemporaneous body composition. We cannot infer cause and effect: lower levels of physical activity may lead to greater adiposity, but it is also possible that increased adiposity leads to less physical activity.

Small studies (n~500) in young adults have shown that, for a given BMI, athletes have a lower body fat percentage than non-athletes (5, 6). These findings are, however, of limited relevance to older adults in the general population, who experience the highest burden of obesity-related disease. An analysis of 466,605 participants in the China Kadoorie Biobank, aged 30-79 years, found relatively weak associations between physical activity and either BMI or body fat percentage: a difference of approximately 100 total MET-hours per week was associated with 0.15 kg/m² lower BMI, and 0.48 percentage points lower body fat (11). Participants in China Kadoorie Biobank differed from those in UK Biobank in ethnicity and lifestyle, and also had a lower average BMI (23.4 (SD 3.2) kg/m² in men; 23.8 (SD 3.4) kg/m² in women). Their physical activity levels were comparable to the middle to upper range of physical activity of UK Biobank participants, and in this range we also saw only a small difference in body fat percentage.

Variation in BMI in the general population is largely due to differences in body fatness, but by definition it incorporates both adipose and lean body mass, and it is therefore difficult to disentangle the roles of adipose and lean mass in associations of BMI with health outcomes. For example, a higher BMI is an established risk factor for post-menopausal breast cancer, and probably increases risk through higher circulating sex hormones produced by the enzyme aromatase in the adipose tissue from precursor androgens (12). Several cohort studies have also shown that more physical activity is associated with a reduced risk of post-menopausal

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breast cancer, even after adjustment for BMI, and this finding is often taken as evidence that physical activity is independent of adiposity as a risk factor for post-menopausal breast cancer (13). Our results suggest, however, that adjustment for BMI may not have fully controlled for adiposity in these analyses.

In conclusion, in this sample of middle-aged British adults who were free from self-reported long-standing illness, men and women who reported doing the most physical activity had a lower BMI and a lower body fat percentage than those who reported doing the least physical activity. We also report new evidence that, for a given BMI, men and women who reported doing more physical activity had a lower body fat percentage; the greatest difference was observed between low and moderate levels of physical activity. BMI incorporates both adipose and lean mass, but is most strongly related to adiposity, and consequently is associated with morbidity and mortality from a wide range of diseases. However, to disentangle the possible effects of physical activity and adiposity on disease risk, future research should focus on more specific measures of adiposity.

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Competing interests: All authors have completed the Unified Competing Interest form at <u>www.icmje.org/coi_disclosure.pdf</u> (available on request from the corresponding author) and declare no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years, no other relationships or activities that could appear to have influenced the submitted work.

Contributorship: KEB and TJK conceived the research, KEB performed the statistical analyses; BJC contributed to the statistical methodology; MEGA contributed to generation of the physical activity variables. KEB, WG, BJC, MEGA, and TJK interpreted the data, drafted and reviewed the article for important intellectual content, KEB has primary responsibility for the final content. All authors read and approved the final manuscript. KEB is the guarantor for the study. This research has been conducted using the UK Biobank Resource. **Ethics approval:** UK Biobank has ethical approval from the North West Multi-centre Research Ethics Committee. Participants gave informed consent on the touchscreen before taking part.

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Data sharing: UK Biobank is an open access resource. Bona fide researchers can apply to use the UK Biobank dataset by registering and applying at

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	Low activity	Moderate activity	High activity	All men
	< 10 excess	10-49.9 excess		
	MET-	MET-hours/wk ¹	\geq 50 excess	
	hours/wk ¹		MET-hours/wk ¹	
	<i>n</i> = 26,405	<i>n</i> = 63,022	<i>n</i> = 29,803	<i>n</i> = 119,230
Age (years)	3			
Mean (SD)	55.3 (8.0)	55.7 (8.4)	56.0 (8.4)	55.7 (8.3)
White ethnicity ^a	24,741 (93.7)	59,842 (95.0)	28,468 (95.5)	113,051 (94.8)
Socioeconomic status ^b				
Upper fifth	6,274 (23.8)	14,701 (23.4)	5,867 (19.7)	26,842 (22.5)
Qualifications ^c				
College or University degree/vocational qualification	18,878 (71.5)	45,453 (72.2)	17,731 (59.5)	82,062 (68.8)
BMI (kg/m ²) ^d				
Mean (SD)	28.0 (4.2)	27.1 (3.7)	27.1 (3.6)	27.3 (3.8)
< 20.00	238 (0.9)	559 (0.9)	289 (1.0)	1,086 (0.9)
20.00-24.99	5,849 (22.2)	17,425 (27.7)	8,326 (28.0)	31,600 (26.6)

Table1 Characteristics of men participating in UK Biobank by physical activity

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3					
4 5 6	25.00-29.99	13,220 (50.2)	32,745 (52.1)	15,403 (51.8)	61,368 (51.6)
7 8	≥ 30.00-34.99	7,015 (26.7)	12,135 (19.3)	5,699 (19.2)	24,849 (20.9)
9 10	Body fat (%) ^e				
11 12	Mean (SD)	25.8 (5.5)	24.2 (5.4)	23.6 (5.5)	24.4 (5.5)
13 14	< 15.00	761 (2.9)	3,062 (4.9)	1,945 (6.6)	5,768 (4.9)
15 16	15.00-19.99	2,810 (10.8)	9,714 (15.6)	5,148 (17.5)	17,672 (15.0)
17 18	20.00-24.99	7,714 (29.6)	21,023 (33.7)	10,080 (34.3)	38,817 (32.9)
19 20	25.00-29.99	9,194 (35.2)	19,816 (31.8)	8,686 (29.5)	37,696 (32.0)
21 22	\geq 30.00	5,629 (21.6)	8,703 (14.0)	3,558 (12.1)	17,890 (15.2)
23 24	Height $(m)^{f}$				
25 26	< 1.70	3,902 (14.8)	9,251 (14.7)	5,467 (18.4)	18,620 (15.7)
27 28	1.70 - 1.74	6,250 (23.8)	15,301 (24.4)	7,917 (26.6)	29,468 (24.8)
29 30	1.75 - 1.79	7,738 (29.4)	18,182 (28.9)	8,246 (27.8)	34,166 (28.7)
31 32	1.80 - 1.84	5,308 (20.2)	12,992 (20.7)	5,408 (18.2)	23,708 (19.9)
33 34	≥ 1.85	3,115 (11.8)	7,120 (11.3)	2,682 (9.0)	12,917 (10.9)
35 36	Mean (SD) excess MET-hours per week ^g	5.1 (2.9)	25.8 (11.0)	92.9 (43.3)	38.0 (40.1)
37 38 39 40 41	Standing or walking job ^h	2,524 (12.7)	9,766 (23.1)	12,961 (65.4)	25,251 (30.8)

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Manual job ¹	561 (2.8)	3,214 (7.6)	8,145 (41.1)	11,920 (14.6)
Smoking status ^{1j}				
Never	14,269 (54.0)	34,209 (54.3)	15,101 (50.7)	63,579 (53.3)
Previous	8,866 (33.6)	22,438 (35.6)	10,936 (36.7)	42,240 (35.4)
Current	3,215 (12.2)	6,252 (9.9)	3,680 (12.4)	13,147 (11.0)
Alcohol consumption ^k				
Three or more times a week	14,391 (54.5)	36,542 (58.0)	15,477 (52.0)	66,410 (55.8)
Fruit and vegetable consumption ¹				
< 3.00 servings per day	8,754 (33.2)	14,052 (22.3)	5,966 (20.0)	28,772 (24.1)
3.00-3.99 servings per day	6,031 (22.8)	13,370 (21.2)	5,204 (17.5)	24,605 (20.6)
4.00-4.99 servings per day	4,619 (17.5)	12,622 (20.0)	5,485 (18.4)	22,726 (19.1)
5.00-5.99 servings per day	2,926 (11.1)	8,930 (14.2)	4,389 (14.7)	16,245 (13.6)
\geq 6.00 servings per day	3,798 (14.4)	13,559 (21.5)	8,405 (28.2)	25,762 (21.6)
fotal red and processed meat consumption ^m				
< 2.00 times per week	2,120 (8.0)	5,838 (9.3)	2,956 (9.9)	10,914 (9.2)
2.00-2.99 times a week	6,291 (23.8)	16,042 (25.5)	7,170 (24.1)	29,503 (24.7)
3.00-3.99 times a week	3,927 (14.9)	9,323 (14.8)	4,186 (14.1)	17,436 (14.6)

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4.00-4.99 times a week	4,866 (18.4)	10,990 (17.4)	5,069 (17.0)	20,925 (17.6)
\geq 5.00 times a week	9,042 (34.2)	20,523 (32.6)	10,229 (34.3)	39,794 (33.4)
Values are number (%) unless otherwise stated				
Number of participants with missing data (the tot	al number participants who have m	issing data, or who rep	oorted 'do not know' o	r 'prefer not to
answer') for each characteristic is as follows: 0 for	or age, 377 for ethnicity, 159 for so	cioeconomic status, 70	95 for qualifications, 32	27 for BMI, 1,367
for body fat %, 351 for height, 0 for excess MET	-hours/wk, 57 for standing or walki	ng job, 38 for manual	job, 264 for smoking	status, 35 for
alcohol consumption, 1,120 for fruit and vegetab	le consumption, 658 for total red an	d processed meat cons	sumption	
^a Participants who reported their ethnicity as 'Whi	te', 'British', 'Irish', or 'Any other	white background'		
^b We generated quintiles of socioeconmic status b	ased on the Townsend deprivation	index for the whole col	hort (UK Biobank vari	able n_189_0_0)
^c Vocational qualifications defined as other professional qualification (eg: nursing or teaching)/ National Vocational Qualification or Higher				
National Diploma or Higher National Certificate) (touchscreen question number D12, UK Biobank variable n_6138_0_0)				
^d We preferentially used BMI derived from height and weight measured during the impedance measurement (UK Biobank variable n_23104_0_0),				
but if missing used the body size measures (UK I	Biobank variable n_21001_0_0); bo	oth of these are direct n	neasures of height and	weight made on
the same day at the assessment centre				
^e Body fat % (UK Biobank variable n_23099_0_0)			
^f Standing height (UK Biobank variable n_50_0_0))			
^g Excess MET-hours/wk estimated from the comb	ination of reported walking, moder	ate and vigorous physi	cal activity (for details	s see methods text)

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^hParticipants who reported their work 'usually' or 'always' involved walking or standing for most of the time (touchscreen question number D9B, UK Biobank variable n_806_0_0) ⁱParticipants who reported their work 'usually' or 'always' involved heavy manual or physical work for most of the time (touchscreen question

number D9C, UK Biobank variable n 816 0 0)

^jSmoking status (UK Biobank variable n_20116_0_0)

^kParticipants who reported consuming alcohol three to four times per week or daily or almost daily (touchscreen question number A1, UK Biobank variable n 1558 0 0)

¹Total fruit and vegetable consumption is the sum of fresh fruit intake (touchscreen question number DT3, UK Biobank variable n_1309_0_0), cooked vegetable intake (touchscreen question numbers DT1, UK Biobank variable n_1289_0_0) and raw vegetable intake (touchscreen question number DT1, and UK Biobank variable n_1299_0_0). To sum the frequencies, 'Less than one' was coded as 0.5, and we coded 1 piece of fresh fruit as a serving and 2 tablespoons of vegetables as a serving.

^mTotal red and processed meat consumption is the sum of processed meat (touchscreen question number DT8 and UK Biobank variable $n_1349_0_0$), beef (touchscreen question number DT7 and UK Biobank variable $n_1369_0_0$), lamb/mutton (touchscreen question number DT7A and UK Biobank variable $n_1379_0_0$), and pork (touchscreen question number DT7B and UK Biobank variable n_1389) intake. To sum the frequencies, we used the following coding: 'Never' = 0, 'Less than once a week' = 0.5, 'Once a week' = 1, '2-4 times a week' = 3, '5-6 times a week' = 5.5, 'Once or more daily' = 7.

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Table 2 Characteristics of women participating in UK Biobank by physical activity

	Low activity	Moderate activity	High activity	All women
	< 10 excess	10-49.9 excess		
	MET-	MET-hours/wk ¹	\geq 50 excess	
	n = 31,931	<i>n</i> = 78,171	m = 30,476	<i>n</i> = 140,578
Age (years)				
Mean (SD)	54.6 (7.8)	55.2 (8.1)	56.2 (8.1)	55.3 (8.1)
White ethnicity ^a	30,164 (94.5)	74,471 (95.3)	29,088 (95.5)	133,723 (95.1)
Socioeconomic status ^b				
Upper fifth	6,956 (21.8)	17,177 (22.0)	6,407 (21.0)	30,540 (21.8)
Qualifications ^c				
College or University degree/vocational qualification	19,320 (60.5)	49,219 (62.9)	17,826 (58.5)	86,365 (61.5)
BMI $(kg/m^2)^d$				
Mean (SD)	27.2 (5.1)	26.0 (4.4)	25.7 (4.2)	26.2 (4.6)
< 20.00	954 (3.0)	2,838 (3.6)	1,270 (4.2)	5,062 (3.6)

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20.00-24.99	10,930 (34.3)	33,256 (42.7)	13,749 (45.2)	57,935 (41.3)
25.00-29.99	12,037 (37.8)	29,041 (37.2)	11,062 (36.4)	52,140 (37.2)
≥ 30.00-34.99	7,930 (24.9)	12,839 (16.5)	4,334 (14.3)	25,103 (17.9)
Body fat (%) ^e				
Mean (SD)	37.1 (6.6)	35.2 (6.5)	34.4 (6.6)	35.5 (6.7)
< 25.00	1,197 (3.8)	4,842 (6.3)	2,524 (8.4)	8,563 (6.2)
25.00-29.99	3,256 (10.3)	11,220 (14.5)	4,920 (16.3)	19,396 (14.0)
30.00-34.99	7,011 (22.2)	20,467 (26.5)	8,224 (27.3)	35.702 (25.7)
35.00-39.99	9,129 (29.0)	22,181 (28.7)	8,347 (27.7)	39,657 (28.6)
≥ 40.00	10,940 (34.7)	18,506 (24.0)	6,110 (20.3)	35,556 (25.6)
Height $(m)^{f}$				
< 1.55	2,758 (8.7)	6,315 (8.1)	2,810 (9.2)	11,883 (8.5)
1.55 - 1.59	6,268 (19.7)	15,551 (19.9)	6,504 (21.4)	28,323 (20.2)
1.60 - 1.64	10,067 (31.6)	24,437 (31.3)	9,631 (31.7)	44,135 (31.5)
1.65 - 1.69	7,993 (25.1)	20,091 (25.8)	7,530 (24.8)	35,614 (25.4)
≥ 1.70	4,779 (15.0)	11,621 (14.9)	3,952 (13.0)	20,352 (14.5)
Mean (SD) excess MET-hours per week ^g	5.3 (2.8)	25.5 (10.9)	83.0 (33.3)	33.4 (32.5)

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Standing or walking job ^h	3,901 (17.4)	12,349 (25.7)	9,593 (56.3)	25,843 (29.53)
Manual job ⁱ	521 (2.3)	2,576 (5.4)	3,883 (22.8)	6,980 (8.0)
Smoking status ⁱ				
Never	19,513 (61.1)	47,974 (61.4)	18,370 (60.3)	85,857 (61.1)
Previous	9,468 (29.7)	24,366 (31.2)	9,635 (31.6)	43,469 (30.9)
Current	2,883 (9.0)	5,661 (7.2)	2,417 (7.9)	10,961 (7.8)
Alcohol consumption ^k				
Three or more times a week	12,670 (39.7)	33,747 (43.2)	12,137 (39.8)	58,554 (41.7)
Fruit and vegetable consumption ¹				
< 3.00 servings per day	6,601 (20.7)	9,849 (12.6)	3,070 (10.1)	19,520 (13.9)
3.00-3.99 servings per day	6,507 (20.4)	13,485 (17.3)	4,232 (13.9)	24,224 (17.2)
4.00-4.99 servings per day	6,672 (20.9)	16,489 (21.1)	5,701 (18.7)	28,862 (20.5)
5.00-5.99 servings per day	5,092 (16.0)	14,460 (18.5)	5,573 (18.3)	25,125 (17.9)
\geq 6.00 servings per day	6,874 (21.5)	23,557 (30.1)	11,740 (38.5)	42,171 (30.0)
Total red and processed meat consumption ^m				
< 2.00 times per week	5,462 (17.1)	15,254 (19.5)	6,729 (22.1)	27,445 (19.5)
2.00-2.99 times a week	10,903 (34.2)	27,329 (35.0)	10,190 (33.4)	48,422 (34.4)
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3.00-3.99 times a week	5,395 (16.9)	12,642 (16.2)	4,823 (15.8)	22,860 (16.3)
4.00-4.99 times a week	4,058 (12.7)	9,143 (11.7)	3,423 (11.2)	16,624 (11.8)
\geq 5.00 times a week	5,973 (18.7)	13,456 (17.2)	5,144 (16.9)	24,573 (17.5)

Values are number (%) unless otherwise stated

Number of participants with missing data (the total number participants who have missing data, or who reported 'do not know' or 'prefer not to answer') for each characteristic is as follows: 0 for age, 263 for ethnicity, 150 for socioeconomic status, 756 for qualifications, 338 for BMI, 1,704 for body fat %, 271 for height, 0 for excess MET-hours/wk, 64 for standing or walking job, 52 for manual job, 291 for smoking status, 44 for alcohol consumption, 676 for fruit and vegetable consumption, 655 for total red and processed meat consumption ^aParticipants who reported their ethnicity as 'White', 'British', 'Irish', or 'Any other white background' ^bWe generated quintiles of socioeconmic status based on the Townsend deprivation index for the whole cohort (UK Biobank variable n 189 0 0) [°]Vocational qualifications defined as other professional qualification (eg: nursing or teaching)/ National Vocational Qualification or Higher National Diploma or Higher National Certificate) (touchscreen question number D12, UK Biobank variable n 6138 0 0) ^dWe preferentially used BMI derived from height and weight measured during the impedance measurement (UK Biobank variable n 23104 0 0), but if missing used the body size measures (UK Biobank variable n 21001 0 0); both of these are direct measures of height and weight made on the same day at the assessment centre. ^eBody fat % (UK Biobank variable n 23099 0 0) ^fStanding height (UK Biobank variable n 50 0 0)

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^gExcess MET-hours/wk estimated from the combination of reported walking, moderate and vigorous physical activity (for details see methods text) ^hParticipants who reported their work 'usually' or 'always' involved walking or standing for most of the time (touchscreen question number D9B, UK Biobank variable n_806_0_0)

ⁱParticipants who reported their work 'usually' or 'always' involved heavy manual or physical work for most of the time (touchscreen question number D9C, UK Biobank variable n_816_0_0)

^jSmoking status (UK Biobank variable n_20116_0_0)

^kParticipants who reported consuming alcohol three to four times per week or daily or almost daily (touchscreen question number A1, UK Biobank variable n 1558 0 0)

¹Total fruit and vegetable consumption is the sum of fresh fruit intake (touchscreen question number DT3, UK Biobank variable n_1309_0_0), cooked vegetable intake (touchscreen question numbers DT1, UK Biobank variable n_1289_0_0) and raw vegetable intake (touchscreen question number DT1, and UK Biobank variable n_1299_0_0). To sum the frequencies, 'Less than one' was coded as 0.5, and we coded 1 piece of fresh fruit as a serving and 2 tablespoons of vegetables as a serving.

