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RESEARCH
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Dietary Patterns and Practices and Leucocyte Telomere Length: Findings from the UK Biobank

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ABSTRACT

Background Shorter telomere length (TL) is associated with risk of several age-related diseases and decreased life span, but the extent to which dietary patterns and practices associate with TL is uncertain.

Objective This study aimed to investigate the association of dietary patterns and practices and leucocyte TL (LTL).

Design This was a cross-sectional study.

Participants and setting Data collected voluntarily from up to 422,797 UK Biobank participants, during 2006-2010.

Main outcome measures LTL was measured as a ratio of the telomere repeat number to a single-copy gene and was $\log_e$-transformed and standardized (z-LTL).

Statistical analyses performed Adherence *a priori* to a Mediterranean-style diet was assessed through the MedDietScore. Principal component analysis was used to *a posteriori* extract the "Meat" and "Prudent" dietary patterns. Additional dietary practices considered were the self-reported adherence to "Vegetarian" diet, "Eating 5-a-day of fruit and vegetables" and "Abstaining from eggs/dairy/wheat/sugar." Associations between quintiles of dietary patterns or adherence to dietary practices with z-LTL were investigated through multivariable linear regression models (adjusted for demographic, lifestyle, and clinical characteristics).

Results Adherence to the "Mediterranean" and the "Prudent" patterns, was positively associated with LTL, with an effect magnitude in z-LTL of 0.020 SD and 0.014 SD, respectively, for the highest vs the lowest quintile of adherence to the pattern (both P values < 0.05). Conversely, a reversed association between quintile of the "Meat" pattern and LTL was observed, with z-LTL being on average shorter by 0.025 SD ($P = 6.12\times10^{-05}$) for participants in the highest quintile of the pattern compared with the lowest quintile. For adherents to "5-a-day" z-LTL was on average longer by 0.027 SD ($P = 5.36\times10^{-09}$), and for "abstainers," LTL was shorter by 0.016 SD ($P = 2.51\times10^{-04}$). The association of LTL with a vegetarian diet was nonsignificant after adjustment for demographic, lifestyle, and clinical characteristics.

Conclusions Several dietary patterns and practices associated with beneficial health effects are significantly associated with longer LTL. However, the magnitude of the association was small, and any clinical relevance is uncertain.
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TELOMERES ARE DNA SEQUENCES LOCATED AT THE ends of chromosomes that contribute to genome stability. As somatic cells divide, telomeres shorten and cells enter replicative senescence when telomeres shorten to a critical length.[1] Rare syndromes associated with accelerated telomere shortening cause premature ageing phenotypes.[2] At a population level, there is wide interindividual variation in telomere length (TL), most often measured in leucocytes (leucocyte telomere length [LTL]), and shorter LTL has been associated with risk of several age-related diseases[3] as well as a reduced life span.[4] This has stimulated an interest in investigating lifestyle and environmental factors[5,6] that could adversely influence an individual's health and life span via processes related to telomere attrition, such as oxidative stress, inflammation, telomerase activity, and DNA methylation.[7]

Recent evidence[6] suggests an independent association, on top of other major LTL determinants,[8] between several lifestyle characteristics and LTL with dietary intake being one of them. In particular, several food items were independently associated with LTL,[6] either positively (eg, muesli, wholemeal bread, cheese, and oily fish) or negatively (eg, salt, margarine, and processed meat). Nonrefined cereals and fish intake, alongside vegetables and fruit intake, form the basis of the healthy eating pattern known as the Mediterranean-style diet,[9] which is associated with longevity,[10] reduced disease risk,[11-13] and inflammation.[14]

Recent systematic reviews and meta-analyses[15,16] have investigated the association between diet and TL. Crous-Bous and colleagues[15] identified eight observational studies, including approximately 10,500 participants, and three randomized trials, including approximately 700 participants, that studied the association between various dietary patterns (ie, vegetable rich, traditional, Mediterranean, Prudent, and Western) and TL. Findings from the observational studies supported the benefits of adherence to Mediterranean diet on TL, although these results were not consistent between men and women or different ethnic backgrounds or study populations, whilst they showed no association between the Western pattern and TL. Regardless, findings between the Prudent diet and LTL from the randomized trials are conflicting.[15] Pérez and colleagues[16] systematically reviewed seven randomized trials, including five of them in a meta-analysis covering nine diets and approximately 500 participants. The authors report no effect of diet on TL, but also acknowledge the presence of strong heterogeneity in the type and duration of dietary interventions that precludes any final statement.[16] Therefore, the extent to which different diets are associated with TL and whether or not this could explain some of the beneficial effects of certain diets, such as the Mediterranean[17] or vegetarian,[18] remains unclear. This study aimed to investigate the extent to which dietary patterns and practices are associated with LTL above and beyond other lifestyle, clinical, and social determinants using data from a large contemporary population.

RESEARCH SNAPSHOT

Research Question: Are dietary patterns and practices independently associated with leucocyte telomere length (LTL)?

Key Findings: Analysis of cross-sectional data from the UK Biobank suggests that adherence to "Mediterranean" or "Prudent" dietary patterns and a practice of "Eating 5-a-day" of fruit and vegetables were positively associated with LTL, whilst adherence to a "Meat intake" pattern or "Abstaining from eggs/dairy/wheat/sugar" pattern was negatively associated with LTL, after adjustment for major lifestyle, clinical, and social determinants of LTL. However, the magnitude of these associations was small and equivalent to about 1-year of age-related change in LTL.

METHODS

Study Participants

Data from the UK Biobank (UKB) (https://www.ukbiobank.ac.uk/), a large prospective study, were used in this study. During 2006-2010 approximately 500,000 men and women from the UK population, aged 40 to 69 years at the date of their baseline assessment visit, consented to participate voluntarily in UKB. Extensive data[19-21] were collected through a touchscreen questionnaire and brief verbal interview at baseline from all participants on their lifestyle, environment, and personal and family medical history. Information on sex and date of birth was obtained before participants' arrival at the assessment centers through the local National Health Service Primary Care Trust registries. Age was then derived from the date of birth and the date of attending assessment center and was truncated to whole year part. Participants were able to update their sex or date of birth during recruitment through a touchscreen questionnaire. Ethnic background was obtained through the touchscreen questionnaire at the assessment center. Participants also underwent a wide range of physical measures, and provided samples of blood, urine, and saliva. In addition to information collected at baseline, participants were invited to wear a wrist-worn activity monitor, to record 7-day physical activity, and completed detailed web-based questionnaires on their diet,[22,23] that was used to determine dietary patterns and practices. Utilizing the in-depth genetic and health information,[21] LTL was measured in 474,074 participants.[8] Baseline data for LTL with no mismatch in self-reported and genetic sex exist for 472,269 UKB participants. For the purposes of the analysis data from 49,472 participants (n = 33,728 genetically related data (randomly excluding one from each pair based on a kinship coefficient of $K > 0.088$), n = 908 who either had no genetic data or failed quality control, and n = 14,836 participants who lacked information on ethnicity or white blood cell (WBC) count, both associated with LTL) were additionally excluded.[8] This left a maximum of 422,797 participants available for the analysis (see Figure 1, available at www.jandonline.org). UKB received approval from the North West Centre for Research Ethics Committee (11/NW/0382) and all participants gave their written informed consent.

LTL Measurement

LTL, the outcome of interest, was measured on DNA samples collected at baseline using a validated qualitative polymerase chain reaction method and reported as a ratio of the telomere repeat number to a single-copy gene. The measurements were $\log_e$-transformed to approximate the normal distribution which were then transformed to z-standardized values (UKB field code: 22192) to facilitate comparison with other datasets. Further details for the quality control of the LTL measurement can be found elsewhere.[8]

Dietary Assessment from the Short Food Frequency Questionnaire

All UKB participants were asked to complete a short computer touchscreen questionnaire at their initial assessment visit that reliably ranks participants according to intakes of the main food groups.[22] The food frequency questionnaire (FFQ) included 29 questions about their average diet over the previous 12 months. The selected questions represented six main food groups:[23] meat (processed meat [UKB field code: 1349], poultry [1359], beef [1369], lamb [1379], pork [1389]); cheese (1408), bread (quantity [1438] and type [1448]), and breakfast cereals (quantity [1458] and type [1468]); fruit (fresh [1309] or dried [1319]); vegetables, excluding potatoes (raw [1299] and cooked [1289]); and fish (oily [1329] and nonoily [1339]). Participants reported frequency of intake (never, less than once per week, once per week, two to four times per week, five to six times per week, or once or more daily) for most of the groups. For fruit and vegetables, and bread and breakfast cereals, participants entered the average intake of daily and weekly number of standard servings, respectively. For alcohol intake the self-reported weekly and

monthly intake, stated in terms of glasses of red wine (UKB field codes: 1568 and 4407, respectively), champagne/white wine (1578/4418), beer/cider (1588/4429), spirits (1598 and 4440), fortified wine intake (1608 and 4451), and other alcoholic drinks (5364 and 4462), was converted into average daily intake by dividing by seven or 30, accordingly. Number of drinks per day were quantified as the number of UK units of alcohol intake and then converted to grams of alcohol (one average bottle of wine has 9 units,[24] hence 1 unit (approximately 83 mL) is equivalent to 8 g alcohol[25]) and participants were classified as "low" (<5 g/day), "moderate" (5 to 15 g/day or ≤1 small wine glass of 12% alcohol by volume for women and 5 to 30 g/day or ≤2 small wine glasses for men), and "heavy" drinkers (>15 g/day or >1 small wine glass for women and >30 g/day or >2 small wine glasses for men).[26]

Mediterranean Dietary Pattern Defined *a priori*

The MedDietScore[27] was used to *a priori* define the adherence to a Mediterranean-style diet.[9] Compared with scores that are based on median intake, rather than specific guidelines, and incorporate binary components' scoring, the MedDietScore is independent of the consumption of the study population and allows for greater variation in the scoring system. The original MedDietScore[27] was modified to account for food items/groups collected in UKB, thus utilizing data from eight of the 11 food groups considered in the creation of the MedDietScore: fruit, vegetables, fish, poultry, cheese (representing dairy products), red meat and its products, alcohol intake, and bread and cereal intake, and omitting potatoes, olive oil, and legumes that were not included in the FFQ. Because consumption of potatoes was not recorded in the UKB, bread and cereal type alongside bread and cereal intake were incorporated to discriminate between nonrefined ("brown/wholemeal/wholegrain" bread and "bran/ biscuit/oat/ muesli" cereal) and refined grains ("white" bread and "other (cornflakes/frosties)" cereal). With the exception of alcohol and meat/poultry intake, monotonic functions were assigned to score the frequency of consumption of the remainder foods. Particularly, scores from zero to four (or on the reverse order) were assigned in each of the food groups according to their position in the Mediterranean diet pyramid.[28] For food groups presumed to be close to this pattern (ie, fruit, vegetables, nonrefined grains, and dairy products) a score of zero or one was assigned when participants reported no or rare consumption to a score of four for daily consumption. For participants reporting frequent consumption of refined grains the scores were reversed; that is, a four was assigned for no consumption and zero for daily consumption. For frequency intake of fish, poultry, and red meat, that should be consumed on a weekly basis, a nonmonotonic scoring system was followed, assigning higher scores for the moderate consumption of fish and poultry and rare consumption of red meat and its products. A nonmonotonic function was also used for scoring alcohol intake, with a score of five assigned to participants reporting alcohol intake with a consumption up to 28 g ethanol per day (>0 mL and <300 mL), scores four to one to a consumption of 28 to 37.9, 38 to 47.9, 48 to 56.9 ,and 57 to 66.9 g ethanol per day, respectively, and a score of zero to no consumption or to 67 g or more ethanol per day (700 mL). Thus, the potential range of this modified MedDietScore is zero to 37, with higher values indicating greater adherence to Mediterranean-style diet. The detailed scoring system is shown in Table 1.

Dietary Patterns Defined *a posteriori*

Principal components analysis was used to *a posteriori* extract dietary patterns, based on the intake of 12 broad food groups (total vegetable intake, total fruit intake, oily fish, nonoily fish, processed meat, poultry, beef, lamb, pork, cheese, bread intake, and frequency of alcohol intake [field code: 1558]). The Kaiser-Mayer-Olkin measure of sample adequacy[29] (0.70) and the Bartlett's test of sphericity[30] (χ^2[df] = 4.56×10^5 [66]; $P < 1.00\times10^{-300}$) supported the suitability of the data for principal components analysis . Four dietary patterns were retained with eigenvalues >1 (ie, the average value of the eigenvalues), that explained in total 51.3% of the variance in food intake. Each derived pattern was named according to the characteristics of food groups whose component loading value was 0.4 or higher. The first pattern ("Meat intake") was characterized by high intake of red meat and processed meat, the second pattern was characterised by high vegetable, fruit, and fish intake ("Prudent" pattern), the third was characterized by high intake of "cheese and bread" and the fourth by high "alcohol" intake (Table 2). For each of the retained components each participant was assigned a score, based on the sum of the component loadings of each food group multiplied with the reported intakes of the specific food group, and they were categorized into quintiles of every derived pattern by their factor score. The two first main patterns that were heavily loaded from multiple food groups and together explain 32.5% of the variation in food intake were used in this analysis.

Other Dietary Practices

Utilizing the self-reported data from the FFQ, participants were also classified as "vegetarian" if they reported "never eating" all of the seven food items describing meat, poultry, and fish intake[23]; "eating 5-a-day" of fruit and vegetables, with one serving defined as four heaped tablespoons of vegetables or one medium-sized piece of fruit[31]; and "abstainers" if they self-reported abstaining from eggs/dairy products/wheat products/sugar (UKB field code: 6144). Those with missing data in the subgroups of fish/meat intake, fruit/vegetable intake, and food abstaining were excluded from the aforementioned classifications.

Statistical Analysis

Descriptive statistics are shown as mean (SD) for the continuous variables and frequencies (%) for the categorical. Linear regression models were used to evaluate the association between z-standardized LTL and quintiles of dietary patterns (three models assessing *a priori* defined Mediterranean diet and *a posteriori* extracted "Prudent" and "Meat intake" patterns), and other dietary practices (three models assessing being vegetarian [yes/no], eat 5-a-day [yes/no], and whether an abstainer [yes/no]). For each case, two linear regression models were examined: the base model, adjusted for age, sex (males/females), ethnic background (defined by UKB as: Asian [2.0% including Asian or Asian British, Indian, Pakistani, Bangladeshi, and any other Asian background], Black [1.6% including Black or Black British, Caribbean, African, and any other Black background], Chinese [0.3%], Mixed

Table 1. Scoring system for the *a priori* defined adherence to Mediterranean Diet

Food group	Scoring system					
Vegetables (servings/d)	<1	≥1 to <2	≥2 to <3	≥3 to <4	≥4	
Score	0	1	2	3	4	
Fruit (piece/d)	<1	1	2	3	≥4	
Score	0	1	2	3	4	
Grains (servings/d)		<2	≥2 to <4	≥4 to <6	≥6	
Nonrefined score		1	2	3	4	
Refined score		4	3	2	1	
Cheese (frequency)		Never/rarely	Monthly	Weekly	Daily	
Score		1	2	3	4	
Fish (frequency)		Never/rarely	Monthly	Weekly	Daily	
Score		1	2	4	3	
Poultry (frequency)		Never/rarely	Monthly	Weekly	Daily	
Score		1	3	4	2	
Red meat (frequency)	Never	Rarely	Monthly	Weekly	Daily	
Score	2	3	4	1	0	
Alcohol (g ethanol/d) (mL/ d)	0 or 67+ (0 or ≥700)	>0 to <28 (>0 to <300)	28 to 37.9 (≥300 to <400)	38 to 47.9 (≥400 to <500)	48 to 56.9 (≥500 to <600)	57 to 66.9 (≥600 to <700)
Score	0	5	4	3	2	1

[0.6% including White and Black African, White and Black Caribbean, White and Asian, and any other mixed background], Other [0.9%] and White [94.5%, including British, Irish, and any other White background]), and WBC count (z-standardized) and the full model, additionally adjusted for smoking (never/previous/ current; UKB field code: 20116), physical activity group (low/moderate/vigorous; 22032), body mass index classification (derived from field 21001;

Table 2. Component loadings for the four major dietary patterns *a posteriori* extracted, using dietary data from 339,013 UK Biobank participants collected during 2006-10

	Meat intake	Prudent pattern	Cheese and bread	Alcohol intake
Food item/group				
Vegetables	−0.11	**0.43**[a]	0.02	−0.34
Fruit	−0.18	**0.42**	−0.09	−0.18
Oily fish	−0.05	**0.53**	0.25	0.15
Non-oily fish	0.03	**0.46**	0.32	0.38
Poultry	0.28	0.22	−0.16	0.33
Cheese	0.10	−0.12	**0.56**	−0.37
Bread	0.13	−0.18	**0.48**	0.32
Processed meat	**0.44**	−0.11	0.16	0.24
Beef	**0.47**	0.07	−0.16	−0.11
Lamb	**0.43**	0.16	−0.20	−0.20
Pork	**0.46**	0.10	−0.13	−0.13
Alcohol	−0.19	−0.02	−0.38	**0.46**
Variation explained (%)	18.8	13.7	10.3	8.5

[a]Boldface type highlights values greater than the threshold (>0.4) used to characterize the dietary patterns.

under and normal weight (body mass index <25), overweight (body mass index 25 to 29.9), and obese (body mass index ≥30), and the variables that were previously found to be independently associated with LTL in this population[7] (highest educational level [none; O-levels/Certificate of Secondary Education/General Certificate of Secondary Education that are equivalent to statutory/compulsory education; A-levels/non-vocational qualifications/other professional educational qualifications that are equivalent to advanced education; degree that is equivalent to college or university degree [6138]), insomnia (never/sometimes/usually [1200]), fed-up feelings (yes/no [1960]), low density lipoprotein cholesterol level (30780), C-reactive protein (CRP) level (30710), estimated glomerular filtration rate (based on Chronic Kidney Disease Epidemiology Collaboration equation [30700]), and self-reported doctor-diagnosed chronic medical conditions (diabetes [2443], cancer [2453], and vascular disease and hypertension [both derived from field 6150]).