^mTotal red and processed meat consumption is the sum of processed meat (touchscreen question number DT8 and UK Biobank variable $n_{1349_0_0}$), beef (touchscreen question number DT7 and UK Biobank variable $n_{1369_0_0}$), lamb/mutton (touchscreen question number DT7A and UK Biobank variable $n_{1379_0_0}$), and pork (touchscreen question number DT7B and UK Biobank variable n_{1389}) intake. To sum the frequencies, we used the following coding: 'Never' = 0, 'Less than once a week' = 0.5, 'Once a week' = 1, '2-4 times a week' = 3, '5-6 times a week' = 5.5, 'Once or more daily' = 7.

Figure legends

Figure 1 UK Biobank participant flow diagram

MPA: moderate physical activity; VPA: vigorous physical activity

Figure 2 Body fat percentage by BMI in UK Biobank

Values are mean body fat % by single-unit BMI categories

Adjusted for age (5 year categories)

Error bars represent 1 SD either side of the mean

Estimates shown for cells with 200 or more participants

Figure 3 Mean BMI and body fat percentage by physical activity in UK Biobank

Panel A: Mean BMI by physical activity (excess MET-hours/wk); Panel B: Mean body fat %

by physical activity (excess MET-hrs/wk)

Values are mean BMI and body fat percentage in the following categories of physcial

activity: <5, 5-9.9, 10-14.9, 15-24.9, 25-34.9, 35-49.9, 50-74.9, 75-99.9, ≥ 100 excess MET-

hrs per week, and are plotted at the value of the mean excess MET-hours/wk in each category

Adjusted for age (5 year categories)

Errors bars are 95% CI

Estimates shown for cells with 200 or more participants

Figure 4 Mean body fat percentage by physical activity, stratified by BMI category in UK Biobank

Panel A: men; Panel B: women

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Values are mean body fat percentage in the following categories of physical activity: <5, 5-

9.9, 10-14.9, 15-24.9, 25-34.9, 35-49.9, 50-74.9, 75-99.9, ≥ 100 excess MET-hrs per week,

and are plotted at the value of the mean excess MET-hours/wk in each category

Estimates shown for cells with 200 or more participants

Adjusted for age (5 year categories)

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Blobank 5 years an	ter recruit	nent							
			Physica	l activity (excess ME	T-hours p	er week) ^a		
	<5	5-9.9	10-14.9	15-24.9	25-34.9	35-49.9	50-74.9	75-99.9	≥ 100
				All m	en (n = 11	9,230)			
Number of men	12,613	13,792	12,381	20,983	15,023	14,635	13,415	7,043	9,345
Baseline ^b	2.5	7.5	12.4	19.7	29.7	41.9	61.1	85.9	143.8
		Me	en who con	pleted the	repeat ass	sessment vi	isit ($n = 5$,	158)	
Number of men	602	614	534	943	691	631	541	279	323
Baseline ^b	2.6	7.6	12.4	19.7	29.8	42.1	60.5	85.6	133.3

Table S1 Repeated measures of physical activity in men who completed the repeat assessment visit in UK Dichards 5 A

^aCategories are defined from baseline data

Repeat^b

^bValues are mean excess MET-hours per week

12.2

16.3

20.8

<u>.2 40.3</u>

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Table S2 Repeated measures of physical activity in women who completed the repeat assessment visit in UK
Biobank 5 years after recruitment

			Physical	activity (excess ME	T-hours p	er week) ^a		
	<5	5-9.9	10-14.9	15-24.9	25-34.9	35-49.9	50-74.9	75-99.9	≥ 100
				All wor	men (n = 1)	40,578)			
Number of women	14,299	17,632	15,970	26,156	18,555	17,490	16,231	7,407	6,838
Baseline ^b	2.6	7.5	12.4	19.6	29.6	41.7	60.9	85.8	132.5
		Wom	en who co	mpleted th	e repeat a	ssessment	visit ($n =$	5,067)	
Number of women	515	659	606	1,004	681	640	555	229	178
Baseline ^b	2.6	7.6	12.3	19.6	29.7	41.7	61.0	85.0	133.0
Repeat ^b	11.9	18.5	21.3	26.1	33.2	40.6	52.8	59.2	80.7
^a Categories are defined	l from bas	seline dat	a						
^b Values are mean exces	ss MET-h	nours per	week						

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			Cat	tegories of phy	ysical activity	(MET-hours/	wk)		
Categories of BMI	<5	5-9.9	10-14.9	15-24.9	25-34.9	35-49.9	50-74.9	75-99.9	≥ 100
	16.6	16.1	15.7	15.4	14.9	15.0	15.0	14.1	14.3
20-	(16.3-16.8)	(15.9-16.4)	(15.4-15.9)	(15.3-15.6)	(14.7-15.1)	(14.7-15.2)	(14.8-15.2)	(13.8-14.4)	(14.0-14.6
	<i>n</i> = 649	<i>n</i> = 780	<i>n</i> = 743	n = 1356	<i>n</i> = 1014	n = 986	n = 940	<i>n</i> = 478	<i>n</i> = 658
Mean BMI	21.6	21.5	21.5	21.5	21.5	21.5	21.6	21.5	21.5
	19.9	19.7	19.2	19.1	18.6	18.6	18.4	17.9	17.9
22.5-	(19.8-20.1)	(19.6-19.8)	(19.0-19.3)	(19.0-19.2)	(18.5-18.7)	(18.4-18.7)	(18.3-18.6)	(17.7-18.1)	(17.8-18.1
	<i>n</i> = 1943	<i>n</i> = 2477	n = 2411	n = 4289	n = 3379	<i>n</i> = <i>3247</i>	n = 2851	n = 1490	n = 1909
Mean BMI	23.9	23.9	23.9	23.9	23.9	23.9	23.8	23.9	23.8
	23.0	22.7	22.4	22.2	21.9	21.7	21.6	21.3	21.2
25-	(22.9-23.1)	(22.6-22.8)	(22.3-22.5)	(22.1-22.3)	(21.8-22.0)	(21.6-21.8)	(21.5-21.7)	(21.1-21.4)	(21.1-21.3
	<i>n</i> = <i>3217</i>	n = 3861	n = 3606	n = 6180	n = 4428	n = 4419	n = 3960	n = 2095	n = 2694
Mean BMI	26.2	26.2	26.2	26.2	26.2	26.2	26.2	26.2	26.2
	25.7	25.4	25.2	25.0	24.7	24.6	24.5	24.4	24.2
27.5-	(25.6-25.8)	(25.3-25.5)	(25.1-25.3)	(24.9-25.1)	(24.6-24.9)	(24.4-24.7)	(24.3-24.6)	(24.2-24.6)	(24.0-24.3
	n = 2950	n = 3192	<i>n</i> = 2793	<i>n</i> = 4818	n = 3302	n = 3199	<i>n</i> = 2948	n = 1561	n = 2145
Mean BMI	28.6	28.6	28.6	28.6	28.6	28.6	28.6	28.6	28.6
	28.1	27.8	27.8	27.6	27.3	27.2	27.1	26.9	26.7
30-	(27.9-28.2)	(27.7-28.0)	(27.7-28.0)	(27.4-27.7)	(27.2-27.5)	(27.1-27.4)	(26.9-27.2)	(26.7-27.1)	(26.5-26.9
	n = 1867	n = 1780	n = 1498	n = 2409	n = 1644	n = 1585	n = 1560	n = 809	n = 1107
Mean BMI	31.1	31.1	31.1	31.0	31.0	31.0	31.0	31.0	31.0
	30.4	30.2	30.0	29.9	29.5	29.5	29.3	29.2	29.5
32.5-	(30.2-30.6)	(30.0-30.4)	(29.7-30.2)	(29.7-30.1)	(29.3-29.8)	(29.2-29.7)	(29.1-29.6)	(28.8-29.6)	(29.2-29.8
	n = 984	<i>n</i> = 873	<i>n</i> = 663	<i>n</i> = 1009	<i>n</i> = 654	<i>n</i> = <i>634</i>	n = 614	<i>n</i> = 335	<i>n</i> = 440
Mean BMI	33.6	33.6	33.5	33.5	33.4	33.5	33.5	33.5	33.5

f DMI and physical activity in in LIV Dichark Table S3 Mean (05% CI) body fat per ontogo hi • . .

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	32.5	32.1	32.0	32.0	32.2	31.8	31.7			
35-	(32.2-32.9)	(31.8-32.5)	(31.6-32.4)	(31.7-32.3)	(31.8-32.5)	(31.4-32.2)	(31.3-32.1)			
	n = 428	n = 358	n = 302	n = 416	n = 280	n = 261	n = 247	-	-	
Mean BMI	36.1	36.0	36.0	36.0	36.0	36.0	36.0			
37 5-	34.3 (33.9-34.8)									
51.5-	n = 217		_	_	_	_	-	_	-	
Mean BMI	38.5									
Adjusted for age (S	5 year categori	ies)	6							
Values not shown	for cells with	less than 200 إ	participants							
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Table S4 Me	ean (95% CI) b	ody fat percen	tage by catego	ries of BMI an	d physical acti	vity in women	in UK Bioban	k	
			Ca	ategories of ph	ysical activity	(MET-hours/w	/k)		
Categories of BMI	<5	5-9.9	10-14.9	15-24.9	25-34.9	35-49.9	50-74.9	75-99.9	≥ 100
	24.4	23.5	23.5	23.1	22.7	22.5	22.3	22.3	22.3
18.5-	(24.0-24.8)	(23.2-23.9)	(23.2-23.8)	(22.9-23.4)	(22.4-23.0)	(22.2-22.7)	(22.0-22.6)	(21.9-22.8)	(21.9-22.7
	<i>n</i> = 313	n = 460	n = 405	n = 749	n = 569	<i>n</i> = 556	<i>n</i> = 526	<i>n</i> = 219	<i>n</i> = 267
Mean BMI	19.4	19.3	19.4	19.4	19.4	19.4	19.4	19.3	19.4
	28.4	28.0	27.8	27.5	27.2	26.8	26.7	26.6	26.2
20-	(28.2-28.6)	(27.9-28.2)	(27.6-27.9)	(27.4-27.6)	(27.1-27.3)	(26.7-27.0)	(26.5-26.8)	(26.4-26.8)	(26.0-26.4
	n = 1657	<i>n</i> = 2333	n = 2378	n = 4095	n = 3115	n = 3034	n = 2746	n = 1327	n = 1156
Mean BMI	21.4	21.4	21.4	21.4	21.4	21.4	21.4	21.4	21.4
	32.6	32.2	32.0	31.8	31.4	31.4	31.2	31.0	30.7
22.5-	(32.4-32.7)	(32.1-32.3)	(31.9-32.1)	(31.7-31.9)	(31.3-31.5)	(31.3-31.5)	(31.1-31.3)	(30.8-31.2)	(30.6-30.9
	<i>n</i> = 2872	<i>n</i> = 4068	n = 4014	n = 6819	n = 4981	n = 4820	n = 4496	<i>n</i> = 2026	n = 1998
Mean BMI	23.8	23.7	23.7	23.7	23.7	23.7	23.7	23.7	23.7
	36.0	35.7	35.4	35.4	35.2	35.1	34.9	34.8	34.8
25-	(35.9-36.2)	(35.6-35.8)	(35.3-35.6)	(35.3-35.5)	(35.1-35.3)	(35.0-35.2)	(34.8-35.0)	(34.6-35.0)	(34.6-35.0
	n = 2953	n = 4016	n = 3594	n = 6034	n = 4288	n = 4069	n = 3705	n = 1692	n = 1516
Mean BMI	26.2	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1
	39.0	38.8	38.5	38.3	38.3	38.2	38.1	38.0	37.7
27.5-	(38.9-39.2)	(38.6-38.9)	(38.4-38.7)	(38.2-38.5)	(38.2-38.4)	(38.1-38.4)	(37.9-38.2)	(37.8-38.2)	(37.5-37.9
	<i>n</i> = 2353	<i>n</i> = 2715	n = 2370	n = 3704	n = 2616	n = 2366	n = 2262	n = 1008	n = 879
Mean BMI	28.6	28.6	28.6	28.6	28.6	28.6	28.6	28.6	28.6
	41.5	41.1	41.1	41.0	40.8	40.6	40.8	40.4	40.3
30-	(41.3-41.7)	(40.9-41.3)	(40.9-41.3)	(40.9-41.2)	(40.6-41.0)	(40.4-40.8)	(40.6-41.0)	(40.1-40.7)	(40.0-40.6)
	<i>n</i> = 1625	n = 1716	<i>n</i> = 1424	<i>n</i> = 2185	n = 1366	<i>n</i> = <i>1237</i>	n = 1181	<i>n</i> = 564	<i>n</i> = 468
Mean BMI	31.1	31.1	31.1	31.1	31.1	31.0	31.1	31.0	31.1
32.5-	43.6	43.4	43.2	43.1	43.2	43.0	42.7	42.7	42.5
	1								

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	(43.4-43.8)	(43.2-43.6)	(43.0-43.5)	(42.9-43.3)	(43.0-43.5)	(42.8-43.3)	(42.4-43.0)	(42.3-43.1)	(42.0-42.9)
	n = 1008	n = 989	n = 774	n = 1149	n = 699	n = 651	n = 611	n = 260	n = 233
Mean BMI	33.6	33.6	33.6	33.6	33.6	33.5	33.5	33.5	33.5
	45.3	45.2	44.9	45.0	44.9	44.9	44.8		
35-	(45.0-45.5)	(45.0-45.5)	(44.6-45.3)	(44.7-45.3)	(44.6-45.3)	(44.5-45.3)	(44.4-45.2)		
	n = 577	n = 577	n=444	n=584	<i>n</i> = 359	n = 313	n = 282	-	-
Mean BMI	36.1	36.1	36.0	36.1	36.1	36.1	36.0		
	47.0	46.6	46.8	46.7	46.6				
37.5-	(46.6-47.3)	(46.2-47.0)	(46.3-47.2)	(46.3-47.1)	(46.1-4/.0)				
	n = 308	n = 303	n = 20/	n = 310	n = 205	-	-	-	-
Mean BMI	38.6	38.5	38.6	38.5	38.5				
40	48.3								
40-	(47.0-40.7) n = 220								
Magn DMI	n = 220	-	-			-	-	-	-

	п	BMI	Body fat percentage
Men			
< 45 years	15176	27.2 (4.0)	22.8 (5.5)
45-49 years	17569	27.4 (3.9)	23.5 (5.5)
50-54 years	18375	27.5 (3.9)	24.1 (5.5)
55-59 years	20580	27.3 (3.8)	24.6 (5.5)
60-64 years	26532	27.3 (3.7)	25.1 (5.4)
\geq 65 years	20671	27.1 (3.6)	25.6 (5.3)
Women			
< 45 years	17392	25.7 (4.8)	33.7 (7.0)
45-49 years	21848	26.0 (4.8)	34.3 (7.0)
50-54 years	23728	26.3 (4.7)	35.3 (6.7)
55-59 years	25329	26.3 (4.6)	35.9 (6.5)
60-64 years	31600	26.5 (4.4)	36.4 (6.3)
\geq 65 years	20343	26.5 (4.2)	36.7 (6.0)
Values are mean	n (SD)		
Numbers of part	ticipants s	shown are for	BMI within each age
category, slightl	ly fewer p	participants ha	ave information on body
fat percentage			

Table S5 BMI and body fat percentage by sex and 5-year age category in UK Biobank

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Figure S2 Body fat percentage by BMI for participants aged 50-59 years in UK Biobank Values are mean body fat percentage by single-unit BMI categories

Error bars represent 1 SD either side of the mean

Estimates shown for cells with 200 or more participants

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Figure S4 Mean BMI and body fat percentage by physical activity for participants aged younger than 50 years in UK Biobank Panel A: Mean BMI by physical activity (excess MET-hours/wk); Panel B: Mean body fat percentage by physical activity (excess MET-hrs/wk) Values are mean BMI and body fat percentage in the following categories of physical activity: <5, 5-9.9, 10-14.9, 15-24.9, 25-34.9, 35-49.9, 50-74.9, 75-99.9, \geq 100 excess MET-hrs per week, and are plotted at the value of the mean excess MET-hours/wk in each category Errors bars are 95% CI

Estimates shown for cells with 200 or more participants

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Body fat (%) 32 30 28

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●Women ◆Men

Physical activity (excess MET-hrs/wk)

r

= 0.0325

 $r^2 = 0.0276$



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Figure S6 Mean BMI and body fat percentage by physical activity in participants aged 60 years or older in UK Biobank Panel A: Mean BMI by physical activity (excess MET-hours/wk); Panel B: Mean body fat percentage by physical activity (excess METhrs/wk)

Values are mean BMI and body fat percentage in the following categories of physical activity: <5, 5-9.9, 10-14.9, 15-24.9, 25-34.9, 35-49.9, 50-74.9, 75-99.9, \geq 100 excess MET-hrs per week, and are plotted at the value of the mean excess MET-hours/wk in each category Errors bars are 95% CI

Estimates shown for cells with 200 or more participants

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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract
	-	Title, and Pg 3
		(b) Provide in the abstract an informative and balanced summary of what was done
		and what was found Pg 3
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
		Pg 5
Objectives	3	State specific objectives, including any prespecified hypotheses Pg 5
Methods		
Study design	4	Present key elements of study design early in the paper Pg 6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment,
-		exposure, follow-up, and data collection Pg 6
Participants	6	(a) Cohort study—Give the eligibility criteria, and the sources and methods of
		selection of participants. Describe methods of follow-up
		Case-control study—Give the eligibility criteria, and the sources and methods of
		case ascertainment and control selection. Give the rationale for the choice of cases
		and controls
		<i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of
		selection of participants Pg 8
		(b) Cohort study—For matched studies, give matching criteria and number of
		exposed and unexposed
		Case-control study—For matched studies, give matching criteria and the number of
		controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect
		modifiers. Give diagnostic criteria, if applicable Pg 9
Data sources/	8*	For each variable of interest, give sources of data and details of methods of
measurement		assessment (measurement). Describe comparability of assessment methods if there is
		more than one group Pgs 6-8, and Footnotes for Table 1 and Table 2
Bias	9	Describe any efforts to address potential sources of bias Pg 10
Study size	10	Explain how the study size was arrived at Pg 8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable,
		describe which groupings were chosen and why Pg 9
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding
		Pgs 9-10
		(b) Describe any methods used to examine subgroups and interactions Pgs 9-10
		(c) Explain how missing data were addressed Pg 8
		(d) Cohort study—If applicable, explain how loss to follow-up was addressed
		<i>Case-control study</i> —If applicable, explain how matching of cases and controls was
		addressed
		Cross-sectional study—If applicable, describe analytical methods taking account of
		sampling strategy N/A
		(<u>e</u>) Describe any sensitivity analyses Pg 9

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Results		
Participants	13*	(a) Report numbers of individuals at each stage of study-eg numbers potentially eligible,
		examined for eligibility, confirmed eligible, included in the study, completing follow-up, and
		analysed Pg 12, and Figure 1
		(b) Give reasons for non-participation at each stage Figure 1
		(c) Consider use of a flow diagram Figure 1
Descriptive	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information
data		on exposures and potential confounders Pg 12, and Tables 1 and 2
		(b) Indicate number of participants with missing data for each variable of interest Footnotes for
		Tables 1 and 2
		(c) Cohort study—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	Cohort study—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of
		exposure
		Cross-sectional study-Report numbers of outcome events or summary measures Tables 1 and
		2.
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their
		precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and
		why they were included Pgs 12-13
		(b) Report category boundaries when continuous variables were categorized Pgs 9-10
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful
		time period N/A
Other analyses	17	Report other analyses done-eg analyses of subgroups and interactions, and sensitivity
		analyses Pgs 13-14
Discussion		
Key results	18	Summarise key results with reference to study objectives Pg 15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision.
		Discuss both direction and magnitude of any potential bias Pgs 15-16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity
		of analyses, results from similar studies, and other relevant evidence Pg 17
Generalisability	21	Discuss the generalisability (external validity) of the study results Pgs 16-17
Other informati	on	
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable,
		for the original study on which the present article is based Pg 18

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

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

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Physically active adults have lower body fat percentage, after adjusting for BMI: a cross-sectional analysis of UK Biobank

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Physically active adults have lower body fat percentage, after adjusting for BMI: a cross-sectional analysis of UK Biobank

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Abstract

Objectives: The objective of this study was to examine if physically active adults have less body fat after taking BMI into account.