Continuous variables were winsorized at the 0.5% and 99.5% percentile values, to exclude extreme outliers, $\log_e$-transformed, where necessary, and scaled to the standardized normal distribution. Results from the regression models are reported as beta coefficients (95% CI). To aid the interpretation of the observed associations between the dietary patterns and practices and LTL, the association with each pattern/practice was expressed in terms of number of equivalent years of age-related change in LTL, by dividing the beta coefficients for adherence to the patterns or the practices by the absolute value of the beta coefficient (|−0.023|) for the age-related change in LTL.[8]

To evaluate the generalizability of the results and minimize any influence of missing data, the analysis was repeated using imputed data. Multiple imputations using chained equations[32] were employed to impute 10 datasets to generate complete datasets. To ensure convergence, 10 iterations for each imputation was performed. Age, sex, ethnicity, and WBC count were included as additional covariates in the imputation model to help improve prediction of the missing values. Linear, logistic, and multinomial regression models were specified as the imputation models for continuous, binary, and categorical variables, respectively. The performance of the imputation was evaluated through the comparison of the distribution plots of the continuous variables and the distribution of categorical variables between the available, imputed, and complete data.

All data were collected at the time of recruitment. All tests were two-sided and statistical significance was set at the 0.05 level. All analyses performed in Stata version 17.0.[33]

RESULTS

Study Participants

Amongst nonrelated UKB participants with complete information on LTL and its major determinants (ie, age, sex, ethnicity, and WBC count [n = 422,797]), complete dietary data for the dietary patterns and the dietary practices analyses exist for approximately 80% (n = 339,013) and 99.5% (n = 420,919), respectively (Figure 1, available at www.jandonline.org). Participants excluded from the analysis due to missing information in either food intake (n = 83,784) or dietary practices data (n = 1,878), were less likely to be of White ethnic background, especially when it comes to dietary practices (ie, 3.4%; 95% CI −3.6% to −3.2%) fewer participants of White ethnic background when reporting missing data for dietary patterns and 21.6% (95% CI −23.6% to −19.5%) fewer participants of White ethnic background when reporting missing data for dietary practices). Compared with participants included in the analysis, participants with missing food intake data were more likely to be women (11.3%; 95% CI 10.9% to 11.7%), whilst those with missing data on diet practices were more likely to be men (6.7%; 95% CI 4.4% to 8.9%). Differences in the age distribution were not observed for either dietary patterns or practices, whilst participants excluded from the dietary pattern analysis had on average longer LTL (mean difference = 0.022 SD; 95% CI 0.014 SD to 0.029 SD) (Table 3, available at www.jandonline.org).

On average, TL is longer in participants of younger age, female sex, of non-White ethnic background, with normal BMI and nonsmokers (Table 4). For the *a priori* defined Mediterranean dietary pattern, participants' age distribution was relatively constant across the quintiles of the MedDietScore, albeit statistically significant, whilst the proportion of men adhering to that pattern was smaller compared with women and gradually decreased toward higher adherence to this pattern (P for trend $< 1.00\times10^{-300}$). In general, the proportion of ethnic minorities adhering to a Mediterranean-style diet was lower compared with participants of White ethnic background. Several clinical and lifestyle characteristics showed a substantial gradient across the quintiles of the MedDietScore, with participants in the highest quintiles having a more favorable profile (ie, normal weight, nonsmokers, physically active, and less disease prevalence in general) compared with those in lowest quintile (Table 5, available at www.jandonline.org).

Participants' lifestyle and social characteristics were similarly distributed when the *a posteriori* extracted "Prudent" pattern was considered, although ethnic differences were not that apparent. Regardless, the disease prevalence showed a linear association with quintiles of adherence to the "Prudent" pattern, compared with the U-shaped association observed with the quintiles of adherence to "Mediterranean" pattern (Table 6, available at www.jandonline.org).

Conversely, a positive gradient of male sex, unfavorable lifestyle characteristics, and disease prevalence, was observed across the quintiles of the "Meat intake" pattern. The distribution of age and ethnicity was similar to the one observed across the quintiles of adherence to the Mediterranean-style diet, whilst those with higher education qualifications showed a lower adherence to the "Meat intake" pattern (Table 7, available at www.jandonlie.org).

Associations of LTL with Dietary Patterns

Significant associations with dietary patterns, either *a priori* or *a posteriori* extracted, and LTL were observed in the available data. Specifically, after adjustment for age, sex, ethnicity, and WBC count (base model), there was a positive gradient in the association between quintiles of adherence to the Mediterranean-style diet or to the *a posteriori* defined "Prudent" pattern and LTL, whilst the association between quintiles of the "Meat intake" pattern and LTL was reversed (see Figure 2 and Table 8, available at www.jandonline.org). Adjustment for the lifestyle factors and the additional social and clinical characteristics associated with LTL attenuated all

Table 4. Distribution of leucocyte telomere length (LTL) by the levels of select characteristics in UK Biobank participants with complete basic information (n = 422,797) collected during 2006-10

Characteristic	n (%)	mean (SD) z-LTL[a]	*P* value[b]
Age group (y)			$< 1.00\times10^{-300}$
40-49	97,837 (23.1)	0.273 (0.984)	
50-59	141,874 (33.6)	0.057 (0.979)	
60-70	183,086 (43.3)	−0.191 (0.985)	
Sex			$< 1.00\times10^{-300}$
Female	227,620 (53.8)	0.086 (0.996)	
Male	195,177 (46.2)	−0.101 (0.995)	
Ethnic background as reported through UK Biobank data collection[c]			4.86×10^{-232}
White	400,036 (94.6)	−0.016 (0.996)	
Asian	6,587 (1.6)	0.518 (1.049)	
Black	8,355 (2)	0.068 (1.002)	
Mixed	2,518 (0.6)	0.234 (1.005)	
Chinese	1,373 (0.32)	0.484 (0.976)	
Other	3,928 (0.93)	0.267 (1.034)	
Body mass index classification			4.60×10^{-253}
Normal weight[d]	139,365 (33)	0.068 (1.003)	
Overweight	179,429 (42.4)	−0.024 (0.998)	
Obese	102,371 (24.2)	−0.052 (0.995)	
Missing[e]	1,632 (0.39)	—	
Smoking status			2.34×10^{-223}
Never	230,529 (54.5)	0.048 (0.997)	
Previous	146,351 (34.6)	−0.058 (0.998)	
Current	44,343 (10.5)	−0.059 (1.012)	
Missing	1,574 (0.37)	—	

[a]zLTL = *z*-standardised leucocyte $\log_e$ telomere length.
[b]*P* values were obtained from the independent *t* test for the comparison between female and male sex or one-way analysis of variance for all other comparisons.
[c]Ethnic background is presented as reported through UK Biobank data collection. White ethnic background also includes British, Irish, and any other White background. Asian ethnic background also includes Asian or Asian British, Indian, Pakistani, Bangladeshi, and any other Asian background. Black ethnic background also includes Black or Black British, Caribbean, African, and any other Black background. Mixed ethnic background also includes White and Black African, White and Black Caribbean, White and Asian, and any other Mixed background.
[d]Normal weight category also includes 2,155 participants with body mass index <18.5.
[e]Missing data were excluded from the comparisons.

the observed associations, although the global trends and the differences between the highest and lowest quintiles remained significant (see Figure 2 and Table 8, available at www.jandonline.org). Results derived from the imputed data were concordant with those from the available data (see Figure 2 and Table 8, available at www.jandonline.org). Moreover, excluding one marker of inflammation (ie, CRP) from the fully adjusted model did not substantially alter the results in a meaningful way (Table 9, available at www.jandonline.org), neither did the inclusion of pack of years of smoking (UKB field code: 20161), total metabolic equivalents of task minutes per week of activity (22040), and body mass index (21001) instead of the respective variables in their categorical form (Table 10, available at www.jandonline.org). In general, the associations between dietary patterns and LTL did not differ by age, sex, or smoking status (Figure 3, available at www.jandonline.org). However, the association of the "Meat intake" pattern with LTL was stronger in participants aged 40 to 49 years than those aged 50 to 59 and 60 to 70 years, and the association of the "Prudent" pattern with LTL was stronger in women (Figure 3, available at www.jandonline.org).