Design: A cross-sectional analysis of participants recruited into UK Biobank in 2006-2010. **Setting:** UK Biobank assessment centres throughout the UK.

Participants: 119,230 men and 140,578 women aged 40-69 years, with complete physical activity information, and without a self-reported long-term illness, disability or infirmity.
Exposures: Physical activity measured as excess MET-hours per week, estimated from a combination of walking, and moderate and vigorous physical activity. BMI from measured height and weight.

Main outcome measure: Body fat percentage estimated from bio-impedance.

Results: BMI and body fat percentage were highly correlated (r=0.85 in women; r=0.79 in men), and both were inversely associated with physical activity. Compared to <5 excess metabolic equivalent (MET)-hours per week at baseline, \geq 100 excess MET-hours per week was associated with a 1.1 kg/m² lower BMI (27.1 versus 28.2 kg/m²) and 2.8 percentage points lower body fat (23.4% versus 26.3%) in men, and 2.2 kg/m² lower BMI (25.6 versus 27.7 kg/m²) and 4.0 percentage points lower body fat (33.9% versus 37.9%) in women. For a given BMI, greater physical activity was associated with lower average body fat percentage (for a BMI of 22.5-24.99 kg/m²: 2.0 (95% CI: 1.8 to 2.2) percentage points lower body fat in men, and 1.8 (95% CI: 1.6 to 2.0) percentage points lower body fat in women, comparing \geq 100 excess MET-hours per week to <5 excess MET-hours per week).

Conclusions: Physical activity was inversely associated with BMI and body fat percentage. For people with the same BMI, those who were more active had a lower body fat percentage.

Strengths and limitations of this study

- This study of older adults, drawn from the general population, is very large (n = 259,808) and height and weight (for the calculation of BMI) were measured by trained staff using standardised techniques.
- Body fat percentage (estimated via bio-impedance) was available for virtually all participants.
- Physical activity was self-reported and therefore there will be some measurement error associated with this variable.
- The study is cross-sectional and therefore we cannot infer cause and effect.

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Introduction

Body mass index (BMI) is a simple index calculated from height and weight, and is usually used as a proxy for body fatness in large epidemiological studies. Correlations between BMI and more direct measures of body fatness are generally strong (r > 0.70) (1-3).

Observational studies have shown that people who do comparatively more physical activity have a lower BMI than less active people (4, 5). Few large epidemiological studies have directly estimated body fatness, and it is of interest to examine whether more comprehensive measures of body fatness provide additional information above and beyond that which is captured by BMI. Previous studies each of approximately 500 young adults have found that, for a given BMI, athletes have a lower body fat percentage than non-athletes (6, 7); however it is unclear whether in the general population, including older adults, those who do more physical activity have a lower body fat percentage than those who do minimal physical activity, after taking into account BMI.

UK Biobank is a population-based cohort of 500,000 UK men and women, aged 40-69 years at recruitment. Body mass index and body fat percentage were measured at recruitment for virtually all participants. For this analysis of data from UK Biobank we aimed firstly to describe the associations of physical activity with BMI and body fat percentage, and secondly to determine whether physical activity is associated with body fat percentage, independently of BMI.

METHODS

Subjects

UK Biobank is a prospective cohort of approximately 500,000 people aged 40-69 years, recruited in 2006-2010 in the UK (8). People aged 40-69 years who lived within reasonable travelling distance of 22 assessment centres were identified from National Health Service patient registers and invited to participate in UK Biobank by attending an assessment centre. Permission for access to patient records for recruitment was approved by the National Information Governance Board for Health and Social Care in England and Wales, and the Community Health Index Advisory Group in Scotland. A sub-sample of approximately 20,000 participants completed a full repeat of the assessment centre visit between August 2012 and June 2013, approximately 5 years after recruitment (9). UK Biobank has ethical approval from the North West Multi-centre Research Ethics Committee. The UK Biobank protocol is available online (http://www.ukbiobank.ac.uk/wp-content/uploads/2011/11/UK-Biobank-Protocol.pdf). The touchscreen questionnaire and other resources are also available on the UK Biobank website (http://www.ukbiobank.ac.uk/resources/).

Anthropometric measurements

At the UK Biobank assessment centres, a touchscreen questionnaire was used to collect information on socio-demographic characteristics and lifestyle exposures. Socks and shoes were removed and height was measured using the Seca 202 height measure (Seca, Hamburg, Germany). Weight and estimated percentage fat were measured with the Tanita BC418ma bio-impedance device (Tanita, Tokyo, Japan). Participants were not asked to fast, nor were they given any specific instructions pertaining to the bio-impedance measures prior to

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attending the assessment centre. Water was available at all times throughout the visit and visits occurred throughout the day (8am-8pm).

Physical activity assessment

Questions on the touchscreen about walking, moderate physical activity, and vigorous physical activity, which were similar to those used in the short form of the International Physical Activity Questionnaire (10), were used to estimate excess metabolic equivalents (MET)-hours per week of physical activity during work and leisure time. For each of the three activity categories (walking, moderate physical activity, and vigorous physical activity) participants were asked how many days in a typical week they did each of the activities for 10 minutes or more (for walking: touchscreen question number WP1, UK Biobank variable n_864_0_0; for moderate physical activity: touchscreen question number WP2, UK Biobank variable n_884_0_0; for vigorous physical activity: touchscreen question number WP3, UK Biobank variable n_904_0_0). For each category, participants who entered one or more days were then asked how many minutes they spent doing those activities on a typical day (for walking: WP1A, n_874_0_0; for moderate physical activity: WP2A, n_894_0_0; for vigorous physical activity: WP3A, n_914_0_0). For each activity category, the number of reported days was multiplied by the number of reported minutes on a typical day to generate duration of activity in minutes per week.

Activity on a typical day of less than 10 minutes was recoded to 0 for any of the three categories of activity. For each of the three categories of activity, values of more than 1260 minutes per week (equivalent to an average of 3 hours per day) were truncated at 1260 (10).

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Total MET values for each category from the International Physical Activity Questionnaire short form were: 3.3 for walking, 4.0 for moderate physical activity, and 8.0 for vigorous physical activity (10). We report excess METs, which are calculated by subtracting 1 MET from the value for each activity, and represent the energy expenditure above that of an inactive person (11). Excess MET values were therefore 2.3 for walking, 3.0 for moderate physical activity, and 7.0 for vigorous physical activity. Excess MET-hours per week were calculated by multiplying the excess MET value for each activity by the duration of activity in hours per week (10).

Exclusions

The UK Biobank dataset used for this analysis included 502,640 participants. Participants were excluded from this analysis if they selected 'Prefer not to answer' or 'Do not know' to any of the possible six questions on physical activity (WP1, WP1A, WP2, WP2A, WP3, WP3A) (n = 66,625). Participants were also excluded from this analysis if they responded to the question: "Do you have a long-term illness, disability or infirmity?" with 'Yes' (n = 159,941), 'Prefer not to answer' (n = 1,052) or 'Do not know' (n = 11,391), or if they had a missing value for this variable (n = 919) (touchscreen question number H4, UK Biobank variable $n_2188_0_0$). In addition, the questions used in the pilot study on the duration of physical activity differed from those in the main study, and participants who answered the pilot version of these questions were excluded (n = 2,253). Based on the International Physical Activity Questionnaire recommendations for data cleaning and processing (10), participants were also excluded from the analysis if the sum of walking, moderate physical

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activity, and vigorous physical activity was greater than 112 hours per week (n = 651), leaving a total of 259,808 participants in the present study.

Statistics

STATA version 14.0 (Stata Corp LP, College Station, TX) was used for all statistical analyses. All analyses were done for men and women separately. Participant characteristics were described by level of physical activity (low, < 10.0; moderate, 10.0-49.9; high, ≥ 50 excess MET-hours per week). Pearson's correlation coefficients between BMI and body fat percentage were calculated; values of 0.80 or above are considered very strong, values between 0.60-0.79 strong, 0.40-0.59 moderate, 0.20-0.39 weak, and 0.00-0.19 very weak (12). Multiple linear regression was used to calculate the mean body fat percentage in single units of BMI (e.g. 17.00-17.99, 18.00-18.99, 19.00-19.99 kg/m², etc), adjusted for age (5 year categories: < 45 years, 45-49.99 years, 50-54.99 years, 55-59.99 years, 60-64.99 years, >65.00 years). Groups with 200 or more participants are shown in the Figure. Multiple linear regression was also used to calculate mean BMI and body fat percentage in categories of excess MET-hours per week (< 5, 5-9.9, 10-14.9, 15-24.9, 25-34.9, 35-49.9, 50-74.9, 75- $99.9 \ge 100$ excess MET-hours per week), adjusted for age (5 year categories, as above). For the final analysis, we used multiple linear regression to examine the association between physical activity (in excess MET-hours per week: < 5, 5-9.9, 10-14.9, 15-24.9, 25-34.9, 35-49.9, 50-74.9, 75-99.9, > 100) and body fat percentage (continuous variable). Body mass index (in 2.5 unit categories, e.g. < 18.50, 18.50-19.99, 20.00-22.49, 22.50-24.99, 25.00- $27.49...,42.50-44.99, \ge 45.00 \text{ kg/m}^2$, etc) and age (5 year categories) were included as covariates. We included a product term of excess MET-hours per week (categories, as above) and BMI (in 2.5 unit categories as above) in the model to calculate mean body fat percentage

in categories of physical activity within strata of BMI. In additional sensitivity analyses, we adjusted for reported intakes of fruit and vegetables (< 3.00 servings/week, 3.00-3.99, 4.00-4.99, 5.00-5.99, ≥ 6.00 servings/week, unknown), and red and processed meat (< 2.00 servings/week, 2.00-2.99, 3.00-3.99, 4.00-4.99, ≥ 5.00 servings/week, unknown). We also restricted the analysis to those with a university or college degree, and separately, to those that do not have a job that usually or always involves standing or walking or manual work.

We also examined mean BMI and body fat percentage in 5 year age categories. For each age decade separately (i.e. participants < 50 years, 50-59 years, and \geq 60 years) linear regression was used to calculate mean body fat percentage in single units of BMI, and to calculate mean BMI and body fat percentage in each category of physical activity (< 5, 5-9.9, 10-14.9, 15-24.9, 25-34.9, 35-49.9, 50-74.9, 75-99.9, \geq 100 excess MET-hours per week).

To explore the repeatability of self-reported physical activity, including effects of measurement error and possible changes in activity over time, we used a sub-sample of 10,225 UK Biobank participants who were eligible for the current study and who completed a repeat assessment visit approximately 5 years after recruitment (Supplementary Tables S1 and S2). For these participants, we calculated excess MET-hours per week from their answers to the touchscreen questionnaire completed at the repeat assessment centre visit, as described above. Then for each category of excess MET-hours per week defined at baseline, we calculated both the mean excess MET-hours per week at their baseline visit (to assess comparability of the sub-sample to the full cohort) and the mean excess MET-hours per week at the repeat visit (to assess measurement error in reporting physical activity and change over time). The sub-sample of participants who completed a repeat assessment centre visit

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approximately 5 years after recruitment was similar at baseline to the full cohort with regard to reported physical activity. However, at the repeat assessment, for participants in the highest category of physical activity defined at baseline (≥ 100 excess MET-hours per week), the mean excess MET-hours per week was much lower than at baseline (80 compared to 130 for both men and women). For the lowest category of physical activity defined at baseline, the mean excess MET-hours per week was somewhat higher at the repeat assessment than at baseline (12 compared to 2.6 for both men and women). Overall, this represents regression to the mean of almost 50% (calculated from the ratio of the range of mean values at the repeat assessment to the range of mean values at baseline). The Pearson's correlation coefficients between recruitment and repeat measurements of BMI and body fat percentage in the subsample of participants who completed a repeat assessment centre visit were 0.92 for both BMI and body fat percentage.

All *p* values were two-sided and P < 0.05 was considered statistically significant.

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RESULTS

Participant flow is shown in Figure 1. Participants who had a high level of physical activity were older, had a lower BMI, a lower body fat percentage, and a higher intake of fruit and vegetables than participants with a low level of physical activity (Table 1 and Table 2). They were also less likely to have a college or university degree, and much more likely to have a standing or manual job than those with a moderate or low level of physical activity. Participants with a moderate activity level were the least likely to be current smokers.

Body fat percentage was positively related to BMI (Figure 2). The correlation between BMI and body fat percentage was very strong in women (r = 0.85), and strong in men (r = 0.79). At the same BMI, women had a much higher body fat percentage than men; for example, women with a BMI of 30.00-30.99 kg/m² had on average 41% body fat, whereas men with the same BMI had on average 28% body fat.

Body fat percentage and BMI were inversely related to physical activity (Figure 3). Men who did < 5 excess MET-hours of physical activity per week had, on average, a BMI of 28.2 kg/m² (95% Confidence Interval (CI): 28.2 to 28.3 kg/m²) and 26.3% (95% CI: 26.2 to 26.4 kg/m²) body fat. Men who did \geq 100 excess MET-hours per week of physical activity per week had, on average, a BMI of 27.1 kg/m² (95% CI: 27.0 to 27.2 kg/m²) and 23.4% (95% CI: 23.3 to 23.5%) body fat. Women who did < 5 excess MET-hours per week of physical activity per week had, on average, a BMI of 27.7 kg/m² (95% CI: 27.7 to 27.8 kg/m²) and 37.9% (95% CI: 37.8 to 38.0%) body fat. Women who did \geq 100 excess MET-hours per week of physical activity per week had, on average, a BMI of 27.7 kg/m² (95% CI: 27.7 to 27.8 kg/m²) and 37.9% (95% CI: 37.8 to 38.0%) body fat. Women who did \geq 100 excess MET-hours per week of physical activity per week had, on average, a BMI of 25.6 kg/m² (95% CI: 25.5 to 25.7 kg/m²) and a 33.9% (95% CI: 33.7 to 34.0%) body fat. For both men and women, as shown by the r² values, age and physical activity explained more of the variation in body fat

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percentage than the variation in BMI in this study population; however, age and physical activity only explained a small proportion of the variation in both BMI and body fat percentage in this study population, with all r^2 values less than 0.06 (Figure 3).

Overall, in males, those doing \geq 100 or more excess MET-hours per week compared with < 5 excess MET-hours per week had a 1.7 (95% CI: 1.6 to 1.7) percentage points lower body fat percentage, on average, after adjustment for BMI and age; in females it was on average 1.5 (95% CI: 1.4 to 1.6) percentage points lower. For both men and women, within each stratum of BMI, a higher physical activity level was associated with a lower body fat percentage, and the difference in body fat percentage between physical activity categories appeared to be slightly larger at lower BMIs (*p* for interaction using likelihood ratio test < 0.001, for both sexes) (Figure 4, Supplementary Tables S3 and S4). For a BMI of 22.5-24.99 kg/m², \geq 100 excess MET-hours per week vs < 5 excess MET-hours per week was associated with 2.0 (95% CI: 1.8 to 2.2) percentage points lower body fat in men and 1.9 (95% CI: 1.6 to 2.0) percentage points lower body fat in women. For both men and women, within each stratum of BMI, the mean BMI was very similar across the categories of physical activity.

When we further adjusted for reported intakes of fruit and vegetables, and red and processed meats, or restricted the analysis to those who did not have an active job or those who had a university or college degree, the results were not materially altered. Comparing those doing \geq 100 excess MET-hours per week to those doing < 5 excess MET-hours per week, body fat percentage was, on average 1.6 (95% CI: 1.5 to 1.7) percentage points lower for men and 1.4 (95% CI: 1.3 to 1.5) percentage points lower for women after adjustment for diet quality; 1.7 (95% CI: 1.6 to 1.9) percentage points lower for men and 1.6 (95% CI: 1.4 to 1.8) percentage points lower for women when restricting analyses to those who had a university or college

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degree; and 1.6 (95% CI: 1.5 to 1.7) percentage points lower for men and 1.4 (95% CI: 1.3 to 1.5) percentage points lower for women when we restricted analyses to those who did not have a standing or manual job.

In men, the mean BMI was similar across 5-year age categories however the mean body fat percentage was higher in older age groups. In women, the mean BMI by 5-year age categories was slightly higher in older age groups, and the mean body fat percentage was also higher in older age groups (Supplementary Table S5). The association between BMI and body fat percentage was similar in each age decade (Supplementary Figures S1, S2, and S3). The differences in BMI between the extreme categories of physical activity were slightly larger and the differences in body fat percentage were slightly smaller with older age (Supplementary Figures S4, S5 and S6).

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In this large sample of middle-aged British men and women, more physical activity was associated with both a lower BMI and a lower body fat percentage, although even men and women who did the most physical activity were, on average, overweight. More physical activity was also associated with a lower body fat percentage within each category of BMI, with an average 1-2 percentage points lower body fat in the most active, compared to the least active individuals. Most of the difference in body fat percentage with physical activity was between the very low and moderately-high levels of physical activity (<5 and 35-49.9 excess MET-hours per week, respectively); there was relatively little difference in body fat percentage between moderately-high and very high levels of physical activity (35-49.9 and ≥100 excess MET-hours per week, respectively).

The current study is large, and height and weight were measured by trained staff using standardised techniques. We examined whether important lifestyle factors (diet quality, education, and job type) which varied by physical activity level might modify the associations between physical activity, BMI and body fat percentage. In each of these sensitivity analyses, the results were essentially unchanged, although because this is an observational study we cannot rule out confounding by other factors. A limitation of the study is that physical activity approximately 5 years after baseline indicates approximately 50% regression to the mean, which represents both the error in reporting physical activity and true changes in physical activity over time. The likely consequence of regression to the mean in physical activity levels over time is bias of associations towards the null, so that the true association between physical activity and body composition measures is likely to be stronger than that observed in this study. Participants were not given any specific

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instructions prior to body fat measurement. Hydration status, exercise and food consumption can have small effects on body fat values measured by bioimpedance; had these factors been standardised between participants, we may have seen slightly stronger associations between body fat percentage and physical activity. The study is cross-sectional, and therefore we can only show associations between reported physical activity and contemporaneous body composition. We cannot infer cause and effect: lower levels of physical activity may lead to greater adiposity, but it is also possible that increased adiposity leads to less physical activity.

Small studies (n~500) in young adults have shown that, for a given BMI, athletes have a lower body fat percentage than non-athletes (6, 7). These findings are, however, of limited relevance to older adults in the general population, who experience the highest burden of obesity-related disease. An analysis of 466,605 participants in the China Kadoorie Biobank, aged 30-79 years, found relatively weak associations between physical activity and either BMI or body fat percentage: a difference of approximately 100 total MET-hours per week was associated with 0.15 kg/m² lower BMI, and 0.48 percentage points lower body fat (13). Participants in China Kadoorie Biobank differed from those in UK Biobank in ethnicity and lifestyle, and also had a lower average BMI (23.4 (SD 3.2) kg/m² in men; 23.8 (SD 3.4) kg/m² in women). Their physical activity levels were comparable to the middle to upper range of physical activity of UK Biobank participants, and in this range we also saw only a small difference in body fat percentage.

Variation in BMI in the general population is largely due to differences in body fatness, but by definition it incorporates both adipose and lean body mass, and it is therefore difficult to disentangle the roles of adipose and lean mass in associations of BMI with health outcomes. For example, a higher BMI is an established risk factor for post-menopausal breast cancer,

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and probably increases risk through higher circulating sex hormones produced by the enzyme aromatase in the adipose tissue from precursor androgens (14). Several cohort studies have also shown that more physical activity is associated with a reduced risk of post-menopausal breast cancer, even after adjustment for BMI, and this finding is often taken as evidence that physical activity is independent of adiposity as a risk factor for post-menopausal breast cancer (15). Our results suggest, however, that adjustment for BMI may not have fully controlled for adiposity in these analyses.

In conclusion, in this sample of middle-aged British adults who were free from self-reported long-standing illness, men and women who reported doing the most physical activity had a lower BMI and a lower body fat percentage than those who reported doing the least physical activity. We also report new evidence that, for a given BMI, men and women who reported doing more physical activity had a lower body fat percentage; the greatest difference was observed between low and moderate levels of physical activity. BMI incorporates both adipose and lean mass, but is most strongly related to adiposity, and consequently is associated with morbidity and mortality from a wide range of diseases. However, to disentangle the possible effects of physical activity and adiposity on disease risk, future research should focus on more specific measures of adiposity.

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Competing interests: All authors have completed the Unified Competing Interest form at <u>www.icmje.org/coi_disclosure.pdf</u> (available on request from the corresponding author) and declare no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years, no other relationships or activities that could appear to have influenced the submitted work.

Contributorship: KEB and TJK conceived the research, KEB performed the statistical analyses; BJC contributed to the statistical methodology; MEGA contributed to generation of the physical activity variables. KEB, WG, BJC, MEGA, and TJK interpreted the data, drafted and reviewed the article for important intellectual content, KEB has primary responsibility for the final content. All authors read and approved the final manuscript. KEB is the guarantor for the study. This research has been conducted using the UK Biobank Resource. **Ethics approval:** UK Biobank has ethical approval from the North West Multi-centre Research Ethics Committee. Participants gave informed consent on the touchscreen before taking part.

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Data sharing: UK Biobank is an open access resource. Bona fide researchers can apply to use the UK Biobank dataset by registering and applying at

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	Low activity	Moderate activity	High activity	All men
	< 10 excess MET-	10-49.9 excess	\geq 50 excess	
	hours/wk ¹	WIL 1-110015/ WK	MET-hours/wk ¹	
	<i>n</i> = 26,405	<i>n</i> = 63,022	<i>n</i> = 29,803	<i>n</i> = 119,230
Age (years)	0.			
Mean (SD)	55.3 (8.0)	55.7 (8.4)	56.0 (8.4)	55.7 (8.3)
White ethnicity ^a	24,741 (93.7)	59,842 (95.0)	28,468 (95.5)	113,051 (94.8)
Socioeconomic status ^b				
Upper fifth	6,274 (23.8)	14,701 (23.4)	5,867 (19.7)	26,842 (22.5)
Qualifications ^c				
College or University degree/vocational qualification	18,878 (71.5)	45,453 (72.2)	17,731 (59.5)	82,062 (68.8)
BMI $(kg/m^2)^d$				
Mean (SD)	28.0 (4.2)	27.1 (3.7)	27.1 (3.6)	27.3 (3.8)
< 20.00	238 (0.9)	559 (0.9)	289 (1.0)	1,086 (0.9)
	5.0.40 (22.2)	17 425 (27 7)	9.22((29.0))	21(00(200))

Table1 Characteristics of men participating in UK Biobank by physical activity

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4 5 6	25.00-29.99	13,220 (50.2)	32,745 (52.1)	15,403 (51.8)	61,368 (51.6)
7 8	≥ 30.00-34.99	7,015 (26.7)	12,135 (19.3)	5,699 (19.2)	24,849 (20.9)
9 10	Body fat (%) ^e				
11 12	Mean (SD)	25.8 (5.5)	24.2 (5.4)	23.6 (5.5)	24.4 (5.5)
13 14	< 15.00	761 (2.9)	3,062 (4.9)	1,945 (6.6)	5,768 (4.9)
15 16	15.00-19.99	2,810 (10.8)	9,714 (15.6)	5,148 (17.5)	17,672 (15.0)
17 18	20.00-24.99	7,714 (29.6)	21,023 (33.7)	10,080 (34.3)	38,817 (32.9)
19 20	25.00-29.99	9,194 (35.2)	19,816 (31.8)	8,686 (29.5)	37,696 (32.0)
21 22	\geq 30.00	5,629 (21.6)	8,703 (14.0)	3,558 (12.1)	17,890 (15.2)
23 24	Height $(m)^{f}$				
25 26	< 1.70	3,902 (14.8)	9,251 (14.7)	5,467 (18.4)	18,620 (15.7)
27 28	1.70 - 1.74	6,250 (23.8)	15,301 (24.4)	7,917 (26.6)	29,468 (24.8)
29 30	1.75 - 1.79	7,738 (29.4)	18,182 (28.9)	8,246 (27.8)	34,166 (28.7)
31 32	1.80 - 1.84	5,308 (20.2)	12,992 (20.7)	5,408 (18.2)	23,708 (19.9)
33 34	≥ 1.85	3,115 (11.8)	7,120 (11.3)	2,682 (9.0)	12,917 (10.9)
35 36	Mean (SD) excess MET-hours per week ^g	5.1 (2.9)	25.8 (11.0)	92.9 (43.3)	38.0 (40.1)
37 38 39 40 41	Standing or walking job ^h	2,524 (12.7)	9,766 (23.1)	12,961 (65.4)	25,251 (30.8)

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Manual job ¹	561 (2.8)	3,214 (7.6)	8,145 (41.1)	11,920 (14.6)
Smoking status ^{1j}				
Never	14,269 (54.0)	34,209 (54.3)	15,101 (50.7)	63,579 (53.3)
Previous	8,866 (33.6)	22,438 (35.6)	10,936 (36.7)	42,240 (35.4)
Current	3,215 (12.2)	6,252 (9.9)	3,680 (12.4)	13,147 (11.0)
Alcohol consumption ^k				
Three or more times a week	14,391 (54.5)	36,542 (58.0)	15,477 (52.0)	66,410 (55.8)
Fruit and vegetable consumption ¹				
< 3.00 servings per day	8,754 (33.2)	14,052 (22.3)	5,966 (20.0)	28,772 (24.1)
3.00-3.99 servings per day	6,031 (22.8)	13,370 (21.2)	5,204 (17.5)	24,605 (20.6)
4.00-4.99 servings per day	4,619 (17.5)	12,622 (20.0)	5,485 (18.4)	22,726 (19.1)
5.00-5.99 servings per day	2,926 (11.1)	8,930 (14.2)	4,389 (14.7)	16,245 (13.6)
\geq 6.00 servings per day	3,798 (14.4)	13,559 (21.5)	8,405 (28.2)	25,762 (21.6)
fotal red and processed meat consumption ^m				
< 2.00 times per week	2,120 (8.0)	5,838 (9.3)	2,956 (9.9)	10,914 (9.2)
2.00-2.99 times a week	6,291 (23.8)	16,042 (25.5)	7,170 (24.1)	29,503 (24.7)
3.00-3.99 times a week	3,927 (14.9)	9,323 (14.8)	4,186 (14.1)	17,436 (14.6)

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4.00-4.99 times a week	4,866 (18.4)	10,990 (17.4)	5,069 (17.0)	20,925 (17.6)
\geq 5.00 times a week	9,042 (34.2)	20,523 (32.6)	10,229 (34.3)	39,794 (33.4)
Values are number (%) unless otherwise stated				
Number of participants with missing data (the total number	er participants who have m	nissing data, or who rep	oorted 'do not know' or	r 'prefer not to
answer') for each characteristic is as follows: 0 for age, 3'	77 for ethnicity, 159 for so	cioeconomic status, 70	5 for qualifications, 32	27 for BMI, 1,367
for body fat %, 351 for height, 0 for excess MET-hours/w	k, 57 for standing or walk	ing job, 38 for manual	job, 264 for smoking	status, 35 for
alcohol consumption, 1,120 for fruit and vegetable consur	mption, 658 for total red ar	nd processed meat cons	umption	
^a Participants who reported their ethnicity as 'White', 'Brit	tish', 'Irish', or 'Any other	white background'		
^b We generated quintiles of socioeconmic status based on t	the Townsend deprivation	index for the whole col	hort (UK Biobank vari	able n_189_0_0)
^c Vocational qualifications defined as other professional qualifi	ualification (eg: nursing or	teaching)/ National Vo	ocational Qualification	or Higher
National Diploma or Higher National Certificate) (touchs	creen question number D1	2, UK Biobank variabl	e n_6138_0_0)	
^d We preferentially used BMI derived from height and wei	ight measured during the in	mpedance measuremen	t (UK Biobank variabl	e n_23104_0_0_),
but if missing used the body size measures (UK Biobank	variable n_21001_0_0); bo	oth of these are direct n	neasures of height and	weight made on
the same day at the assessment centre				
^e Body fat % (UK Biobank variable n_23099_0_0)				
fStanding height (UK Biobank variable n_50_0_0)				
^g Excess MET-hours/wk estimated from the combination of	of reported walking, moder	rate and vigorous physi	cal activity (for details	see methods text)

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^hParticipants who reported their work 'usually' or 'always' involved walking or standing for most of the time (touchscreen question number D9B, UK Biobank variable n 806 0 0) ⁱParticipants who reported their work 'usually' or 'always' involved heavy manual or physical work for most of the time (touchscreen question

number D9C, UK Biobank variable n 816 0 0)

^jSmoking status (UK Biobank variable n 20116 0 0)

^kParticipants who reported consuming alcohol three to four times per week or daily or almost daily (touchscreen question number A1, UK Biobank variable n 1558 0 0)

¹Total fruit and vegetable consumption is the sum of fresh fruit intake (touchscreen question number DT3, UK Biobank variable n 1309 0 0), cooked vegetable intake (touchscreen question numbers DT1, UK Biobank variable n 1289 0 0) and raw vegetable intake (touchscreen question number DT1, and UK Biobank variable n 1299 0 0). To sum the frequencies, 'Less than one' was coded as 0.5, and we coded 1 piece of fresh fruit as a serving and 2 tablespoons of vegetables as a serving.

^mTotal red and processed meat consumption is the sum of processed meat (touchscreen question number DT8 and UK Biobank variable n 1349 0 0), beef (touchscreen question number DT7 and UK Biobank variable n 1369 0 0), lamb/mutton (touchscreen question number DT7A and UK Biobank variable n 1379 0 0), and pork (touchscreen question number DT7B and UK Biobank variable n 1389) intake. To sum the frequencies, we used the following coding: 'Never' = 0, 'Less than once a week' = 0.5, 'Once a week' = 1, '2-4 times a week' = 3, '5-6 times a week' = 5.5, 'Once or more daily' = 7.

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Table 2 Characteristics of women participating in UK Biobank by physical activity

	Low activity	Moderate activity	High activity	All women
	< 10 excess	10-49.9 excess		
	MET-	MET-hours/wk ¹	\geq 50 excess	
	n = 31,931	<i>n</i> = 78,171	m = 30,476	<i>n</i> = 140,578
Age (years)				
Mean (SD)	54.6 (7.8)	55.2 (8.1)	56.2 (8.1)	55.3 (8.1)
White ethnicity ^a	30,164 (94.5)	74,471 (95.3)	29,088 (95.5)	133,723 (95.1)
Socioeconomic status ^b				
Upper fifth	6,956 (21.8)	17,177 (22.0)	6,407 (21.0)	30,540 (21.8)
Qualifications ^c				
College or University degree/vocational qualification	19,320 (60.5)	49,219 (62.9)	17,826 (58.5)	86,365 (61.5)
BMI $(kg/m^2)^d$				
Mean (SD)	27.2 (5.1)	26.0 (4.4)	25.7 (4.2)	26.2 (4.6)
< 20.00	954 (3.0)	2,838 (3.6)	1,270 (4.2)	5,062 (3.6)

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20.00-24.99	10,930 (34.3)	33,256 (42.7)	13,749 (45.2)	57,935 (41.3)
25.00-29.99	12,037 (37.8)	29,041 (37.2)	11,062 (36.4)	52,140 (37.2)
≥ 30.00-34.99	7,930 (24.9)	12,839 (16.5)	4,334 (14.3)	25,103 (17.9)
Body fat (%) ^e				
Mean (SD)	37.1 (6.6)	35.2 (6.5)	34.4 (6.6)	35.5 (6.7)
< 25.00	1,197 (3.8)	4,842 (6.3)	2,524 (8.4)	8,563 (6.2)
25.00-29.99	3,256 (10.3)	11,220 (14.5)	4,920 (16.3)	19,396 (14.0)
30.00-34.99	7,011 (22.2)	20,467 (26.5)	8,224 (27.3)	35.702 (25.7)
35.00-39.99	9,129 (29.0)	22,181 (28.7)	8,347 (27.7)	39,657 (28.6)
≥ 40.00	10,940 (34.7)	18,506 (24.0)	6,110 (20.3)	35,556 (25.6)
Height $(m)^{f}$				
< 1.55	2,758 (8.7)	6,315 (8.1)	2,810 (9.2)	11,883 (8.5)
1.55 - 1.59	6,268 (19.7)	15,551 (19.9)	6,504 (21.4)	28,323 (20.2)
1.60 - 1.64	10,067 (31.6)	24,437 (31.3)	9,631 (31.7)	44,135 (31.5)
1.65 - 1.69	7,993 (25.1)	20,091 (25.8)	7,530 (24.8)	35,614 (25.4)
≥ 1.70	4,779 (15.0)	11,621 (14.9)	3,952 (13.0)	20,352 (14.5)
Mean (SD) excess MET-hours per week ^g	5.3 (2.8)	25.5 (10.9)	83.0 (33.3)	33.4 (32.5)

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- 5 6	Standing or walking job ^h	3,901 (17.4)	12,349 (25.7)	9,593 (56.3)	25,843 (29.53)	
7 8	Manual job ⁱ	521 (2.3)	2,576 (5.4)	3,883 (22.8)	6,980 (8.0)	
9 10	Smoking status ⁱ					
11 12	Never	19,513 (61.1)	47,974 (61.4)	18,370 (60.3)	85,857 (61.1)	
13 14	Previous	9,468 (29.7)	24,366 (31.2)	9,635 (31.6)	43,469 (30.9)	
15 16	Current	2,883 (9.0)	5,661 (7.2)	2,417 (7.9)	10,961 (7.8)	
17 18	Alcohol consumption ^k					
19 20	Three or more times a week	12,670 (39.7)	33,747 (43.2)	12,137 (39.8)	58,554 (41.7)	
21 22	Fruit and vegetable consumption ¹					
23 24	< 3.00 servings per day	6,601 (20.7)	9,849 (12.6)	3,070 (10.1)	19,520 (13.9)	
25 26	3.00-3.99 servings per day	6,507 (20.4)	13,485 (17.3)	4,232 (13.9)	24,224 (17.2)	
27 28 20	4.00-4.99 servings per day	6,672 (20.9)	16,489 (21.1)	5,701 (18.7)	28,862 (20.5)	
29 30 21	5.00-5.99 servings per day	5,092 (16.0)	14,460 (18.5)	5,573 (18.3)	25,125 (17.9)	
32 33	\geq 6.00 servings per day	6,874 (21.5)	23,557 (30.1)	11,740 (38.5)	42,171 (30.0)	
34 35	Total red and processed meat consumption ^m					
36 37	< 2.00 times per week	5,462 (17.1)	15,254 (19.5)	6,729 (22.1)	27,445 (19.5)	
38 39	2.00-2.99 times a week	10,903 (34.2)	27,329 (35.0)	10,190 (33.4)	48,422 (34.4)	
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3.00-3.99 times a week	5,395 (16.9)	12,642 (16.2)	4,823 (15.8)	22,860 (16.3)
4.00-4.99 times a week	4,058 (12.7)	9,143 (11.7)	3,423 (11.2)	16,624 (11.8)
\geq 5.00 times a week	5,973 (18.7)	13,456 (17.2)	5,144 (16.9)	24,573 (17.5)

Values are number (%) unless otherwise stated

Number of participants with missing data (the total number participants who have missing data, or who reported 'do not know' or 'prefer not to answer') for each characteristic is as follows: 0 for age, 263 for ethnicity, 150 for socioeconomic status, 756 for qualifications, 338 for BMI, 1,704 for body fat %, 271 for height, 0 for excess MET-hours/wk, 64 for standing or walking job, 52 for manual job, 291 for smoking status, 44 for alcohol consumption, 676 for fruit and vegetable consumption, 655 for total red and processed meat consumption ^aParticipants who reported their ethnicity as 'White', 'British', 'Irish', or 'Any other white background' ^bWe generated quintiles of socioeconmic status based on the Townsend deprivation index for the whole cohort (UK Biobank variable n 189 0 0) [°]Vocational qualifications defined as other professional qualification (eg: nursing or teaching)/ National Vocational Qualification or Higher National Diploma or Higher National Certificate) (touchscreen question number D12, UK Biobank variable n 6138 0 0) ^dWe preferentially used BMI derived from height and weight measured during the impedance measurement (UK Biobank variable n 23104 0 0), but if missing used the body size measures (UK Biobank variable n 21001 0 0); both of these are direct measures of height and weight made on the same day at the assessment centre. ^eBody fat % (UK Biobank variable n 23099 0 0) ^fStanding height (UK Biobank variable n 50 0 0)

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^gExcess MET-hours/wk estimated from the combination of reported walking, moderate and vigorous physical activity (for details see methods text) ^hParticipants who reported their work 'usually' or 'always' involved walking or standing for most of the time (touchscreen question number D9B, UK Biobank variable n_806_0_0)

ⁱParticipants who reported their work 'usually' or 'always' involved heavy manual or physical work for most of the time (touchscreen question number D9C, UK Biobank variable n_816_0_0)

^jSmoking status (UK Biobank variable n_20116_0_0)

^kParticipants who reported consuming alcohol three to four times per week or daily or almost daily (touchscreen question number A1, UK Biobank variable n 1558 0 0)

¹Total fruit and vegetable consumption is the sum of fresh fruit intake (touchscreen question number DT3, UK Biobank variable n_1309_0_0), cooked vegetable intake (touchscreen question numbers DT1, UK Biobank variable n_1289_0_0) and raw vegetable intake (touchscreen question number DT1, and UK Biobank variable n_1299_0_0). To sum the frequencies, 'Less than one' was coded as 0.5, and we coded 1 piece of fresh fruit as a serving and 2 tablespoons of vegetables as a serving.

^mTotal red and processed meat consumption is the sum of processed meat (touchscreen question number DT8 and UK Biobank variable $n_{1349_0_0}$), beef (touchscreen question number DT7 and UK Biobank variable $n_{1369_0_0}$), lamb/mutton (touchscreen question number DT7A and UK Biobank variable $n_{1379_0_0}$), and pork (touchscreen question number DT7B and UK Biobank variable n_{1389}) intake. To sum the frequencies, we used the following coding: 'Never' = 0, 'Less than once a week' = 0.5, 'Once a week' = 1, '2-4 times a week' = 3, '5-6 times a week' = 5.5, 'Once or more daily' = 7.