Associations of LTL with Other Dietary Practices

The distribution of social, lifestyle, and clinical characteristics across participants' dietary practices are shown in Table 11 (available at www.jandonline.org). Those following a "vegetarian" diet were on average younger, whilst those eating "5-a-day" and "abstainers" were slightly older. Sex and ethnic differences were observed regarding these dietary practices

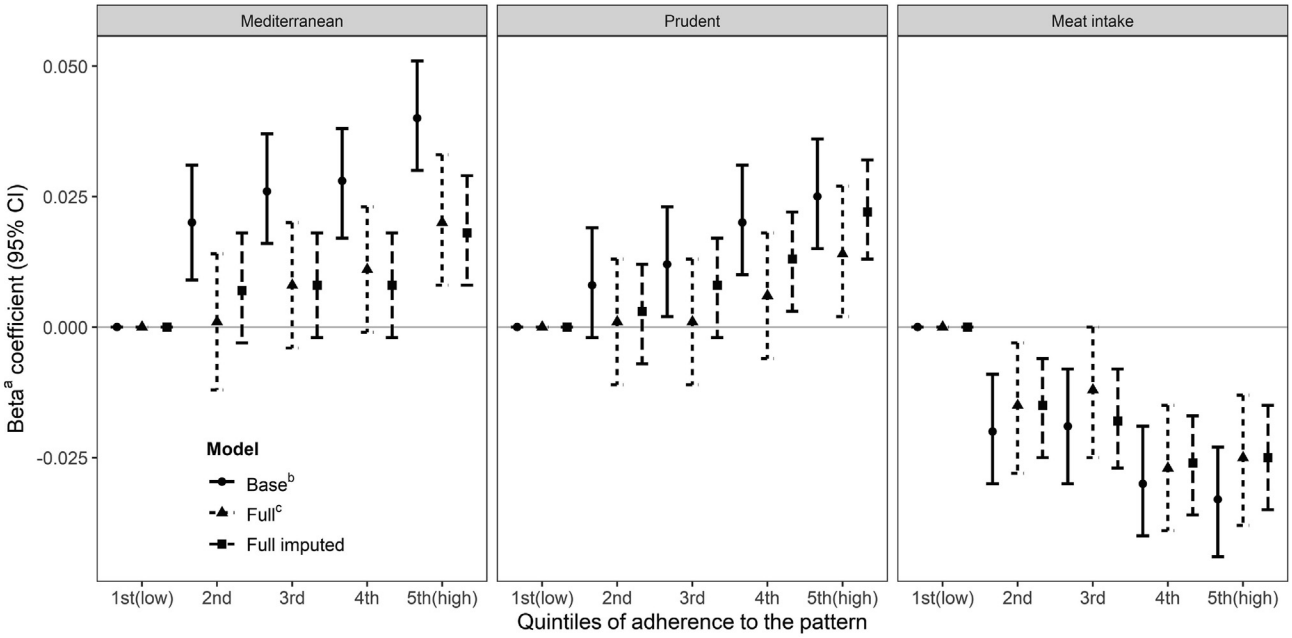

Figure 2. Association of UK Biobank participants' adherence to a dietary pattern with leucocyte telomere length (LTL) using data collected during 2006-10. [a]Point estimates are beta coefficients for z-standardized LTL. Error bars represent 95% CI. [b]The base model includes the quintiles of adherence to the specific pattern and is adjusted for age, sex, ethnic background, and white blood cell count. [c]The full model is additionally adjusted for smoking habits, physical activity, body mass index classification, highest educational qualification, experiencing insomnia, fed-up feelings, low-density lipoprotein cholesterol level, C-reactive protein level, estimated glomerular filtration rate (Chronic Kidney Disease Epidemiology Collaboration equation) and self-reported diseases diagnosed by doctor (eg, diabetes, cancer, hypertension, and vascular diseases).

with men being less and Asian adults being more frequently classified as "vegetarian" and eating "5-a-day." Higher proportion of "vegetarians," eating "5-a-day," and "non-abstainers" had in general a favorable lifestyle profile (ie, nonsmokers, physically active, and normal weight). Whilst the clinical profile was in general better among "vegetarian" participants, the trend was reversed for those eating "5-a-day" and food "abstainers" as suggested by the increased prevalence of the self-reported diagnosed diseases (Table 11, available at www.jandonline.org).

A "vegetarian" diet and eating "5-a-day" were both associated with longer LTL, whereas abstaining from "eggs/dairy products/wheat products/sugar" was associated with shorter LTL in the base model with adjustment for age, sex, ethnicity, and WBC count (Figure 4). However, after adjustment for other variables associated with LTL, the association with "vegetarian" diet became nonsignificant, whereas the associations with eating "5-a-day" and "abstainers" attenuated but remained significant (Figure 4). These findings were concordant in the imputed data (Table 12, available at www.jandonline.org, and Figure 4), whilst no substantial changes in the associations between the dietary behaviors and LTL were observed when CRP was excluded from the analyses (Table 13, available at www.jandonline.org) or when pack of years of smoking (UKB field code: 20161), total metabolic equivalents of task minutes per week of activity (22040), and body mass index (21001) were included in the model instead of the respective variables in their categorical form (Table 14, available at www.jandonline.org). Significant differences by sex were observed for the association between LTL and "being vegetarian," with the association being stronger for men, and "eating 5-a-day," with the association being stronger for women (Figure 6, available at www.jandonline.org).

DISCUSSION

To the best of our knowledge, this is the first large-scale contemporary study to investigate the association among dietary patterns and practices and TL at a population level. The findings suggest that amongst dietary patterns, higher adherence to a Mediterranean-style diet and a prudent diet are significantly associated with longer LTL, whilst higher adherence to a "Meat intake" pattern is associated with shorter LTL. Adjustment for social, lifestyle, and clinical characteristics associated with LTL attenuated the associations with either pattern, although they remained significant. Amongst dietary practices, an "eat-5-a-day" of fruit and vegetables pattern was associated with longer LTL, whereas abstinence from "eggs/dairy products/wheat products/sugar" was associated with shorter LTL. Notably, a self-reported "vegetarian" diet per se was not significantly associated with LTL after adjustment for other lifestyle, social, and clinical characteristics.

The design and scale of the UKB afforded the opportunity to identify dietary patterns and practices in a contemporary population, across a wide age range, and further explore the association between diet and TL. Dietary data were retrospectively collected and as such are prone to recall bias. However, data collected using a touchscreen, short, reproducible FFQ that successfully discriminates participants