Figure legends

Figure 1 UK Biobank participant flow diagram

MPA: moderate physical activity; VPA: vigorous physical activity

Figure 2 Body fat percentage by BMI in UK Biobank

Values are mean body fat % by single-unit BMI categories

Adjusted for age (5 year categories)

Error bars represent 1 SD either side of the mean

Estimates shown for cells with 200 or more participants

Figure 3 Mean BMI and body fat percentage by physical activity in UK Biobank

Panel A: Mean BMI by physical activity (excess MET-hours/wk); Panel B: Mean body fat %

by physical activity (excess MET-hrs/wk)

Values are mean BMI and body fat percentage in the following categories of physcial

activity: <5, 5-9.9, 10-14.9, 15-24.9, 25-34.9, 35-49.9, 50-74.9, 75-99.9, ≥ 100 excess MET-

hrs per week, and are plotted at the value of the mean excess MET-hours/wk in each category

Adjusted for age (5 year categories)

Errors bars are 95% CI

Estimates shown for cells with 200 or more participants

Figure 4 Mean body fat percentage by physical activity, stratified by BMI category in UK Biobank

Panel A: men; Panel B: women

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Values are mean body fat percentage in the following categories of physical activity: <5, 5-

9.9, 10-14.9, 15-24.9, 25-34.9, 35-49.9, 50-74.9, 75-99.9, ≥ 100 excess MET-hrs per week,

and are plotted at the value of the mean excess MET-hours/wk in each category

Estimates shown for cells with 200 or more participants

Adjusted for age (5 year categories)





Figure 1 UK Biobank participant flow diagram MPA: moderate physical activity; VPA: vigorous physical activity

131x171mm (600 x 600 DPI)







Panel A: Mean BMI by physical activity (excess MET-hours/wk); Panel B: Mean body fat % by physical activity (excess MET-hrs/wk)

Values are mean BMI and body fat percentage in the following categories of physical activity: <5, 5-9.9, 10-14.9, 15-24.9, 25-34.9, 35-49.9, 50-74.9, 75-99.9, \geq 100 excess MET-hrs per week, and are plotted at the value of the mean excess MET-hours/wk in each category

Adjusted for age (5 year categories) Errors bars are 95% CI

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15	20 40 60 80 100 120 140 160 15 Physical activity (excess MET-hours/wk) Physical activity (excess MET-hours/wk)
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17	Figure 4 Mean body fat percentage by physical activity, stratified by BMI category in UK Biobank
18	Panel A: men; Panel B: women
19	Values are mean body fat percentage in the following categories of physical activity: <5, 5-9.9, 10-14.9, 15-
20	24.9, 25-34.9, 35-49.9, 50-74.9, 75-99.9, \geq 100 excess MET-hrs per week, and are plotted at the value of
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BMJ OpenTable S1 Repeated measures of physical activity in men who completed the repeat assessment visit in U
Biobank 5 years after recruitmentPhysical activity (excess MET-hours per week)^a<55-9.910-14.915-24.925-34.935-49.950-74.975-99.94ll men (n = 119, 230)*All men* (n = 119,230)Number of men 12,613 13.792 12.381 20.983 15,023 14,635 13.415 7.043 19.7 2.5 7.5 12.4 29.7 41.9 61.1 85.9 Baseline^b Men who completed the repeat assessment visit (n = 5, 158)602 614 534 943 691 631 541 Number of men 279

19.7

26.1

29.8

32.2

42.1

40.3

60.5

47.9

85.6

60.5

^aCategories are defined from baseline data

Baseline^b

Repeat^b

^bValues are mean excess MET-hours per week

2.6

12.2

7.6

16.3

12.4

20.8

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Page 39 of	52
1 2 3 4 5 6 7	Table S2 Repear Biobank 5 years
	Number of wom Baseline ^b Number of wom Baseline ^b <u>Repeat^b</u> ^a Categories are d ^b Values are mean
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ng, Al training, and similar technologies.

2 Table S2 Repeated me	asures of	physical	activity in	women v	BMJ	Open	neat assess	sment visit	mjopen-2016-011843 by copyright, inclue
Biobank 5 years after r	ecruitmen	nt			r -		F		on 2
			Physical	activity (excess ME	ET-hours p	er week) ^a		4 Ma er us
	<5	5-9.9	10-14.9	15-24.9	25-34.9	35-49.9	50-74.9	75-99.9	
	1 / 200		1	All wo	$men \ (n = 1)$	40,578)	1 < 0.01		201 elat
Number of women	14,299	17,632	15,970	26,156	18,555	17,490	16,231	7,407	80.3838 €
Baseline ^b	2.6	7.5	12.4	19.6	29.6	41.7	60.9	85.8	e te
		Wom	en who co	mpleted th	ie repeat a	ssessment	visit ($n =$	5,067)	loac upe xt ai
Number of women	515	659	606	1,004	681	640	555	229	a Tien Tien
Baseline ^b	2.6	7.6	12.3	19.6	29.7	41.7	61.0	85.0	
Repeat ^b	11.9	18.5	21.3	26.1	33.2	40.6	52.8	59.2	n <mark>Att</mark> BEES
^a Categories are defined	l from bas	seline dat	a						o://b
^b Values are mean exce	ss MET-h	ours per	week						mjor Al tra
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Table 55 Weat ()	570 CI) UUU I	iai percentage	by categories	or Divir and p	nysicai activit				
			Cat	tegories of phy	ysical activity	(MET-hours/	wkog 24		
Categories of BMI	<5	5-9.9	10-14.9	15-24.9	25-34.9	35-49.9	ruses March	75-99.9	≥ 100
	16.6	16.1	15.7	15.4	14.9	15.0		14.1	14.3
20-	(16.3-16.8)	(15.9-16.4)	(15.4-15.9)	(15.3-15.6)	(14.7-15.1)	(14.7-15.2)	(ह ें4्रुं8 में15.2)	(13.8-14.4)	(14.0-14.6)
	n = 649	n = 780	n = 743	n = 1356	n = 1014	n = 986	ရာရှိခို စို <i>940</i>	n = 478	n = 658
Mean BMI	21.6	21.5	21.5	21.5	21.5	21.5		21.5	21.5
	19.9	19.7	19.2	19.1	18.6	18.6		17.9	17.9
22.5-	(19.8-20.1)	(19.6-19.8)	(19.0-19.3)	(19.0-19.2)	(18.5-18.7)	(18.4-18.7)	(ૡૢૻૢૢૢૢૢૢૢૢ ² <u>,</u> 18.6)	(17.7-18.1)	(17.8-18.1)
	<i>n</i> = 1943	n = 2477	n = 2411	n = 4289	<i>n</i> = <i>3379</i>	<i>n</i> = <i>3247</i>	Ĩ. A A A A A A A A A A	n = 1490	n = 1909
Mean BMI	23.9	23.9	23.9	23.9	23.9	23.9		23.9	23.8
	23.0	22.7	22.4	22.2	21.9	21.7	ng. 24.6	21.3	21.2
25-	(22.9-23.1)	(22.6-22.8)	(22.3-22.5)	(22.1-22.3)	(21.8-22.0)	(21.6-21.8)	(⊉ 1. <mark>5</mark> 21.7)	(21.1-21.4)	(21.1-21.3)
	<i>n</i> = <i>3217</i>	n = 3861	n = 3606	n = 6180	n = 4428	n = 4419	j∰ = <mark>%</mark> 960	n = 2095	n = 2694
Mean BMI	26.2	26.2	26.2	26.2	26.2	26.2	ning 23.2	26.2	26.2
	25.7	25.4	25.2	25.0	24.7	24.6	ar 274.5	24.4	24.2
27.5-	(25.6-25.8)	(25.3-25.5)	(25.1-25.3)	(24.9-25.1)	(24.6-24.9)	(24.4-24.7)	(2 4. 2 24.6)	(24.2-24.6)	(24.0-24.3)
	<i>n</i> = 2950	n = 3192	<i>n</i> = <i>2793</i>	<i>n</i> = 4818	n = 3302	n = 3199	<u>⊒</u> = 2 948	n = 1561	<i>n</i> = 2145
Mean BMI	28.6	28.6	28.6	28.6	28.6	28.6	ar 282.6	28.6	28.6
	28.1	27.8	27.8	27.6	27.3	27.2	29.1	26.9	26.7
30-	(27.9-28.2)	(27.7-28.0)	(27.7-28.0)	(27.4-27.7)	(27.2-27.5)	(27.1-27.4)	(<u>a</u> 6.9 <u>2</u> 27.2)	(26.7-27.1)	(26.5-26.9)
	n = 1867	n = 1780	n = 1498	<i>n</i> = 2409	n = 1644	<i>n</i> = 1585	କ୍ଲି = ମ୍ପି 560	n = 809	n = 1107
Mean BMI	31.1	31.1	31.1	31.0	31.0	31.0	34 .0	31.0	31.0
	30.4	30.2	30.0	29.9	29.5	29.5	22.3	29.2	29.5
32.5-	(30.2-30.6)	(30.0-30.4)	(29.7-30.2)	(29.7-30.1)	(29.3-29.8)	(29.2-29.7)	(29. Ĕ 29.6)	(28.8-29.6)	(29.2-29.8)
	n = 984	<i>n</i> = 873	<i>n</i> = 663	n = 1009	<i>n</i> = 654	<i>n</i> = <i>634</i>	n = <u>0</u> 614	<i>n</i> = 335	n = 440
Mean BMI	33.6	33.6	33.5	33.5	33.4	33.5	3 ਝ .5	33.5	33.5
	•						ă		

BMJ Open Table S3 Mean (95% CI) body fat percentage by categories of BMI and physical activity in men in UK Bio Bank.

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Table S4 Mean (95% CI) body fat percentage by categories of BMI and physical activity in women in UK Bobank									
			Ca	ategories of ph	ysical activity	(MET-hours/w	vk) ing		
Categories of BMI	<5	5-9.9	10-14.9	15-24.9	25-34.9	35-49.9	244 .9 50-7 4 .9 510-7	75-99.9	≥ 100
	24.4	23.5	23.5	23.1	22.7	22.5	L se est up	22.3	22.3
18.5-	(24.0-24.8)	(23.2-23.9)	(23.2-23.8)	(22.9-23.4)	(22.4-23.0)	(22.2-22.7)	(2 2.9 - <u>9</u> 2.6)	(21.9-22.8)	(21.9-22.7)
	n = 313	n = 460	n = 405	n = 749	n = 569	<i>n</i> = 556	ne 326	n = 219	n = 267
Mean BMI	19.4	19.3	19.4	19.4	19.4	19.4		19.3	19.4
	28.4	28.0	27.8	27.5	27.2	26.8	X 20 0	26.6	26.2
20-	(28.2-28.6)	(27.9-28.2)	(27.6-27.9)	(27.4-27.6)	(27.1-27.3)	(26.7-27.0)	(2 8.3.56 .8)	(26.4-26.8)	(26.0-26.4)
	n = 1657	<i>n</i> = 2333	n = 2378	n = 4095	n = 3115	n = 3034	na 46	<i>n</i> = <i>1327</i>	n = 1156
Mean BMI	21.4	21.4	21.4	21.4	21.4	21.4		21.4	21.4
	32.6	32.2	32.0	31.8	31.4	31.4		31.0	30.7
22.5-	(32.4-32.7)	(32.1-32.3)	(31.9-32.1)	(31.7-31.9)	(31.3-31.5)	(31.3-31.5)	(3 ళ .1- 3 1.3)	(30.8-31.2)	(30.6-30.9)
	n = 2872	n = 4068	n = 4014	n = 6819	n = 4981	n = 4820	n 🛓 🐴 96	n = 2026	n = 1998
Mean BMI	23.8	23.7	23.7	23.7	23.7	23.7		23.7	23.7
	36.0	35.7	35.4	35.4	35.2	35.1	.	34.8	34.8
25-	(35.9-36.2)	(35.6-35.8)	(35.3-35.6)	(35.3-35.5)	(35.1-35.3)	(35.0-35.2)	(3 4 .8-35.0)	(34.6-35.0)	(34.6-35.0)
	n = 2953	n = 4016	n = 3594	n = 6034	n = 4288	n = 4069	ng= 3705	n = 1692	<i>n</i> = <i>1516</i>
Mean BMI	26.2	26.1	26.1	26.1	26.1	26.1	<u>n</u> .26 9	26.1	26.1
	39.0	38.8	38.5	38.3	38.3	38.2	1 38 4	38.0	37.7
27.5-	(38.9-39.2)	(38.6-38.9)	(38.4-38.7)	(38.2-38.5)	(38.2-38.4)	(38.1-38.4)	(3 <u>2</u> .9- <u>3</u> 8.2)	(37.8-38.2)	(37.5-37.9)
	<i>n</i> = 2353	<i>n</i> = 2715	n = 2370	n = 3704	n = 2616	<i>n</i> = 2366	n <u>e</u> 2262	<i>n</i> = 1008	n = 879
Mean BMI	28.6	28.6	28.6	28.6	28.6	28.6		28.6	28.6
	41.5	41.1	41.1	41.0	40.8	40.6	."40 %	40.4	40.3
30-	(41.3-41.7)	(40.9-41.3)	(40.9-41.3)	(40.9-41.2)	(40.6-41.0)	(40.4 - 40.8)	(40.6 -4 1.0)	(40.1-40.7)	(40.0-40.6)
	<i>n</i> = 1625	n = 1716	<i>n</i> = 1424	n = 2185	n = 1366	<i>n</i> = <i>1237</i>	n = 17 81	<i>n</i> = 564	n = 468
Mean BMI	31.1	31.1	31.1	31.1	31.1	31.0	31 🚆	31.0	31.1
32.5-	43.6	43.4	43.2	43.1	43.2	43.0	42	42.7	42.5

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3		(43.4-43.8)	(43.2-43.6)	(43.0-43.5)	(42.9-43.3)	(43.0-43.5)	(42.8-43.3)	$(4\vec{2}.4-\vec{2}.3.0)$	(42.3-43.1)	(42.0-42.9)
4 5		n = 1008	n = 989	n = 774	n = 1149	n = 699	n = 651	$d = \omega_1$	n = 260	n = 233
6	Mean BMI	33.6	33.6	33.6	33.6	33.6	33.5	<u>ē</u> 33 2	33.5	33.5
7 - 8		45.3	45.2	44.9	45.0	44.9	44.9	54425		
9	35-	(45.0-45.5)	(45.0-45.5)	(44.6-45.3)	(44.7-45.3)	(44.6-45.3)	(44.5-45.3)	(4 4 . 		
10		n = 577	<i>n</i> = 577	n = 444	n = 584	n = 359	<i>n</i> = 313		-	-
11	Mean BMI	36.1	36.1	36.0	36.1	36.1	36.1	8 <u>.</u>		
12 -		47.0	46.6	46.8	46.7	46.6		own nt S o te		
14	37.5-	(46.6-47.3)	(46.2-47.0)	(46.3-47.2)	(46.3-47.1)	(46.1-47.0)		iloa		
15		n = 368	n = 303	n = 207	n = 316	n = 205	-	ded prieu	-	-
16 17 -	Mean BMI	38.6	38.5	38.6	38.5	38.5		fro ur (<i>l</i> data		
18		48.3								
19	40-	(47.8-48.7)						S) Ning		
20 21		n = 220	-	-	-	-	-	g, A	-	-
22	Mean BMI	41.1						njop 1 tr:		
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Table S5 BMI and body fat percentage by sex and 5-year age category in UK Biobank

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Panel A: Mean BMI by physical activity (excess MET-hours/wk); Panel B: Mean body fat percentage bgphysical activity (excess MET-hrs/wk) Values are mean BMI and body fat percentage in the following categories of physcial activity: <5, 5-9, 9, 10, 15-24.9, 25-34.9, 35-49.9, 50-74.9, 75-99.9, \geq 100 excess MET-hrs per week, and are plotted at the value of the mean excess MET-hours/wk in each category Errors bars are 95% CI gence Bibliographique

Estimates shown for cells with 200 or more participants



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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract
	-	Title, and Pg 3
		(b) Provide in the abstract an informative and balanced summary of what was done
		and what was found Pg 3
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
		Pg 5
Objectives	3	State specific objectives, including any prespecified hypotheses Pg 5
Methods		
Study design	4	Present key elements of study design early in the paper Pg 6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment,
-		exposure, follow-up, and data collection Pg 6
Participants	6	(a) Cohort study—Give the eligibility criteria, and the sources and methods of
		selection of participants. Describe methods of follow-up
		Case-control study—Give the eligibility criteria, and the sources and methods of
		case ascertainment and control selection. Give the rationale for the choice of cases
		and controls
		<i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of
		selection of participants Pg 8
		(b) Cohort study—For matched studies, give matching criteria and number of
		exposed and unexposed
		Case-control study—For matched studies, give matching criteria and the number of
		controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect
		modifiers. Give diagnostic criteria, if applicable Pg 9
Data sources/	8*	For each variable of interest, give sources of data and details of methods of
measurement		assessment (measurement). Describe comparability of assessment methods if there is
		more than one group Pgs 6-8, and Footnotes for Table 1 and Table 2
Bias	9	Describe any efforts to address potential sources of bias Pg 10
Study size	10	Explain how the study size was arrived at Pg 8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable,
		describe which groupings were chosen and why Pg 9
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding
		Pgs 9-10
		(b) Describe any methods used to examine subgroups and interactions Pgs 9-10
		(c) Explain how missing data were addressed Pg 8
		(d) Cohort study—If applicable, explain how loss to follow-up was addressed
		<i>Case-control study</i> —If applicable, explain how matching of cases and controls was
		addressed
		Cross-sectional study—If applicable, describe analytical methods taking account of
		sampling strategy N/A
		(<u>e</u>) Describe any sensitivity analyses Pg 9

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Results		
Participants	13*	(a) Report numbers of individuals at each stage of study-eg numbers potentially eligible,
		examined for eligibility, confirmed eligible, included in the study, completing follow-up, and
		analysed Pg 12, and Figure 1
		(b) Give reasons for non-participation at each stage Figure 1
		(c) Consider use of a flow diagram Figure 1
Descriptive	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information
data		on exposures and potential confounders Pg 12, and Tables 1 and 2
		(b) Indicate number of participants with missing data for each variable of interest Footnotes for
		Tables 1 and 2
		(c) Cohort study—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	Cohort study—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of
		exposure
		Cross-sectional study-Report numbers of outcome events or summary measures Tables 1 and
		2.
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their
		precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and
		why they were included Pgs 12-13
		(b) Report category boundaries when continuous variables were categorized Pgs 9-10
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful
		time period N/A
Other analyses	17	Report other analyses done-eg analyses of subgroups and interactions, and sensitivity
		analyses Pgs 13-14
Discussion		
Key results	18	Summarise key results with reference to study objectives Pg 15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision.
		Discuss both direction and magnitude of any potential bias Pgs 15-16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity
		of analyses, results from similar studies, and other relevant evidence Pg 17
Generalisability	21	Discuss the generalisability (external validity) of the study results Pgs 16-17
Other informati	on	
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable,
		for the original study on which the present article is based Pg 18

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

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

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The association between physical activity and body fat percentage, with adjustment for BMI: a large crosssectional analysis of UK Biobank

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BMJ Open

The association between physical activity and body fat percentage, with adjustment for BMI: a large cross-sectional analysis of UK Biobank Kathryn E Bradbury, Wenji Guo, Benjamin J Cairns, Miranda EG Armstrong, and **Timothy J Key**

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Abstract

Objectives: The objective of this study was to examine if, in the general population, physically active adults have less body fat after taking BMI into account.
Design: A cross-sectional analysis of participants recruited into UK Biobank in 2006-2010.
Setting: UK Biobank assessment centres throughout the UK.
Participants: 119,230 men and 140,578 women aged 40-69 years, with complete physical activity information, and without a self-reported long-term illness, disability or infirmity.
Exposures: Physical activity measured as excess MET-hours per week, estimated from a combination of walking, and moderate and vigorous physical activity. BMI from measured height and weight.

Main outcome measure: Body fat percentage estimated from bio-impedance.

Results: BMI and body fat percentage were highly correlated (r=0.85 in women; r=0.79 in men), and both were inversely associated with physical activity. Compared to <5 excess metabolic equivalent (MET)-hours per week at baseline, \geq 100 excess MET-hours per week was associated with a 1.1 kg/m² lower BMI (27.1 versus 28.2 kg/m²) and 2.8 percentage points lower body fat (23.4% versus 26.3%) in men, and 2.2 kg/m² lower BMI (25.6 versus 27.7 kg/m²) and 4.0 percentage points lower body fat (33.9% versus 37.9%) in women. For a given BMI, greater physical activity was associated with lower average body fat percentage (for a BMI of 22.5-24.99 kg/m²: 2.0 (95% CI: 1.8 to 2.2) percentage points lower body fat in men, and 1.8 (95% CI: 1.6 to 2.0) percentage points lower body fat in women, comparing \geq 100 excess MET-hours per week to <5 excess MET-hours per week).

Conclusions: In this sample of middle-aged adults, drawn from the general population, physical activity was inversely associated with BMI and body fat percentage. For people with the same BMI, those who were more active had a lower body fat percentage.

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Strengths and limitations of this study

- This study of middle-aged adults, drawn from the general population, is very large (n = 259,808) and height and weight (for the calculation of BMI) were measured by trained staff using standardised techniques.
- Body fat percentage (estimated via bio-impedance) was available for virtually all participants.
- Physical activity was self-reported and therefore there will be some measurement error associated with this variable.
- The study is cross-sectional and therefore we cannot infer cause and effect.

Introduction

Body mass index (BMI) is a simple index calculated from height and weight, and is usually used as a proxy for body fatness in large epidemiological studies. Correlations between BMI and more direct measures of body fatness are generally strong (r > 0.70) (1-4).

Observational studies have shown that people who do comparatively more physical activity have a lower BMI than less active people (5, 6). Few large epidemiological studies have directly estimated body fatness, and it is of interest to examine whether more comprehensive measures of body fatness provide additional information above and beyond that which is captured by BMI. Previous studies each of approximately 500 young adults have found that, for a given BMI, athletes have a lower body fat percentage than non-athletes (7, 8); however it is unclear whether in the general population of middle-aged adults, those who do more physical activity have a lower body fat percentage than those who do minimal physical activity, after taking into account BMI.

UK Biobank is a population-based cohort of 500,000 UK men and women, aged 40-69 years at recruitment. Body mass index and body fat percentage were measured at recruitment for virtually all participants. For this analysis of data from UK Biobank we aimed firstly to describe the associations of physical activity with BMI and body fat percentage, and secondly to determine whether physical activity is associated with body fat percentage, independently of BMI.

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METHODS

Subjects

UK Biobank is a prospective cohort of approximately 500,000 people aged 40-69 years, recruited in 2006-2010 in the UK (9). People aged 40-69 years who lived within reasonable travelling distance of 22 assessment centres were identified from National Health Service patient registers and invited to participate in UK Biobank by attending an assessment centre. Permission for access to patient records for recruitment was approved by the National Information Governance Board for Health and Social Care in England and Wales, and the Community Health Index Advisory Group in Scotland. A sub-sample of approximately 20,000 participants completed a full repeat of the assessment centre visit between August 2012 and June 2013, approximately 5 years after recruitment (10). UK Biobank has ethical approval from the North West Multi-centre Research Ethics Committee. The UK Biobank protocol is available online (http://www.ukbiobank.ac.uk/wp-content/uploads/2011/11/UK-Biobank-Protocol.pdf). The touchscreen questionnaire and other resources are also available on the UK Biobank website (http://www.ukbiobank.ac.uk/resources/).

Anthropometric measurements

At the UK Biobank assessment centres, a touchscreen questionnaire was used to collect information on socio-demographic characteristics and lifestyle exposures. Socks and shoes were removed and height was measured using the Seca 202 height measure (Seca, Hamburg, Germany). Weight and estimated percentage fat were measured with the Tanita BC418ma bio-impedance device (Tanita, Tokyo, Japan). Participants were not asked to fast, nor were they given any specific instructions pertaining to the bio-impedance measures prior to

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attending the assessment centre. Water was available at all times throughout the visit and visits occurred throughout the day (8am-8pm).

Physical activity assessment

Questions on the touchscreen about walking, moderate physical activity, and vigorous physical activity, which were similar to those used in the short form of the International Physical Activity Questionnaire (11), were used to estimate excess metabolic equivalents (MET)-hours per week of physical activity during work and leisure time. For each of the three activity categories (walking, moderate physical activity, and vigorous physical activity) participants were asked how many days in a typical week they did each of the activities for 10 minutes or more (for walking: touchscreen question number WP1, UK Biobank variable n_864_0_0; for moderate physical activity: touchscreen question number WP2, UK Biobank variable n_884_0_0; for vigorous physical activity: touchscreen question number WP3, UK Biobank variable n_904_0_0). For each category, participants who entered one or more days were then asked how many minutes they spent doing those activities on a typical day (for walking: WP1A, n_874_0_0; for moderate physical activity: WP2A, n_894_0_0; for vigorous physical activity: WP3A, n_914_0_0). For each activity category, the number of reported days was multiplied by the number of reported minutes on a typical day to generate duration of activity in minutes per week.

Activity on a typical day of less than 10 minutes was recoded to 0 for any of the three categories of activity. For each of the three categories of activity, values of more than 1260 minutes per week (equivalent to an average of 3 hours per day) were truncated at 1260 (11).

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Total MET values for each category from the International Physical Activity Questionnaire short form were: 3.3 for walking, 4.0 for moderate physical activity, and 8.0 for vigorous physical activity (11). We report excess METs, which are calculated by subtracting 1 MET from the value for each activity, and represent the energy expenditure above that of an inactive person (12). Excess MET values were therefore 2.3 for walking, 3.0 for moderate physical activity, and 7.0 for vigorous physical activity. Excess MET-hours per week were calculated by multiplying the excess MET value for each activity by the duration of activity in hours per week (11).

Exclusions

The UK Biobank dataset used for this analysis included 502,640 participants. Participants were excluded from this analysis if they selected 'Prefer not to answer' or 'Do not know' to any of the possible six questions on physical activity (WP1, WP1A, WP2, WP2A, WP3, WP3A) (n = 66,625). Participants were also excluded from this analysis if they responded to the question: "Do you have a long-term illness, disability or infirmity?" with 'Yes' (n = 159,941), 'Prefer not to answer' (n = 1,052) or 'Do not know' (n = 11,391), or if they had a missing value for this variable (n = 919) (touchscreen question number H4, UK Biobank variable $n_2188_0_0$). In addition, the questions used in the pilot study on the duration of physical activity differed from those in the main study, and participants who answered the pilot version of these questions were excluded (n = 2,253). Based on the International Physical Activity Questionnaire recommendations for data cleaning and processing (11), participants were also excluded from the analysis if the sum of walking, moderate physical

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activity, and vigorous physical activity was greater than 112 hours per week (n = 651), leaving a total of 259,808 participants in the present study.

Statistics

STATA version 14.0 (Stata Corp LP, College Station, TX) was used for all statistical analyses. All analyses were done for men and women separately. Participant characteristics were described by level of physical activity (low, < 10.0; moderate, 10.0-49.9; high, ≥ 50 excess MET-hours per week). Pearson's correlation coefficients between BMI and body fat percentage were calculated; values of 0.80 or above are considered very strong, values between 0.60-0.79 strong, 0.40-0.59 moderate, 0.20-0.39 weak, and 0.00-0.19 very weak (13). Multiple linear regression was used to calculate the mean body fat percentage in single units of BMI (e.g. 17.00-17.99, 18.00-18.99, 19.00-19.99 kg/m², etc), adjusted for age (5 year categories: < 45 years, 45-49.99 years, 50-54.99 years, 55-59.99 years, 60-64.99 years, >65.00 years). Groups with 200 or more participants are shown in the Figure. Multiple linear regression was also used to calculate mean BMI and body fat percentage in categories of excess MET-hours per week (< 5, 5-9.9, 10-14.9, 15-24.9, 25-34.9, 35-49.9, 50-74.9, 75- $99.9 \ge 100$ excess MET-hours per week), adjusted for age (5 year categories, as above). For the final analysis, we used multiple linear regression to examine the association between physical activity (in excess MET-hours per week: < 5, 5-9.9, 10-14.9, 15-24.9, 25-34.9, 35-49.9, 50-74.9, 75-99.9, > 100) and body fat percentage (continuous variable). Body mass index (in 2.5 unit categories, e.g. < 18.50, 18.50-19.99, 20.00-22.49, 22.50-24.99, 25.00- $27.49...,42.50-44.99, \ge 45.00 \text{ kg/m}^2$, etc) and age (5 year categories) were included as covariates. We included a product term of excess MET-hours per week (categories, as above) and BMI (in 2.5 unit categories as above) in the model to calculate mean body fat percentage

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in categories of physical activity within strata of BMI. In additional sensitivity analyses, we adjusted for reported intakes of fruit and vegetables (< 3.00 servings/week, 3.00-3.99, 4.00-4.99, 5.00-5.99, ≥ 6.00 servings/week, unknown), and red and processed meat (< 2.00 servings/week, 2.00-2.99, 3.00-3.99, 4.00-4.99, ≥ 5.00 servings/week, unknown). We also restricted the analysis to those with a university or college degree, and separately, to those that do not have a job that usually or always involves standing or walking or manual work.

We also examined mean BMI and body fat percentage in 5 year age categories. For each age decade separately (i.e. participants < 50 years, 50-59 years, and \geq 60 years) linear regression was used to calculate mean body fat percentage in single units of BMI, and to calculate mean BMI and body fat percentage in each category of physical activity (< 5, 5-9.9, 10-14.9, 15-24.9, 25-34.9, 35-49.9, 50-74.9, 75-99.9, \geq 100 excess MET-hours per week).

To explore the repeatability of self-reported physical activity, including effects of measurement error and possible changes in activity over time, we used a sub-sample of 10,225 UK Biobank participants who were eligible for the current study and who completed a repeat assessment visit approximately 5 years after recruitment (Supplementary Tables S1 and S2). For these participants, we calculated excess MET-hours per week from their answers to the touchscreen questionnaire completed at the repeat assessment centre visit, as described above. Then for each category of excess MET-hours per week defined at baseline, we calculated both the mean excess MET-hours per week at their baseline visit (to assess comparability of the sub-sample to the full cohort) and the mean excess MET-hours per week at the repeat visit (to assess measurement error in reporting physical activity and change over time). The sub-sample of participants who completed a repeat assessment centre visit

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approximately 5 years after recruitment was similar at baseline to the full cohort with regard to reported physical activity. However, at the repeat assessment, for participants in the highest category of physical activity defined at baseline (\geq 100 excess MET-hours per week), the mean excess MET-hours per week was much lower than at baseline (80 compared to 130 for both men and women). For the lowest category of physical activity defined at baseline, the mean excess MET-hours per week was somewhat higher at the repeat assessment than at baseline (12 compared to 2.6 for both men and women). Overall, this represents regression to the mean of almost 50% (calculated from the ratio of the range of mean values at the repeat assessment to the range of mean values at baseline). The Pearson's correlation coefficients between recruitment and repeat measurements of BMI and body fat percentage in the subsample of participants who completed a repeat assessment centre visit were 0.92 for both BMI and body fat percentage.

All p values were two-sided and P < 0.05 was considered statistically significant.

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RESULTS

Participant flow is shown in Figure 1. Participants who had a high level of physical activity were older, had a lower BMI, a lower body fat percentage, and a higher intake of fruit and vegetables than participants with a low level of physical activity (Table 1 and Table 2). They were also less likely to have a college or university degree, and much more likely to have a standing or manual job than those with a moderate or low level of physical activity. Participants with a moderate activity level were the least likely to be current smokers.

Body fat percentage was positively related to BMI (Figure 2). The correlation between BMI and body fat percentage was very strong in women (r = 0.85), and strong in men (r = 0.79). At the same BMI, women had a much higher body fat percentage than men; for example, women with a BMI of 30.00-30.99 kg/m² had on average 41% body fat, whereas men with the same BMI had on average 28% body fat.

Body fat percentage and BMI were inversely related to physical activity (Figure 3). Men who did < 5 excess MET-hours of physical activity per week had, on average, a BMI of 28.2 kg/m² (95% Confidence Interval (CI): 28.2 to 28.3 kg/m²) and 26.3% (95% CI: 26.2 to 26.4 kg/m²) body fat. Men who did \geq 100 excess MET-hours per week of physical activity per week had, on average, a BMI of 27.1 kg/m² (95% CI: 27.0 to 27.2 kg/m²) and 23.4% (95% CI: 23.3 to 23.5%) body fat. Women who did < 5 excess MET-hours per week of physical activity per week had, on average, a BMI of 27.7 kg/m² (95% CI: 27.7 to 27.8 kg/m²) and 37.9% (95% CI: 37.8 to 38.0%) body fat. Women who did \geq 100 excess MET-hours per week of physical activity per week had, on average, a BMI of 27.7 kg/m² (95% CI: 27.7 to 27.8 kg/m²) and 37.9% (95% CI: 37.8 to 38.0%) body fat. Women who did \geq 100 excess MET-hours per week of physical activity per week had, on average, a BMI of 25.6 kg/m² (95% CI: 25.5 to 25.7 kg/m²) and a 33.9% (95% CI: 33.7 to 34.0%) body fat. For both men and women, as shown by the r² values, age and physical activity explained more of the variation in body fat

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percentage than the variation in BMI in this study population; however, age and physical activity only explained a small proportion of the variation in both BMI and body fat percentage in this study population, with all r^2 values less than 0.06 (Figure 3).

Overall, in males, those doing \geq 100 or more excess MET-hours per week compared with < 5 excess MET-hours per week had a 1.7 (95% CI: 1.6 to 1.7) percentage points lower body fat percentage, on average, after adjustment for BMI and age; in females it was on average 1.5 (95% CI: 1.4 to 1.6) percentage points lower. For both men and women, within each stratum of BMI, a higher physical activity level was associated with a lower body fat percentage, and the difference in body fat percentage between physical activity categories appeared to be slightly larger at lower BMIs (*p* for interaction using likelihood ratio test < 0.001, for both sexes) (Figure 4, Supplementary Tables S3 and S4). For a BMI of 22.5-24.99 kg/m², \geq 100 excess MET-hours per week vs < 5 excess MET-hours per week was associated with 2.0 (95% CI: 1.8 to 2.2) percentage points lower body fat in men and 1.9 (95% CI: 1.6 to 2.0) percentage points lower body fat in women. For both men and women, within each stratum of BMI, the mean BMI was very similar across the categories of physical activity.

When we further adjusted for reported intakes of fruit and vegetables, and red and processed meats, or restricted the analysis to those who did not have an active job or those who had a university or college degree, the results were not materially altered. Comparing those doing \geq 100 excess MET-hours per week to those doing < 5 excess MET-hours per week, body fat percentage was, on average 1.6 (95% CI: 1.5 to 1.7) percentage points lower for men and 1.4 (95% CI: 1.3 to 1.5) percentage points lower for women after adjustment for diet quality; 1.7 (95% CI: 1.6 to 1.9) percentage points lower for men and 1.6 (95% CI: 1.4 to 1.8) percentage points lower for women when restricting analyses to those who had a university or college

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degree; and 1.6 (95% CI: 1.5 to 1.7) percentage points lower for men and 1.4 (95% CI: 1.3 to 1.5) percentage points lower for women when we restricted analyses to those who did not have a standing or manual job.

In men, the mean BMI was similar across 5-year age categories however the mean body fat percentage was higher in older age groups. In women, the mean BMI by 5-year age categories was slightly higher in older age groups, and the mean body fat percentage was also higher in older age groups (Supplementary Table S5). The association between BMI and body fat percentage was similar in each age decade (Supplementary Figures S1, S2, and S3). The differences in BMI between the extreme categories of physical activity were slightly larger and the differences in body fat percentage were slightly smaller with older age (Supplementary Figures S4, S5 and S6).

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DISCUSSION

In this large sample of middle-aged British men and women, more physical activity was associated with both a lower BMI and a lower body fat percentage, although even men and women who did the most physical activity were, on average, overweight. More physical activity was also associated with a lower body fat percentage within each category of BMI, with an average 1-2 percentage points lower body fat in the most active, compared to the least active individuals. Most of the difference in body fat percentage with physical activity was between the very low and moderately-high levels of physical activity (<5 and 35-49.9 excess MET-hours per week, respectively); there was relatively little difference in body fat percentage between moderately-high and very high levels of physical activity (35-49.9 and ≥100 excess MET-hours per week, respectively).

The current study is large, and height and weight were measured by trained staff using standardised techniques. We examined whether important lifestyle factors (diet quality, education, and job type) which varied by physical activity level might modify the associations between physical activity, BMI and body fat percentage. In each of these sensitivity analyses, the results were essentially unchanged, although because this is an observational study we cannot rule out confounding by other factors. A limitation of the study is that physical activity approximately 5 years after baseline indicates approximately 50% regression to the mean, which represents both the error in reporting physical activity and true changes in physical activity over time. The likely consequence of regression to the mean in physical activity levels over time is bias of associations towards the null, so that the true association between physical activity and body composition measures is likely to be stronger than that observed in this study. Participants were not given any specific

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instructions prior to body fat measurement. Hydration status, exercise and food consumption can have small effects on body fat values measured by bioimpedance; had these factors been standardised between participants, we may have seen slightly stronger associations between body fat percentage and physical activity. The study is cross-sectional, and therefore we can only show associations between reported physical activity and contemporaneous body composition. We cannot infer cause and effect: lower levels of physical activity may lead to greater adiposity, but it is also possible that increased adiposity leads to less physical activity.

Previous small studies (n<200), in young athletic populations have found inverse relationships between measures of physical fitness and BMI and body fat percentage (14, 15). Small studies (n~500) in young adults have also shown that, for a given BMI, athletes have a lower body fat percentage than non-athletes (7, 8). These findings are, however, of limited relevance to older adults in the general population, who experience the highest burden of obesity-related disease. An analysis of 466,605 participants in the China Kadoorie Biobank, aged 30-79 years, found relatively weak associations between physical activity and either BMI or body fat percentage: a difference of approximately 100 total MET-hours per week was associated with 0.15 kg/m² lower BMI, and 0.48 percentage points lower body fat (16). Participants in the China Kadoorie Biobank differed from those in UK Biobank in ethnicity and lifestyle, and also had a lower average BMI (23.4 (SD 3.2) kg/m² in men; 23.8 (SD 3.4) kg/m² in women). Their physical activity levels were comparable to the middle to upper range of physical activity of UK Biobank participants, and in this range we also saw only a small difference in body fat percentage.

Variation in BMI in the general population is largely due to differences in body fatness, but by definition it incorporates both adipose and lean body mass, and it is therefore difficult to

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disentangle the roles of adipose and lean mass in associations of BMI with health outcomes. For example, a higher BMI is an established risk factor for post-menopausal breast cancer, and probably increases risk through higher circulating sex hormones produced by the enzyme aromatase in the adipose tissue from precursor androgens (17). Several cohort studies have also shown that more physical activity is associated with a reduced risk of post-menopausal breast cancer, even after adjustment for BMI, and this finding is often taken as evidence that physical activity is independent of adiposity as a risk factor for post-menopausal breast cancer (18). Our results suggest, however, that adjustment for BMI may not have fully controlled for adiposity in these analyses.