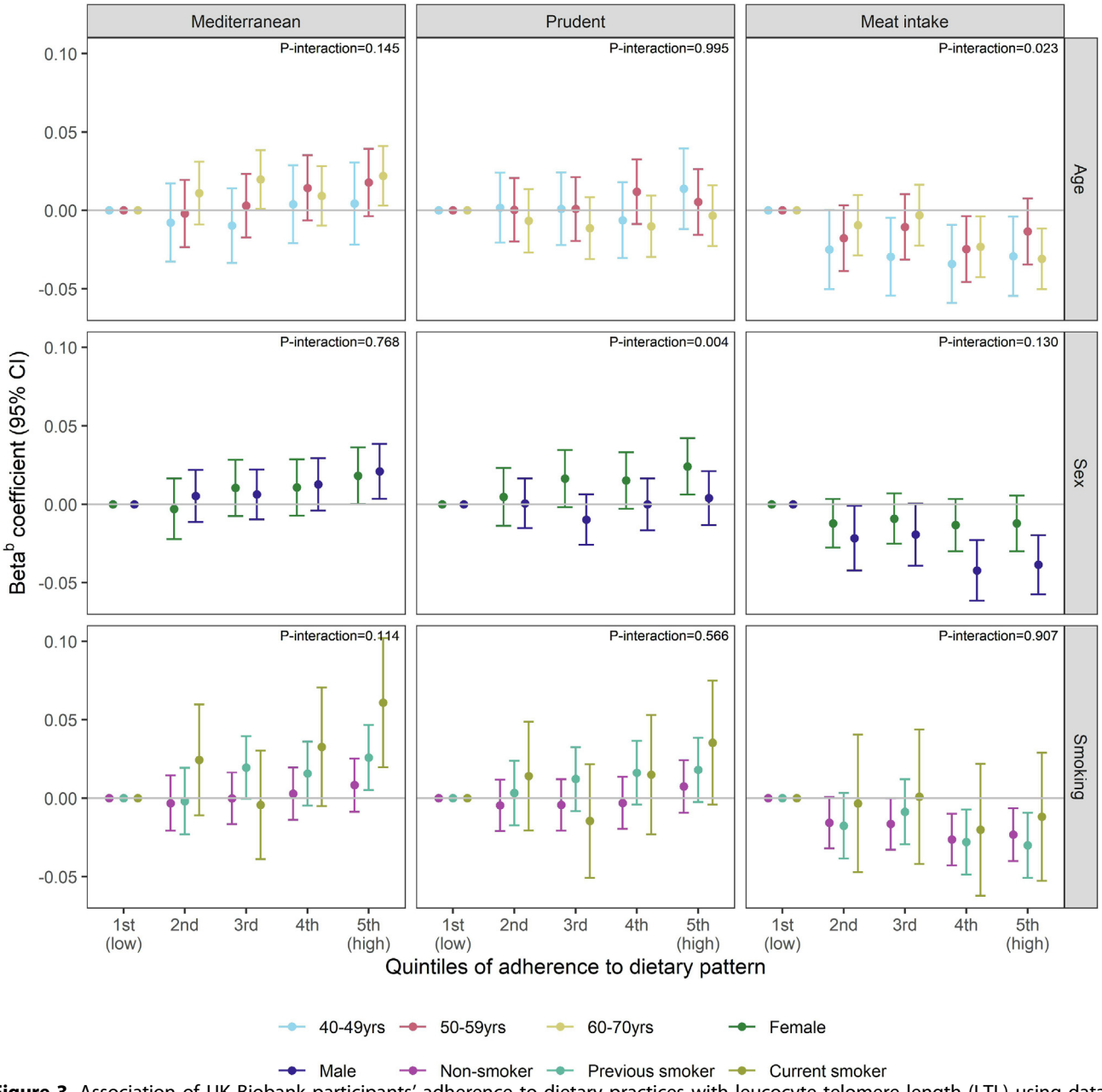

Figure 3. Association of UK Biobank participants' adherence to dietary practices with leucocyte telomere length (LTL) using data collected during 2006-10. [a]Point estimates are beta coefficients for z-standardized LTL. Error bars represent 95% CI. [b]The base model includes the quintiles of adherence to the specific pattern and is adjusted for age, sex, ethnic background, and white blood cell count. [c]The full model is additionally adjusted for smoking habits, physical activity, body mass index classification, highest educational qualification, experiencing insomnia, fed-up feelings, low-density (Chronic Kidney Disease Epidemiology Collaboration equation), and self-reported diseases diagnosed by doctor (diabetes, cancer, hypertension, and vascular diseases).

between low and high intakes of main food groups[22,23] in the presence of UKB staff members who helped to reduce participants' burden and bias. Moreover, dietary patterns were extracted using established methods[27,34] and the ones identified here were also reported in other settings.[35] Olive oil (rich in monounsaturated fatty acids and antioxidants, and a usual component of Mediterranean-style diets[28]) intake was not recorded in the UKB. However, small associations between olive-oil based spread and LTL were previously demonstrated[6]; hence, it is anticipated that the inclusion of olive oil in the MedDietScore would have, if anything, strengthened the observed associations. The MedDietScore employed in this analysis was also limited by the lack of information regarding legumes intake (rich in plant protein). However, legumes intake has been captured, by definition, under the "vegetarian" diet, where association with LTL was

fully explained by the additional lifestyle, social, and clinical characteristics. Within this context, significant changes in the association between a Mediterranean-style diet and LTL should legumes be included in the MedDietScore, re-created for the purposes of this analysis, are not anticipated. Moreover, previous interrogations of TL determinants[3,6,8] enabled accounting for all known potential confounders to date providing a comprehensive analysis for potential confounders. In addition, results utilizing the imputed data showed that the conclusions were unlikely to be influenced by missing data. Risk factor associations in UKB are accepted to be generalizable,[36] although there is evidence of "healthy volunteers" bias.[37] However, this is a cross-sectional study and as such the possibility of residual confounding exists, so associations reported here do not imply causality.

Dietary pattern analysis allows for any interactive, additive, synergistic, or attenuating effect that occurs when foods are consumed in combination, and captures the cumulative effect of the overall diet, which is ignored when food items are examined in isolation.[38] Recent evidence suggests that greater adherence to a "healthy dietary pattern," such as the Mediterranean-style or the "Prudent" diet, reduces the risk of chronic diseases and overall mortality[39] and increases life span.[10] Rich in antioxidants, unrefined cereals, and mono-unsaturated fats, a Mediterranean-style diet may help to counteract telomere attrition via a series of potential mechanisms such as oxidative stress and inflammation.[7] Consistent with other studies,[16] a positive gradient in the association between greater adherence to a Mediterranean-style diet and LTL was observed, even after adjustment for several potential confounding factors.

Because *a priori* defined Mediterranean-style diet may not be relevant to the UK population or neglect important dietary components that could affect LTL, results from the data-driven dietary pattern analyses are also reported. The observed associations of the "Prudent" pattern with LTL were consistent with the findings regarding a Mediterranean-style diet. Conversely, an inverse association between higher adherence to "Meat intake" and LTL was observed that retained at some extent the effect magnitude in the full model, suggesting that the association is only partly mediated through lifestyle, social, and clinical factors. These findings were directionally concordant with other studies,[40,41] with differences in the point estimates attributed to differences to populations studied (eg, differences in race, sociodemographic factors, and clinical profile), the way diet and LTL were measured, and the covariates included in the models.

Results from the full model indicate a null association between being a vegetarian and LTL. Being a vegetarian covers a wide spectrum of dietary habits and practices, from unhealthy plant-based food intake, such as the intake of refined grains (pasta, white rice, and processed breads and cereals), potatoes (French fries and potato chips), or juices and sugar-sweetened beverages, to a healthy diet, such as the intake of whole grains, fruits, vegetables, nuts, legumes, and healthy oils. Therefore, the lack of association could have been anticipated. It was not possible to delineate which end of the spectrum "vegetarians" of this study represented, but results suggest that being vegetarian is a behavior associated with cultural, social (including lifestyle), and health influences and any association with LTL is mediated by other factors. Moreover, some vegetarians still consume animal products (eg, lacto-ovo vegetarians[42]); it could thus be possible that their intake hinders the true association between pure plant origin intake (eg, vegans[42]) and LTL. This hypothesis can be supported by the findings regarding adherence to the public health guidance of daily consumption of at least five portions of fruit and vegetables, with similar results reported elsewhere.[43]

Abstaining from "eggs/dairy products/wheat/sugar" was associated with shorter LTL, albeit of a small magnitude. Although the individual effect of these items cannot be unraveled with the current data, results are contradictory to previous studies.[44-46] Food avoidance could be related to undesirable and aversive past experiences of consuming certain food items, and as such is quite prevalent in people with chronic gastrointestinal diseases[47] or food allergies or intolerances,[48] or to the global interest in dieting leading to dietary trends mainly focused on fast weight loss or how to improve appearence.[49] Because the reason for food abstaining was not recorded in UKB, we cannot unravel whether avoiding eggs, milk, wheat, and sugar are linked to food allergy,[50] increased obesity prevalence,[51] or fad diets.[52] Therefore, the observed negative association between "abstainers" and LTL could also suggest either an underlying association with a health condition or current dieting trends rather than with the avoidance of specific food items per se.

TL is a highly heritable[53] diverse trait that is influenced by a combination of genetic and environmental determinants and the range of factors and the way they influence telomere dynamics is not fully understood. Research suggests that telomere attrition is due to oxidative stress[54] and inflammation.[55] Whilst fruit and vegetables have significant antioxidant and anti-inflammatory properties,[56] and therefore could delay biological ageing by maintaining TL, meat intake has antagonistic action. Processed meat, in particular, consists of saturated fat, sodium, nitrates, and glycotoxins that were found to promote oxidative stress and inflammation.[57,58] Regardless, excluding one inflammation marker from the fully adjusted model did not substantially change the association between the dietary patterns and practices with LTL, which suggests that CRP is an unlikely biological pathway of diet's influence on TL.

CONCLUSIONS

Data from a large-scale study that offers the ability to account for several determinants of LTL and other confounders were used in this study. Although the observed associations between several dietary patterns and practices and LTL were significant, the magnitude of the associations were small and equivalent in most cases (after adjustment for confounding factors) to 1 year or less of age-related change in LTL (Tables 8 and 11, available at www.jandonline.org). As such, the clinical importance of the associations and any relevance to the effects of healthy diets toward chronic disease prevention remains uncertain.

References

1. Armanios M, Blackburn EH. The telomere syndromes. *Nat Rev Genet*. 2012;13(10):693-704.
2. Chan SWRL, Blackburn EH. Telomeres and telomerase. *Philos Trans R Soc Lond B Biol Sci*. 2004;359(1441):109-121.