In conclusion, in this sample of middle-aged British adults who were free from self-reported long-standing illness, men and women who reported doing the most physical activity had a lower BMI and a lower body fat percentage than those who reported doing the least physical activity. We also report new evidence that, for a given BMI, men and women who reported doing more physical activity had a lower body fat percentage; the greatest difference was observed between low and moderate levels of physical activity. BMI incorporates both adipose and lean mass, but is most strongly related to adiposity, and consequently is associated with morbidity and mortality from a wide range of diseases. However, to disentangle the possible effects of physical activity and adiposity on disease risk, future research should focus on more specific measures of adiposity.

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Competing interests: All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years, no other relationships or activities that could appear to have influenced the submitted work.

Contributorship: KEB and TJK conceived the research, KEB performed the statistical analyses; BJC contributed to the statistical methodology; MEGA contributed to generation of the physical activity variables. KEB, WG, BJC, MEGA, and TJK interpreted the data, drafted and reviewed the article for important intellectual content, KEB has primary responsibility for the final content. All authors read and approved the final manuscript. KEB is the guarantor for the study. This research has been conducted using the UK Biobank Resource under Application Number 3037.

Ethics approval: UK Biobank has ethical approval from the North West Multi-centre Research Ethics Committee. Participants gave informed consent on the touchscreen before taking part.

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Data sharing: UK Biobank is an open access resource. Bona fide researchers can apply to use the UK Biobank dataset by registering and applying at

http://www.ukbiobank.ac.uk/register-apply/. Statistical code for used for this manuscript is

available to other researchers on request by emailing Kathryn Bradbury

(kathryn.bradbury@ceu.ox.ac.uk).

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Table1 Characteristics of men participating in UK Biobank by physical activity

	Low activity	Moderate activity	High activity	All men
	< 10 excess	10,40,0 average		
	MET-	10-49.9 excess	\geq 50 excess	
	hours/wk ¹	ME1-hours/wk*	MET-hours/wk ¹	
	<i>n</i> = 26,405	<i>n</i> = 63,022	<i>n</i> = 29,803	<i>n</i> = 119,230
ge (years)	0.			
Mean (SD)	55.3 (8.0)	55.7 (8.4)	56.0 (8.4)	55.7 (8.3)
hite ethnicity ^a	24,741 (93.7)	59,842 (95.0)	28,468 (95.5)	113,051 (94.8)
cioeconomic status ^b				
Upper fifth	6,274 (23.8)	14,701 (23.4)	5,867 (19.7)	26,842 (22.5)
alifications ^c				
College or University degree/vocational qualification	18,878 (71.5)	45,453 (72.2)	17,731 (59.5)	82,062 (68.8)
/II (kg/m ²) ^d				
Mean (SD)	28.0 (4.2)	27.1 (3.7)	27.1 (3.6)	27.3 (3.8)
< 20.00	238 (0.9)	559 (0.9)	289 (1.0)	1,086 (0.9)
	5,849 (22.2)	17,425 (27.7)	8,326 (28.0)	31,600 (26.6)

25.00-29.99		13,220 (50.2)	32,745 (52.1)	15,403 (51.8)	61,368 (51.
≥ 30.00-34.99		7,015 (26.7)	12,135 (19.3)	5,699 (19.2)	24,849 (20.
ody fat (%) ^e					
Mean (SD)		25.8 (5.5)	24.2 (5.4)	23.6 (5.5)	24.4 (5.5)
< 15.00		761 (2.9)	3,062 (4.9)	1,945 (6.6)	5,768 (4.9
15.00-19.99		2,810 (10.8)	9,714 (15.6)	5,148 (17.5)	17,672 (15
20.00-24.99		7,714 (29.6)	21,023 (33.7)	10,080 (34.3)	38,817 (32
25.00-29.99		9,194 (35.2)	19,816 (31.8)	8,686 (29.5)	37,696 (32
≥ 30.00		5,629 (21.6)	8,703 (14.0)	3,558 (12.1)	17,890 (15
leight (m) ^f					
< 1.70		3,902 (14.8)	9,251 (14.7)	5,467 (18.4)	18,620 (15
1.70 - 1.74		6,250 (23.8)	15,301 (24.4)	7,917 (26.6)	29,468 (24
1.75 - 1.79		7,738 (29.4)	18,182 (28.9)	8,246 (27.8)	34,166 (28
1.80 - 1.84		5,308 (20.2)	12,992 (20.7)	5,408 (18.2)	23,708 (19
≥ 1.85		3,115 (11.8)	7,120 (11.3)	2,682 (9.0)	12,917 (10
fean (SD) excess MET-h	nours per week ^g	5.1 (2.9)	25.8 (11.0)	92.9 (43.3)	38.0 (40.1

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1						
2						25
3						
4 5 6	Manual job ⁱ	561 (2.8)	3,214 (7.6)	8,145 (41.1)	11,920 (14.6)	
7 8	Smoking status ^{1j}					
9 10	Never	14,269 (54.0)	34,209 (54.3)	15,101 (50.7)	63,579 (53.3)	
11 12	Previous	8,866 (33.6)	22,438 (35.6)	10,936 (36.7)	42,240 (35.4)	
13 14	Current	3,215 (12.2)	6,252 (9.9)	3,680 (12.4)	13,147 (11.0)	
15 16	Alcohol consumption ^k					
17 18	Three or more times a week	14,391 (54.5)	36,542 (58.0)	15,477 (52.0)	66,410 (55.8)	
19 20	Fruit and vegetable consumption ¹					
21 22	< 3.00 servings per day	8,754 (33.2)	14,052 (22.3)	5,966 (20.0)	28,772 (24.1)	
23 24	3.00-3.99 servings per day	6,031 (22.8)	13,370 (21.2)	5,204 (17.5)	24,605 (20.6)	
25 26	4.00-4.99 servings per day	4,619 (17.5)	12,622 (20.0)	5,485 (18.4)	22,726 (19.1)	
27 28 20	5.00-5.99 servings per day	2,926 (11.1)	8,930 (14.2)	4,389 (14.7)	16,245 (13.6)	
29 30 21	\geq 6.00 servings per day	3,798 (14.4)	13,559 (21.5)	8,405 (28.2)	25,762 (21.6)	
32 32	Total red and processed meat consumption ^m					
34 35	< 2.00 times per week	2,120 (8.0)	5,838 (9.3)	2,956 (9.9)	10,914 (9.2)	
36 37	2.00-2.99 times a week	6,291 (23.8)	16,042 (25.5)	7,170 (24.1)	29,503 (24.7)	
38 39 40	3.00-3.99 times a week	3,927 (14.9)	9,323 (14.8)	4,186 (14.1)	17,436 (14.6)	
40 41 42						
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46 47	ມູ່ມູ່ຜູ້ ອຸກຸ ດຣ ີໄຫຼ່ເຊິ່ສ technologies.	viewula. epittiki (etebi boeuxpiugi)	panalaitaashanat/autik	អ្វីលៀតអ្វីស្វីល្អផ្លូវផ្លូវផ្លូវ vd bet:	Protec	
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4.00-4.99 times a week	4,866 (18.4)	10,990 (17.4)	5,069 (17.0)	20,925 (17.6)
\geq 5.00 times a week	9,042 (34.2)	20,523 (32.6)	10,229 (34.3)	39,794 (33.4)

Number of participants with missing data (the total number participants who have missing data, or who reported 'do not know' or 'prefer not to answer') for each characteristic is as follows: 0 for age, 377 for ethnicity, 159 for socioeconomic status, 705 for qualifications, 327 for BMI, 1,367 for body fat %, 351 for height, 0 for excess MET-hours/wk, 57 for standing or walking job, 38 for manual job, 264 for smoking status, 35 for alcohol consumption, 1,120 for fruit and vegetable consumption, 658 for total red and processed meat consumption ^aParticipants who reported their ethnicity as 'White', 'British', 'Irish', or 'Any other white background' ^bWe generated quintiles of socioeconmic status based on the Townsend deprivation index for the whole cohort (UK Biobank variable n_189_0_0) ^cVocational qualifications defined as other professional qualification (eg: nursing or teaching)/ National Vocational Qualification or Higher National Diploma or Higher National Certificate) (touchscreen question number D12, UK Biobank variable n_6138_0_0) ^dWe preferentially used BMI derived from height and weight measured during the impedance measurement (UK Biobank variable n_23104_0_0_), but if missing used the body size measures (UK Biobank variable n_21001_0_0); both of these are direct measures of height and weight made on the same day at the assessment centre ^cBody fat % (UK Biobank variable n_23099_0_0)

^gExcess MET-hours/wk estimated from the combination of reported walking, moderate and vigorous physical activity (for details see methods text)

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^hParticipants who reported their work 'usually' or 'always' involved walking or standing for most of the time (touchscreen question number D9B, UK Biobank variable n_806_0_0) ⁱParticipants who reported their work 'usually' or 'always' involved heavy manual or physical work for most of the time (touchscreen question number D9C, UK Biobank variable n_816_0_0) ^jSmoking status (UK Biobank variable n_20116_0_0) ^kParticipants who reported consuming alcohol three to four times per week or daily or almost daily (touchscreen question number A1, UK Biobank variable n_1558_0_0)

¹Total fruit and vegetable consumption is the sum of fresh fruit intake (touchscreen question number DT3, UK Biobank variable n_1309_0_0), cooked vegetable intake (touchscreen question numbers DT1, UK Biobank variable n_1289_0_0) and raw vegetable intake (touchscreen question number DT1, and UK Biobank variable n_1299_0_0). To sum the frequencies, 'Less than one' was coded as 0.5, and we coded 1 piece of fresh fruit as a serving and 2 tablespoons of vegetables as a serving.

^mTotal red and processed meat consumption is the sum of processed meat (touchscreen question number DT8 and UK Biobank variable $n_{1349_0_0}$), beef (touchscreen question number DT7 and UK Biobank variable $n_{1369_0_0}$), lamb/mutton (touchscreen question number DT7A and UK Biobank variable $n_{1379_0_0}$), and pork (touchscreen question number DT7B and UK Biobank variable n_{1389}) intake. To sum the frequencies, we used the following coding: 'Never' = 0, 'Less than once a week' = 0.5, 'Once a week' = 1, '2-4 times a week' = 3, '5-6 times a week' = 5.5, 'Once or more daily' = 7.

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	Low activity	Moderate activity	High activity	All women
	< 10 excess MET-	10-49.9 excess	> 50 excess	
	hours/wk ¹	MET-hours/wk ¹	MET-hours/wk ¹	
	<i>n</i> = 31,931	<i>n</i> = 78,171	<i>n</i> = 30,476	<i>n</i> = 140,578
Age (years)				
Mean (SD)	54.6 (7.8)	55.2 (8.1)	56.2 (8.1)	55.3 (8.1)
White ethnicity ^a	30,164 (94.5)	74,471 (95.3)	29,088 (95.5)	133,723 (95.1)
Socioeconomic status ^b				
Upper fifth	6,956 (21.8)	17,177 (22.0)	6,407 (21.0)	30,540 (21.8)
Qualifications ^c				
College or University degree/vocational qualification	19,320 (60.5)	49,219 (62.9)	17,826 (58.5)	86,365 (61.5)
BMI (kg/m ²) ^d				
Mean (SD)	27.2 (5.1)	26.0 (4.4)	25.7 (4.2)	26.2 (4.6)
< 20.00	954 (3.0)	2,838 (3.6)	1,270 (4.2)	5,062 (3.6)

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1 2 3						29
4 5 6	20.00-24.99	10,930 (34.3)	33,256 (42.7)	13,749 (45.2)	57,935 (41.3)	
7	25.00-29.99	12,037 (37.8)	29,041 (37.2)	11,062 (36.4)	52,140 (37.2)	
9 10	≥ 30.00-34.99	7,930 (24.9)	12,839 (16.5)	4,334 (14.3)	25,103 (17.9)	
11	Body fat (%) ^e					
12 13 14	Mean (SD)	37.1 (6.6)	35.2 (6.5)	34.4 (6.6)	35.5 (6.7)	
15 16	< 25.00	1,197 (3.8)	4,842 (6.3)	2,524 (8.4)	8,563 (6.2)	
17 18	25.00-29.99	3,256 (10.3)	11,220 (14.5)	4,920 (16.3)	19,396 (14.0)	
19 20	30.00-34.99	7,011 (22.2)	20,467 (26.5)	8,224 (27.3)	35.702 (25.7)	
20 21 22	35.00-39.99	9,129 (29.0)	22,181 (28.7)	8,347 (27.7)	39,657 (28.6)	
23	≥ 40.00	10,940 (34.7)	18,506 (24.0)	6,110 (20.3)	35,556 (25.6)	
24 25 26	Height (m) ^f					
27 28	< 1.55	2,758 (8.7)	6,315 (8.1)	2,810 (9.2)	11,883 (8.5)	
29 30	1.55 - 1.59	6,268 (19.7)	15,551 (19.9)	6,504 (21.4)	28,323 (20.2)	
31 32	1.60 - 1.64	10,067 (31.6)	24,437 (31.3)	9,631 (31.7)	44,135 (31.5)	
33 34	1.65 - 1.69	7,993 (25.1)	20,091 (25.8)	7,530 (24.8)	35,614 (25.4)	
35 36	≥ 1.70	4,779 (15.0)	11,621 (14.9)	3,952 (13.0)	20,352 (14.5)	
37 38 39 40	Mean (SD) excess MET-hours per week ^g	5.3 (2.8)	25.5 (10.9)	83.0 (33.3)	33.4 (32.5)	
40						

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Standing or walking job ^h	3,901 (17.4)	12,349 (25.7)	9,593 (56.3)	25,843 (29.53)
Manual job ⁱ	521 (2.3)	2,576 (5.4)	3,883 (22.8)	6,980 (8.0)
Smoking status ⁱ				
Never	19,513 (61.1)	47,974 (61.4)	18,370 (60.3)	85,857 (61.1)
Previous	9,468 (29.7)	24,366 (31.2)	9,635 (31.6)	43,469 (30.9)
Current	2,883 (9.0)	5,661 (7.2)	2,417 (7.9)	10,961 (7.8)
Alcohol consumption ^k				
Three or more times a week	12,670 (39.7)	33,747 (43.2)	12,137 (39.8)	58,554 (41.7)
Fruit and vegetable consumption ¹				
< 3.00 servings per day	6,601 (20.7)	9,849 (12.6)	3,070 (10.1)	19,520 (13.9)
3.00-3.99 servings per day	6,507 (20.4)	13,485 (17.3)	4,232 (13.9)	24,224 (17.2)
4.00-4.99 servings per day	6,672 (20.9)	16,489 (21.1)	5,701 (18.7)	28,862 (20.5)
5.00-5.99 servings per day	5,092 (16.0)	14,460 (18.5)	5,573 (18.3)	25,125 (17.9)
\geq 6.00 servings per day	6,874 (21.5)	23,557 (30.1)	11,740 (38.5)	42,171 (30.0)
Total red and processed meat consumption ^m				
< 2.00 times per week	5,462 (17.1)	15,254 (19.5)	6,729 (22.1)	27,445 (19.5)
2.00-2.99 times a week	10,903 (34.2)	27,329 (35.0)	10,190 (33.4)	48,422 (34.4)

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3.00-3.99 times a week	5,395 (16.9)	12,642 (16.2)	4,823 (15.8)	22,860 (16.3
4.00-4.99 times a week	4,058 (12.7)	9,143 (11.7)	3,423 (11.2)	16,624 (11.8
\geq 5.00 times a week	5,973 (18.7)	13,456 (17.2)	5,144 (16.9)	24,573 (17.5
Values are number (%) unless otherwise stated				
Number of participants with missing data (the total r	number participants who have mi	ssing data, or who repo	orted 'do not know' or	'prefer not to
answer') for each characteristic is as follows: 0 for a	ge, 263 for ethnicity, 150 for soc	ioeconomic status, 756	for qualifications, 33	8 for BMI, 1,704
for body fat %, 271 for height, 0 for excess MET-ho	urs/wk, 64 for standing or walki	ng job, 52 for manual j	ob, 291 for smoking s	status, 44 for
alcohol consumption, 676 for fruit and vegetable cor	nsumption, 655 for total red and p	processed meat consum	ption	
^a Participants who reported their ethnicity as 'White',	, 'British', 'Irish', or 'Any other	white background'		
^b We generated quintiles of socioeconmic status base	d on the Townsend deprivation in	ndex for the whole coh	ort (UK Biobank varia	ble n_189_0_0)
^c Vocational qualifications defined as other profession	nal qualification (eg: nursing or t	teaching)/ National Voc	cational Qualification	or Higher Nation
Diploma or Higher National Certificate) (touchscree	n question number D12, UK Bio	bank variable n_6138_	0_0)	
^d We preferentially used BMI derived from height an	d weight measured during the im	pedance measurement	(UK Biobank variable	n_23104_0_0_)
but if missing used the body size measures (UK Biol	bank variable n_21001_0_0); bot	th of these are direct me	easures of height and v	weight made on the
same day at the assessment centre.				
Body fat % (UK Biobank variable n_23099_0_0)				

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^gExcess MET-hours/wk estimated from the combination of reported walking, moderate and vigorous physical activity (for details see methods text) ^hParticipants who reported their work 'usually' or 'always' involved walking or standing for most of the time (touchscreen question number D9B, UK Biobank variable n 806 0 0)

ⁱParticipants who reported their work 'usually' or 'always' involved heavy manual or physical work for most of the time (touchscreen question number D9C, UK Biobank variable n_816_0_0)

^jSmoking status (UK Biobank variable n_20116_0_0)

^kParticipants who reported consuming alcohol three to four times per week or daily or almost daily (touchscreen question number A1, UK Biobank variable n 1558 0 0)

¹Total fruit and vegetable consumption is the sum of fresh fruit intake (touchscreen question number DT3, UK Biobank variable n_1309_0_0), cooked vegetable intake (touchscreen question numbers DT1, UK Biobank variable n_1289_0_0) and raw vegetable intake (touchscreen question number DT1, and UK Biobank variable n_1299_0_0). To sum the frequencies, 'Less than one' was coded as 0.5, and we coded 1 piece of fresh fruit as a serving and 2 tablespoons of vegetables as a serving.

^mTotal red and processed meat consumption is the sum of processed meat (touchscreen question number DT8 and UK Biobank variable $n_{1349_0_0}$), beef (touchscreen question number DT7 and UK Biobank variable $n_{1369_0_0}$), lamb/mutton (touchscreen question number DT7A and UK Biobank variable $n_{1379_0_0}$), and pork (touchscreen question number DT7B and UK Biobank variable n_{1389}) intake. To sum the frequencies, we used the following coding: 'Never' = 0, 'Less than once a week' = 0.5, 'Once a week' = 1, '2-4 times a week' = 3, '5-6 times a week' = 5.5, 'Once or more daily' = 7.