3. Codd V, Wang Q, Allara E, et al. Polygenic basis and biomedical consequences of telomere length variation. *Nat Genet*. 2021;53:1425-1433.
4. Samani NJ, van der Harst P. Biological ageing and cardiovascular disease. *Heart*. 2008;94(5):537-539.
5. Shammas MA. Telomeres, lifestyle, cancer, and aging. *Curr Opin Clin Nutr Metab Care*. 2011;14(1):28-34.
6. Bountziouka V, Musicha C, Allara E, et al. Modifiable traits, healthy practices, and leucocyte telomere length. *Lancet Heal Longev*. 2022;3:e321-e331.
7. Paul L. Diet, nutrition and telomere length. *J Nutr Biochem*. 2011;22(10):895-901.
8. Codd V, Denniff M, Swinfield C, et al. Measurement and initial characterization of leukocyte telomere length in 474,074 participants in UK Biobank. *Nat Aging*. 2022;2(2):170-179.
9. Trichopoulou A, Costacou T, Bamia C, Trichopoulos D. Adherence to a Mediterranean diet and survival in a Greek population. *N Engl J Med*. 2003;348(26):2599-2608.
10. Ekmekcioglu C. Nutrition and longevity—from mechanisms to uncertainties. *Crit Rev Food Sci Nutr*. 2020;60(18):3063-3082.
11. Grosso G, Bella F, Godos J, Sciacca S, et al. Possible role of diet in cancer: systematic review and multiple meta-analyses of dietary patterns, lifestyle factors, and cancer risk. *Nutr Rev*. 2017;75(6):405-419.
12. Jannasch F, Kröger J, Schulze MB. Dietary patterns and type 2 diabetes: a systematic literature review and meta-analysis of prospective studies. *J Nutr*. 2017;147(6):1174-1182.
13. Rezagholizadeh F, Djafarian K, Khosravi S, Shab-Bidar S. A posteriori healthy dietary patterns may decrease the risk of central obesity: findings from a systematic review and meta-analysis. *Nutr Res*. 2017;41:1-13.
14. Koelman L, Egea Rodrigues C, Aleksandrova K. Effects of dietary patterns on biomarkers of inflammation and immune responses: a systematic review and meta-analysis of randomized controlled trials. *Adv Nutr*. 2021:nmab086.
15. Crous-Bou M, Molineuevo J-L, Sala-Vila A. Plant-rich dietary patterns, plant foods and nutrients, and telomere length. *Adv Nutr*. 2019;10(Suppl 4):S296-S303.
16. Marçal Pérez M, Amaral MA, Mundstock E, et al. Effects of diet on telomere length: systematic review and meta-analysis. *Public Health Genomics*. 2017;20(5):286-292.
17. Sánchez-Sánchez ML, García-Vigara A, Hidalgo-Mora JJ, García-Pérez MÁ, Tarín J, Cano A. Mediterranean diet and health: a systematic review of epidemiological studies and intervention trials. *Maturitas*. 2020;136:25-37.
18. Dinu M, Abbate R, Gensini GF, Casini A, Sofi F. Vegetarian, vegan diets and multiple health outcomes: a systematic review with meta-analysis of observational studies. *Crit Rev Food Sci Nutr*. 2017;57(17):3640-3649.
19. UK Biobank. Protocol for a large-scale prospective epidemiological resource. Accessed August 1, 2022. https://www.ukbiobank.ac.uk/media/gnkeyh2q/study-rationale.pdf
20. Sudlow C, Gallacher J, Allen N, et al. UK biobank: an open access resource for identifying the causes of a wide range of complex diseases of middle and old age. *PLoS Med*. 2015;12(3):e1001779.
21. Bycroft C, Freeman C, Petkova D, et al. The UK Biobank resource with deep phenotyping and genomic data. *Nature*. 2018;562:203-209.
22. Bradbury KE, Young HJ, Guo W, Key TJ. Dietary assessment in UK Biobank: an evaluation of the performance of the touchscreen dietary questionnaire. *J Nutr Sci*. 2018;7:e6.
23. Carter JL, Lewington S, Piernas C, et al. Reproducibility of dietary intakes of macronutrients, specific food groups, and dietary patterns in 211 050 adults in the UK Biobank study. *J Nutr Sci*. 2019;8:e34.
24. UK Biobank. Frequency of drinking alcohol. Accessed November 1, 2020. https://biobank.ndph.ox.ac.uk/showcase/refer.cgi?id=437
25. Department of Health. Alcohol Guidelines Review—Report from the Guidelines Development Group to the UK Chief Medical Officers; 2016. Accessed January 21, 2023. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/545739/GDG_report-Jan2016.pdf
26. Li Y, Pan A, Wang DD, et al. Impact of healthy lifestyle factors on life expectancies in the US Population. *Circulation*. 2018;138:345-355.
27. Panagiotakos DB, Pitsavos C, Arvaniti F, Stefanadis C. Adherence to the Mediterranean food pattern predicts the prevalence of hypertension, hypercholesterolemia, diabetes and obesity, among healthy adults; the accuracy of the MedDietScore. *Prev Med*. 2007;44(4):335-340.
28. The Mediterranean diet pyramid. Accessed November 1, 2022. http://www.mediterradiet.org/nutrition/mediterranean_diet_pyramid
29. Kaiser HF. An index of factorial simplicity. *Psychometrika*. 1974;39(1):31-36.
30. Bartlett MS. The effect of standardization on a Chi-square approximation in factor analysis. *Biometrika*. 1951;38(3/4):337-344.
31. NHS advice for healthy living. Accessed February 1, 2022. https://www.nhs.uk/live-well/eat-well/5-a-day-portion-sizes/
32. White IR, Royston P, Wood AM. Multiple imputation using chained equations: issues and guidance for practice. *Stat Med*. 2011;30(4):377-399.
33. Stata Statistical Software. Release 17. StataCorp LLC; 2021.
34. Hu FB. Dietary pattern analysis: a new direction in nutritional epidemiology. *Curr Opin Lipidol*. 2002;13(1):3-9.
35. Edefonti V, De Vito R, Dalmartello M, Patel L, Salvatori A, Ferraroni M. Reproducibility and validity of a posteriori dietary patterns: a systematic review. *Adv Nutr*. 2020;11(2):293-326.
36. Batty GD, Gale CR, Kivimäki M, Deary IJ, Bell S. Comparison of risk factor associations in UK Biobank against representative, general population-based studies with conventional response rates: prospective cohort study and individual participant meta-analysis. *BMJ*. 2020;368:m131.
37. Kant AK. Dietary patterns and health outcomes. *J Am Diet Assoc*. 2004;104(4):615-635.
38. Dinu M, Pagliai G, Casini A, Sofi E. Mediterranean diet and multiple health outcomes: an umbrella review of meta-analyses of observational studies and randomised trials. *Eur J Clin Nutr*. 2018;72(1):30-43.
39. Fry A, Littlejohns TJ, Sudlow C, et al. Comparison of sociodemographic and health-related characteristics of UK biobank participants with those of the general population. *Am J Epidemiol*. 2017;186(9):1026-1034.
40. Nettleton JA, Diez-Roux A, Jenny NS, Fitzpatrick AL, Jacobs DR. Dietary patterns, food groups, and telomere length in the Multi-Ethnic Study of Atherosclerosis (MESA). *Am J Clin Nutr*. 2008;88(5):1405-1412.
41. Fretts AM, Howard BV, Siscovick DS, Best LG, Beresford SAA, Mete M, Eilat-Adar S, Sotoodehnia N, Zhao J. Processed meat, but not unprocessed red meat, is inversely associated with leukocyte telomere length in the Strong Heart Family study. *J Nutr*. 2016;146(10):2013-2018.
42. Melina V, Craig W, Levin S. Position of the Academy of Nutrition and Dietetics: Vegetarian diets. *J Acad Nutr Diet*. 2016;116(12):1970-1980.
43. Tucker LA. Fruit and vegetable intake and telomere length in a random sample of 5448 U.S. adults. *Nutrients*. 2021;13(5):1415.
44. Gu Y, Honig LS, Schupf N, Lee JH, Luchsinger JA, Stern Y, et al. Mediterranean diet and leukocyte telomere length in a multi-ethnic elderly population. *Age (Dordr)*. 2015;37(2):24.
45. Leung CW, Laraia BA, Needham BL, Rehkopf DH, Adler NE, Lin J, et al. Soda and cell aging: associations between sugar-sweetened beverage consumption and leukocyte telomere length in healthy adults from the National Health and Nutrition Examination Surveys. *Am J Public Health*. 2014;104(12):2425-2431.
46. Garcia-Calzon S, Moleres A, Martinez-Gonzalez MA, Martinez JA, Zalba G, Marti A, et al. Dietary total antioxidant capacity is associated with leukocyte telomere length in a children and adolescent population. *Clin Nutr*. 2015;34(4):694-699.
47. Day AS, Yao CK, Costello SP, Andrew JM, Bryant RV. Food avoidance, restrictive eating behaviour and association with quality of life in adults with inflammatory bowel disease: a systematic scoping review. *Appetite*. 2021;167:105650.
48. Fitzgerald M, Frankum B. Food avoidance and restriction in adults: a cross-sectional pilot study comparing patients from an immunology clinic to a general practice. *J Eat Disord*. 2017;5:30.