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Values are mean body fat percentage in the following categories of physical activity: <5, 5-

9.9, 10-14.9, 15-24.9, 25-34.9, 35-49.9, 50-74.9, 75-99.9, ≥ 100 excess MET-hrs per week,

and are plotted at the value of the mean excess MET-hours/wk in each category

Estimates shown for cells with 200 or more participants

Adjusted for age (5 year categories)



Figure 1 UK Biobank participant flow diagram MPA: moderate physical activity; VPA: vigorous physical activity

262x342mm (300 x 300 DPI)






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II I Ŧ • BMI 18.5-BMI 20 BMI 22.5 ▲ BMI 22.5-× BMI 25-×BMI 27.5 **XBMI 27.5** ×BMI 30-• BMI 30-BMI 32.5-+ BMI 32.5-BMI 32 BMI 37.5-40.0 Figure 4 Mean body fat percentage by physical activity, stratified by BMI category in UK Biobank Panel A: men; Panel B: women Values are mean body fat percentage in the following categories of physical activity: <5, 5-9.9, 10-14.9, 15-24.9, 25-34.9, 35-49.9, 50-74.9, 75-99.9, ≥ 100 excess MET-hrs per week, and are plotted at the value of the mean excess MET-hours/wk in each category Estimates shown for cells with 200 or more participants Adjusted for age (5 year categories) 141x40mm (300 x 300 DPI)

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Table S1 Repeated measures of physical activity in men who con	npleted the repeat assessment visit in U
Biobank 5 years after recruitment	ngf

			Physica	l activity (excess ME	ET-hours p	er week) ^a	
	<5	5-9.9	10-14.9	15-24.9	25-34.9	35-49.9	50-74.9	75-99.9
				All m	en (n = 11	9,230)		
Number of men	12,613	13,792	12,381	20,983	15,023	14,635	13,415	7,043
Baseline ^b	2.5	7.5	12.4	19.7	29.7	41.9	61.1	85.9
		Me	en who con	npleted the	repeat ass	sessment vi	isit ($n = 5$,	158)
Number of men	602	614	534	943	691	631	541	279
Baseline ^b	2.6	7.6	12.4	19.7	29.8	42.1	60.5	85.6
Repeat ^b	12.2	16.3	20.8	26.1	32.2	40.3	47.9	60.5

^aCategories are defined from baseline data

^bValues are mean excess MET-hours per week

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Table S2 Repeated m	easures of	physical	activity in	ı women w	BMJ /ho compl	Open eted the re	peat assess	sment visit	d by copyright, includin	mjopen-2016-011842 د
Biobank 5 years after	recruitmer	nt							Bu	ž
			Physical	l activity (excess MI	ET-hours p	er week) ^a		or u	24 M
	<5	5-9.9	10-14.9	15-24.9	25-34.9	35-49.9	50-74.9	75-99.9	S/€\$	(Ā)
				All wor	men (n = 1)	140,578)			eıgr rela	20
Number of women	14,299	17,632	15,970	26,156	18,555	17,490	16,231	7,407		338
Baseline ^b	2.6	7.5	12.4	19.6	29.6	41.7	60.9	85.8	Ę3	28
		Wom	en who co	mpleted th	e repeat a	ssessment	visit ($n =$	5,067)	exta	nlo
Number of women	515	659	606	1,004	681	640	555	229	and	
D 1: h	26	76	12.2	10.6	20.7	417	61.0	85.0		2

19.6

26.1

29.7

33.2

41.7

40.6

61.0

52.8

85.0

59.2

2.6 7.6 12.3 Baseline^b 11.9 18.5 21.3 Repeat^b

^aCategories are defined from baseline data

5

11 12

13

14 15

16

17 18

19

20

21

^bValues are mean excess MET-hours per week

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× ×	, ,	1 0	5 6	1	5	5	idin 3 o		
			Ca	tegories of phy	ysical activity	(MET-hours/	wkjar 22		
Categories of BMI	<5	5-9.9	10-14.9	15-24.9	25-34.9	35-49.9		75-99.9	≥ 100
	16.6	16.1	15.7	15.4	14.9	15.0		14.1	14.3
20-	(16.3-16.8)	(15.9-16.4)	(15.4-15.9)	(15.3-15.6)	(14.7-15.1)	(14.7-15.2)	(ह ें4ुं8्रे 15.2)	(13.8-14.4)	(14.0-14.6)
	n = 649	n = 780	<i>n</i> = 743	n = 1356	n = 1014	n = 986	ත <u>ස</u>	n = 478	<i>n</i> = 658
Mean BMI	21.6	21.5	21.5	21.5	21.5	21.5	text S24.6	21.5	21.5
	19.9	19.7	19.2	19.1	18.6	18.6	an eriad.4	17.9	17.9
22.5-	(19.8-20.1)	(19.6-19.8)	(19.0-19.3)	(19.0-19.2)	(18.5-18.7)	(18.4-18.7)	(a&)	(17.7-18.1)	(17.8-18.1)
	n = 1943	<i>n</i> = 2477	n = 2411	n = 4289	n = 3379	<i>n</i> = <i>3247</i>	₩ ₽	n = 1490	n = 1909
Mean BMI	23.9	23.9	23.9	23.9	23.9	23.9	nin 8	23.9	23.8
	23.0	22.7	22.4	22.2	21.9	21.7	ng, 24.6	21.3	21.2
25-	(22.9-23.1)	(22.6-22.8)	(22.3-22.5)	(22.1-22.3)	(21.8-22.0)	(21.6-21.8)	(⊉ 1. 5 21.7)	(21.1-21.4)	(21.1-21.3)
	<i>n</i> = <i>3217</i>	n = 3861	n = 3606	n = 6180	n = 4428	n = 4419	🖣 式	n = 2095	n = 2694
Mean BMI	26.2	26.2	26.2	26.2	26.2	26.2	ning 25.2	26.2	26.2
	25.7	25.4	25.2	25.0	24.7	24.6	ar 274.5	24.4	24.2
27.5-	(25.6-25.8)	(25.3-25.5)	(25.1-25.3)	(24.9-25.1)	(24.6-24.9)	(24.4-24.7)	(2 4. 2 24.6)	(24.2-24.6)	(24.0-24.3)
	<i>n</i> = 2950	<i>n</i> = 3192	<i>n</i> = 2793	<i>n</i> = 4818	n = 3302	n = 3199	$\frac{1}{2} = 2948$	n = 1561	<i>n</i> = 2145
Mean BMI	28.6	28.6	28.6	28.6	28.6	28.6	lar t 282.6	28.6	28.6
	28.1	27.8	27.8	27.6	27.3	27.2	27.1	26.9	26.7
30-	(27.9-28.2)	(27.7-28.0)	(27.7-28.0)	(27.4-27.7)	(27.2-27.5)	(27.1-27.4)	(<u>a</u> 6.9 <u>-</u> 27.2)	(26.7-27.1)	(26.5-26.9)
	n = 1867	<i>n</i> = 1780	<i>n</i> = 1498	n = 2409	n = 1644	<i>n</i> = 1585	କ୍ରି = ମୁଁ 560	n = 809	n = 1107
Mean BMI	31.1	31.1	31.1	31.0	31.0	31.0	s 34.0	31.0	31.0
	30.4	30.2	30.0	29.9	29.5	29.5	22.3	29.2	29.5
32.5-	(30.2-30.6)	(30.0-30.4)	(29.7-30.2)	(29.7-30.1)	(29.3-29.8)	(29.2-29.7)	(29. Ĕ 29.6)	(28.8-29.6)	(29.2-29.8)
	n = 984	<i>n</i> = 873	<i>n</i> = 663	n = 1009	<i>n</i> = 654	<i>n</i> = <i>634</i>	n = <u>0</u> 614	<i>n</i> = 335	n = 440
Mean BMI	33.6	33.6	33.5	33.5	33.4	33.5	3 ₽ .5	33.5	33.5
							(0		

BMJ Open BMJ Open Table S3 Mean (95% CI) body fat percentage by categories of BMI and physical activity in men in UK bioBank.

					BMJ Op	ben		mjopen-201 1 by copyrig			Page 42 of 53
	35-	$\begin{array}{c} 32.5 \\ (32.2-32.9) \\ n = 428 \end{array}$	32.1 (31.8-32.5)	32.0 (31.6-32.4) n = 202	32.0 (31.7-32.3)	32.2 (31.8-32.5) x = 280	31.8 (31.4-32.2)	1, including 33.7 (including 32.1)			
	Mean BMI	n = 420 36.1	n = 338 36.0	n = 302 36.0	n = 410 36.0	n = 280 36.0	n = 201 36.0	or - 3247 us - 35.0	-	-	
-	37.5- Mean BMI	$ \begin{array}{r} 34.3 \\ (33.9-34.8) \\ n = 217 \\ 38.5 \end{array} $		-	-	-	-	rch 2017. 'Dow inseignement ses related to t	-	-	_
	Mean BMI Adjusted for age (Values not shown	38.5 5 year categor for cells with	ries) less than 200	participants			0	wnloaded from http://bmjopen.bmj.com/ on June 12, 2025 at Agence Bibliograph t Superieur (ABES) . text and data mining, Al training, and similar technologies.			
			For peer re	view only - htt	p://bmjopen.b	mj.com/site/ab	out/guidelines	Lie de s.xhtme			

 $\begin{array}{c} 12\\ 13\\ 14\\ 5\\ 16\\ 17\\ 18\\ 19\\ 20\\ 22\\ 23\\ 24\\ 25\\ 26\\ 27\\ 28\\ 29\\ 30\\ 13\\ 23\\ 34\\ 35\\ 36\\ 37\\ 8\\ 39\\ 41\\ 42\\ 43\\ \end{array}$

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Table S4 M	ean (95% CI) b	ody fat percen	tage by catego	ries of BMI an	d physical acti	vity in women	in UK Boban	k	
			Ca	ategories of ph	ysical activity	(MET-hours/w	/k) on		
Categories of BMI	<5	5-9.9	10-14.9	15-24.9	25-34.9	35-49.9	бо-741.9 50-741.9 болого Пан	75-99.9	≥100
	24.4	23.5	23.5	23.1	22.7	22.5	es r nse ch	22.3	22.3
18.5-	(24.0-24.8)	(23.2-23.9)	(23.2-23.8)	(22.9-23.4)	(22.4-23.0)	(22.2-22.7)	(2 2.6)	(21.9-22.8)	(21.9-22.7)
	<i>n</i> = 313	n = 460	<i>n</i> = 405	n = 749	n = 569	<i>n</i> = 556		<i>n</i> = 219	<i>n</i> = 267
Mean BMI	19.4	19.3	19.4	19.4	19.4	19.4		19.3	19.4
	28.4	28.0	27.8	27.5	27.2	26.8	X 25 d	26.6	26.2
20-	(28.2-28.6)	(27.9-28.2)	(27.6-27.9)	(27.4-27.6)	(27.1-27.3)	(26.7-27.0)	(2 8.3-8 6.8)	(26.4-26.8)	(26.0-26.4)
	<i>n</i> = <i>1657</i>	<i>n</i> = 2333	<i>n</i> = <i>2378</i>	n = 4095	n = 3115	n = 3034	ng 12746	n = 1327	n = 1156
Mean BMI	21.4	21.4	21.4	21.4	21.4	21.4		21.4	21.4
	32.6	32.2	32.0	31.8	31.4	31.4		31.0	30.7
22.5-	(32.4-32.7)	(32.1-32.3)	(31.9-32.1)	(31.7-31.9)	(31.3-31.5)	(31.3-31.5)	(3 9 .1- 3 1.3)	(30.8-31.2)	(30.6-30.9)
	<i>n</i> = 2872	<i>n</i> = 4068	n = 4014	n = 6819	n = 4981	n = 4820	n e 4496	<i>n</i> = 2026	n = 1998
Mean BMI	23.8	23.7	23.7	23.7	23.7	23.7		23.7	23.7
	36.0	35.7	35.4	35.4	35.2	35.1	ਫ਼ 34 9	34.8	34.8
25-	(35.9-36.2)	(35.6-35.8)	(35.3-35.6)	(35.3-35.5)	(35.1-35.3)	(35.0-35.2)	(3 4 .8-35.0)	(34.6-35.0)	(34.6-35.0)
	n = 2953	n = 4016	n = 3594	n = 6034	n = 4288	n = 4069	n g 3705	n = 1692	n = 1516
Mean BMI	26.2	26.1	26.1	26.1	26.1	26.1	<u>1</u> 269	26.1	26.1
	39.0	38.8	38.5	38.3	38.3	38.2	a 38 4	38.0	37.7
27.5-	(38.9-39.2)	(38.6-38.9)	(38.4-38.7)	(38.2-38.5)	(38.2-38.4)	(38.1-38.4)	(3 2 .9 - <u>3</u> 8.2)	(37.8-38.2)	(37.5-37.9)
	n = 2353	<i>n</i> = 2715	n = 2370	n = 3704	n = 2616	n = 2366	n o 2262	n = 1008	n = 879
Mean BMI	28.6	28.6	28.6	28.6	28.6	28.6	ge283	28.6	28.6
	41.5	41.1	41.1	41.0	40.8	40.6	~40 දී	40.4	40.3
30-	(41.3-41.7)	(40.9-41.3)	(40.9-41.3)	(40.9-41.2)	(40.6-41.0)	(40.4-40.8)	(40.6 -ឆ្ន័ 1.0)	(40.1-40.7)	(40.0-40.6)
	n = 1625	n = 1716	n = 1424	n = 2185	n = 1366	n = 1237	n = 17 81	<i>n</i> = 564	n = 468
Mean BMI	31.1	31.1	31.1	31.1	31.1	31.0	<u>31 🖉</u>	31.0	31.1
32.5-	43.6	43.4	43.2	43.1	43.2	43.0	42 6	42.7	42.5

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	(43.4-43.8)	(43.2-43.6)	(43.0-43.5)	(42.9-43.3)	(43.0-43.5)	(42.8-43.3)	(4 <u>4</u> .4- <u>4</u> .3.0)	(42.3-43.1)	(42.0-42.9)
	<i>n</i> = 1008	n = 989	n = 774	n = 1149	n = 699	n = 651	₽ g = g 11	<i>n</i> = 260	<i>n</i> = 233
Mean BMI	33.6	33.6	33.6	33.6	33.6	33.5	ē 33 ½	33.5	33.5
35-	45.3 (45.0-45.5) n = 577	45.2 (45.0-45.5) n = 577	44.9 (44.6-45.3) n = 444	45.0 (44.7-45.3) n = 584	44.9 (44.6-45.3) n = 359	44.9 (44.5-45.3) n = 313	5.2) (447.92-345.2)	_	_
Mean RMI	36.1	36.1	36.0	361	36.1	36.1			
Mean DMI	47.0	46.6	46.8	46.7	46.6	50.1			
37.5-	(46.6-47.3) n = 368	(46.2-47.0) n = 303	(46.3-47.2) n = 207	(46.3-47.1) n = 316	(46.1-47.0) n = 205	-	/nloadec Superie lext and	-	-
Mean BMI	38.6	38.5	38.6	38.5	38.5		d fro ur () dat		
40-	$ \begin{array}{r} 48.3 \\ (47.8-48.7) \\ n = 220 \\ 41.1 \end{array} $	-	-	r.	-	-	m http://bm ABES) - a mining, Al	-	-
Mean BMI	41.1	• 、					trai		
Adjusted for	age (5 year cat	egories)					nin,		
Values not sh	own for cells	For per	200 participant	S	h hmi com/site/		mj.com/ on June 12, 2025 at Agence Bibliographique de g, and similar technologies.		
		For pee	- review only -	mup.//binjoper	i.biiij.com/site/	abourguidelli	C2.XIIIIIL		

Table S5 BMI and body fat percentage by sex and 5-year age category in UK Biobank

	n	BMI	Body fat percentage		ř Us
Men				—	Ses
< 45 years	15176	27.2 (4.0)	22.8 (5.5)		reia
45-49 years	17569	27.4 (3.9)	23.5 (5.5)		Leu
50-54 years	18375	27.5 (3.9)	24.1 (5.5)		2
55-59 years	20580	27.3 (3.8)	24.6 (5.5)		EXL
60-64 years	26532	27.3 (3.7)	25.1 (5.4)		and
\geq 65 years	20671	27.1 (3.6)	25.6 (5.3)		200
Women					6
< 45 years	17392	25.7 (4.8)	33.7 (7.0)		
45-49 years	21848	26.0 (4.8)	34.3 (7.0)		ç
50-54 years	23728	26.3 (4.7)	35.3 (6.7)		2
55-59 years	25329	26.3 (4.6)	35.9 (6.5)		2
60-64 years	31600	26.5 (4.4)	36.4 (6.3)		S
\geq 65 years	20343	26.5 (4.2)	36.7 (6.0)		2
Values are mear	n (SD)			_	2
Numbers of part	ticipants s	shown are for	BMI within each age		
category, slightl	v fewer p	articipants ha	ve information on body		
fat percentage	<i>ј</i> Г	···· F····			
					6
					é

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Panel A: Mean BMI by physical activity (excess MET-hours/wk); Panel B: Mean body fat percentage bgphysical activity (excess MET-hrs/wk) Values are mean BMI and body fat percentage in the following categories of physcial activity: <5, 5-9, 9, 10, 15-24.9, 25-34.9, 35-49.9, 50-74.9, 75-99.9, \geq 100 excess MET-hrs per week, and are plotted at the value of the mean excess MET-hours/wk in each category Errors bars are 95% CI gence Bibliographique

Estimates shown for cells with 200 or more participants



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STROBE Statement-checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract
		Title, and Pg 3
		(b) Provide in the abstract an informative and balanced summary of what was done
		and what was found Pg 3
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
		Pg 5
Objectives	3	State specific objectives, including any prespecified hypotheses Pg 5
Methods		
Study design	4	Present key elements of study design early in the paper Pg 6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment,
		exposure, follow-up, and data collection Pg 6
Participants	6	(a) Cohort study—Give the eligibility criteria, and the sources and methods of
		selection of participants. Describe methods of follow-up
		Case-control study—Give the eligibility criteria, and the sources and methods of
		case ascertainment and control selection. Give the rationale for the choice of cases
		and controls
		Cross-sectional study—Give the eligibility criteria, and the sources and methods of
		selection of participants Pg 8
		(b) Cohort study—For matched studies, give matching criteria and number of
		exposed and unexposed
		Case-control study—For matched studies, give matching criteria and the number of
		controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect
		modifiers. Give diagnostic criteria, if applicable Pg 9
Data sources/	8*	For each variable of interest, give sources of data and details of methods of
measurement		assessment (measurement). Describe comparability of assessment methods if there is
		more than one group Pgs 6-8, and Footnotes for Table 1 and Table 2
Bias	9	Describe any efforts to address potential sources of bias Pg 10
Study size	10	Explain how the study size was arrived at Pg 8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable,
		describe which groupings were chosen and why Pg 9
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding
		Pgs 9-10
		(b) Describe any methods used to examine subgroups and interactions Pgs 9-10
		(c) Explain how missing data were addressed Pg 8
		(d) Cohort study—If applicable, explain how loss to follow-up was addressed
		Case-control study-If applicable, explain how matching of cases and controls was
		addressed
		Cross-sectional study-If applicable, describe analytical methods taking account of
		sampling strategy N/A
		(<u>e</u>) Describe any sensitivity analyses Pg 9

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and
		analysed Pg 12, and Figure 1
		(b) Give reasons for non-participation at each stage Figure 1
		(c) Consider use of a flow diagram Figure 1
Descriptive	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information
data		on exposures and potential confounders Pg 12, and Tables 1 and 2
		(b) Indicate number of participants with missing data for each variable of interest Footnotes for Tables 1 and 2
		(c) Cohort study—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	Cohort study-Report numbers of outcome events or summary measures over time
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures Tables 1 and 2.
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their
		precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and
		why they were included Pgs 12-13
		(b) Report category boundaries when continuous variables were categorized Pgs 9-10
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses Pgs 13-14
Discussion		
Key results	18	Summarise key results with reference to study objectives Pg 15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision.
		Discuss both direction and magnitude of any potential bias Pgs 15-16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity
		of analyses, results from similar studies, and other relevant evidence Pg 17
Generalisability	21	Discuss the generalisability (external validity) of the study results Pgs 16-17
Other informati	on	
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable,
-		for the original study on which the present article is based Pg 18

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

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