49. Gui G. Fad diets, fats & weight management. *Singapore Fam Physician*. 2008;34:14-19.
50. Sampson HA, Aceves S, Bock A, James J, Jones S, Lang D, et al. Food allergy: a practice parameter update—2014. *J Allergy Clin Immunol*. 2014;134(5):1016-1025.
51. Faruque S, Tong J, Lacmanovic V, Agbonghae C, Minaya DM, Czaja K. The dose makes the poison: sugar and obesity in the United States—a review. *Pol J Food Nutr Sci*. 2019;69(3):219-233.
52. Tahreem A, Rakha A, Rabail R, et al. Fad diets: Facts and fiction. *Front Nutr*. 2022;9:960922.
53. Broer L, Codd V, Nyholt DR, et al. Meta-analysis of telomere length in 19,713 subjects reveals high heritability, stronger maternal inheritance and a paternal age effect. *Eur J Hum Genet*. 2013;21(10). 1163-1110.
54. von Zglinicki T. Oxidative stress shortens telomeres. *Trends Biochem Sci*. 2002;27(7):339-344.
55. Kordinas V, Ioannidis A, Chatzipanagiotou S. The telomere/telomerase system in chronic inflammatory diseases. Cause or effect? *Genes*. 2016;7(9):60.
56. Lapuente M, Estruch R, Shahbaz M, Casas R. Relation of fruits and vegetables with major cardiometabolic risk factors, markers of oxidation, and inflammation. *Nutrients*. 2019;11(10):2381.
57. Cai W, Gao QD, Zhu L, Peppa M, He C, Vlassara H. Oxidative stress-inducing carbonyl compounds from common foods: novel mediators of cellular dysfunction. *Mol Med*. 2002;8(7):337-346.
58. Ford JH. Saturated fatty acid metabolism is key link between cell division, cancer, and senescence in cellular and whole organism aging. *Age*. 2010;32(2):231-237.

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STATEMENT OF POTENTIAL CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors.

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UK Biobank received approval from the North West Centre for Research Ethics Committee (11/NW/0382). The use of data presented in this article was approved by the Access Committee of the UK Biobank under application No 6077.

AUTHOR CONTRIBUTIONS

V. Bountziouka and NJS conceptualized and designed this study; V. Bountziouka, Q. Wang, and C. Musicha performed the data management; V. Bountziouka analyzed and interpreted the data with advice from C. Nelson; V. Codd, C. Nelson, and N. Samani were responsible for data acquisition; N. Samani acquired the financial support for the project leading to this publication; V. Bountziouka and N. Samani drafted the manuscript. All authors commented on subsequent drafts of the manuscript and critically reviewed it for important intellectual content and gave their final approval to the version to be published.

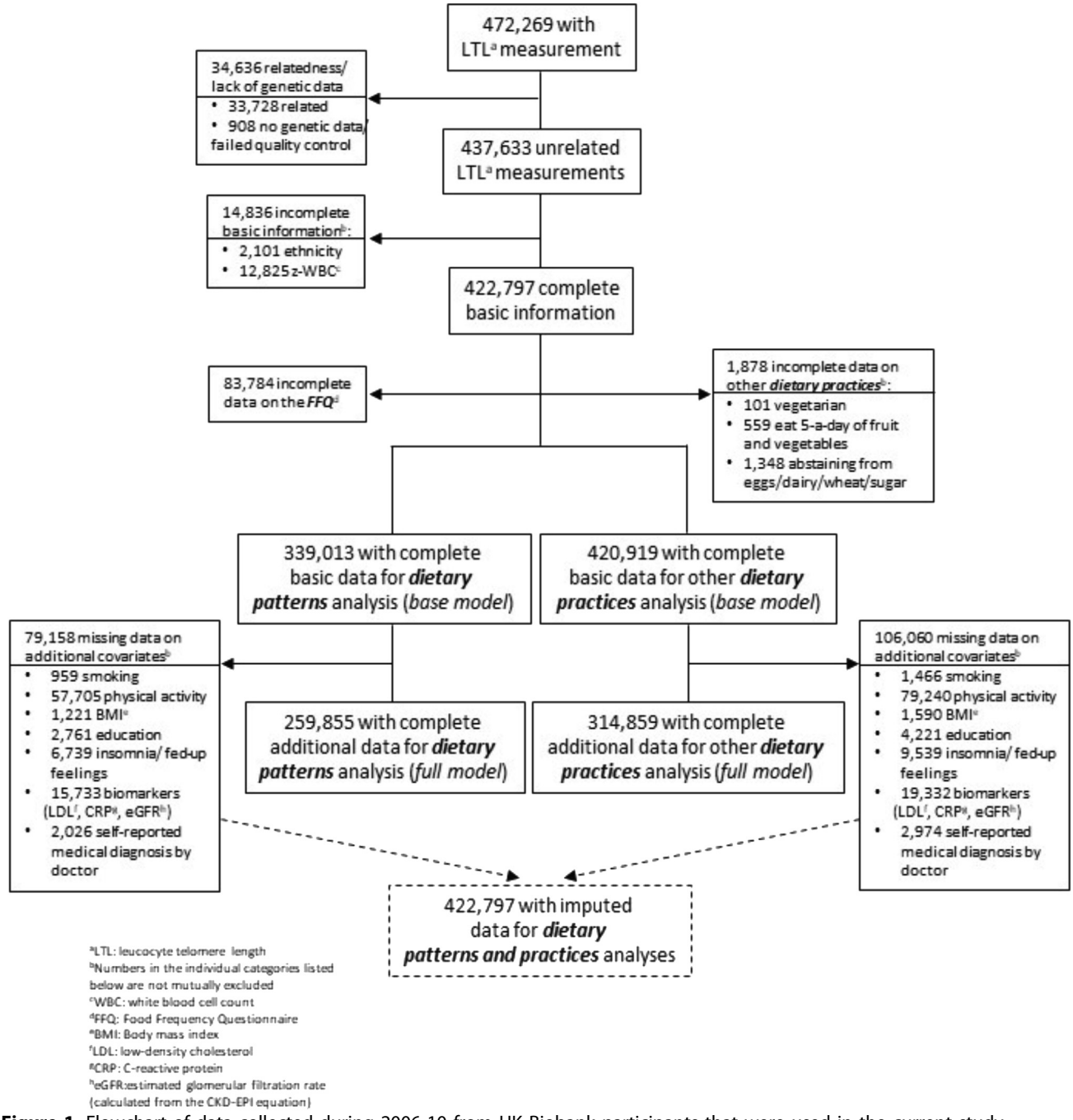

Figure 1. Flowchart of data collected during 2006-10 from UK Biobank participants that were used in the current study.

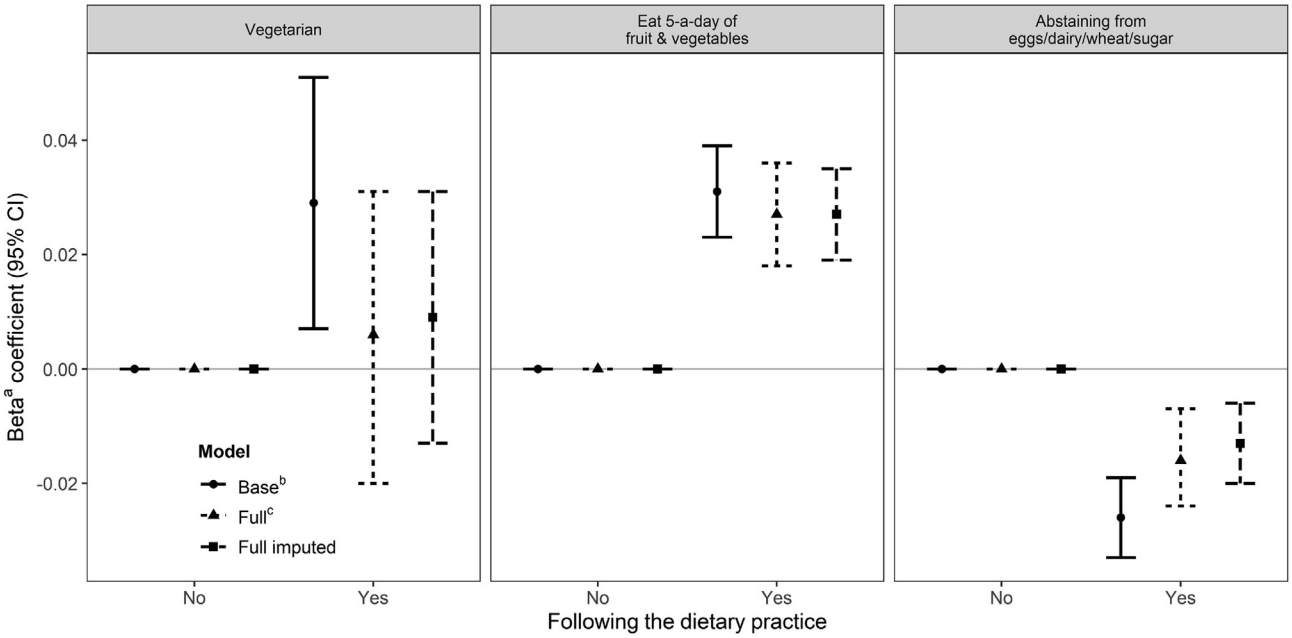

Figure 4. Age-, sex-, and smoking-stratified analyses of the associations of adherence to a dietary pattern with leucocyte telomere length (LTL), in the fully adjusted[a] model using data from the UK Biobank collected during 2006-10. [a]Each model is adjusted for age, sex, ethnic background, white blood cell count, smoking habits, physical activity, body mass index classification, highest educational qualification, experiencing insomnia, fed-up feelings, low-density lipoprotein cholesterol level, C-reactive protein level, estimated glomerular filtration rate (Chronic Kidney Disease Epidemiology Collaboration equation), and self-reported diseases diagnosed by doctor (eg, diabetes, cancer, hypertension, and vascular diseases). Variables considered in the stratification are excluded from the modeling. [b]Point estimates are beta coefficients for z-standardized LTL. Error bars represent 95% CI.

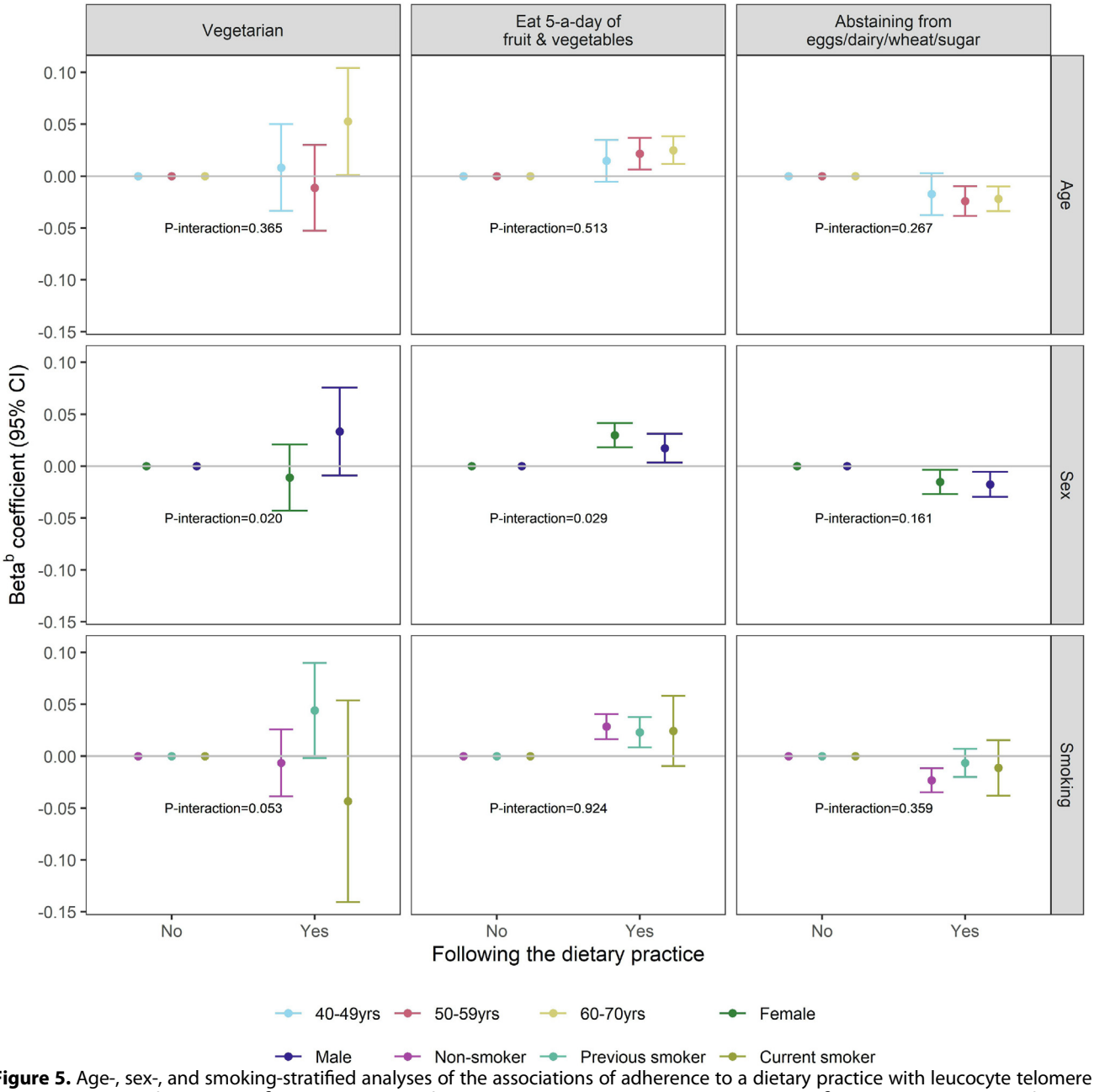

Figure 5. Age-, sex-, and smoking-stratified analyses of the associations of adherence to a dietary practice with leucocyte telomere length (LTL), in the fully adjusted[a] model using data from the UK Biobank collected during 2006-10. [a]Each model is adjusted for age, sex, ethnic background, white blood cell count, smoking habits, physical activity, body mass index classification, highest educational qualification, experiencing insomnia, fed-up feelings, low-density lipoprotein cholesterol level, C-reactive protein level, estimated glomerular filtration rate (Chronic Kidney Disease Epidemiology Collaboration equation), and self-reported diseases diagnosed by doctor (eg, diabetes, cancer, hypertension, and vascular diseases). Variables considered in the stratification are excluded from the modeling. [b]Point estimates are beta coefficients for z-standardized LTL. Error bars represent 95% CI.

Table 3. Distribution of basic demographic and clinical characteristics, collected during 2006-10, between UK Biobank participants with complete and missing data

Characteristic	Complete basic information (n = 422,797)	Dietary patterns		Mean difference missing-complete (95% CI)	Dietary behaviours		Mean difference missing-complete (95% CI)
		Complete data (n = 339,013)	Missing data (n = 83,784)		complete data (n = 420,919)	missing data (n = 1,878)	
	←———— *mean (SD)* ————→						
z-LTL[a]	0.000 (1.000)	−0.005 (0.998)	0.017 (1.009)	0.022 (0.014 to 0.029)	0.000 (1.000)	−0.009 (1.016)	−0.009 (−0.054 to 0.036)
Age (y)	56.6 (8.0)	56.6 (8.0)	56.4 (8.2)	−0.20 (−0.26 to −0.14)	56.6 (8.0)	56.2 (8.6)	−0.40 (−0.76 to −0.04)
	←———— *n (%)* ————→						
Male sex	195,177 (46.2)	164,087 (48.4)	31,090 (37.1)	−11.3 (−11.7 to −10.9)	194,186 (46.1)	991 (52.8)	6.7 (4.4 to 8.9)
Ethnic background[b]							
White	400,036 (94.6)	323,084 (95.3)	76,952 (91.9)	−3.4 (−3.6 to −3.2)	398,663 (94.7)	1,373 (73.1)	−21.6 (−23.6 to −19.5)
Black	6,587 (1.6)	4,332 (1.3)	2,255 (2.7)	—	6,455 (1.5)	132 (7.0)	—
Asian	8,355 (2.0)	6,224 (1.8)	2,131 (2.5)	—	8,113 (1.9)	242 (12.9)	—
Mixed	2,518 (0.60)	1,892 (0.56)	626 (0.75)	—	2,497 (0.59)	21 (1.1)	—
Chinese	1,373 (0.32)	840 (0.25)	533 (0.64)	—	1,356 (0.32)	17 (0.91)	—
Other	3,928 (0.93)	2,641 (0.78)	1,287 (1.5)	—	3,835 (0.91)	93 (5.0)	—
White blood cell (cells/mm^3)	6,869 (1,737)	6,840 (1,714)	6,987 (1,820)	147 (134 to 160)	6,868 (1,736)	7,089 (1,861)	221 (142 to 300)

[a]z-LTL = *z*-standardized leucocyte loge telomere length.

[b]Ethnic background is presented as reported through UK Biobank data collection. White ethnic background also includes British, Irish, and any other White background; Asian ethnic background also includes Asian or Asian British, Indian, Pakistani, Bangladeshi, and any other Asian background); Black ethnic background also includes Black or Black British, Caribbean, African, and any other Black background); Mixed ethnic background also includes White and Black African, White and Black Caribbean, White and Asian, and any other Mixed background).

Table 5. UK Biobank participants' demographic, lifestyle, and clinical characteristics collected during 2006-10, by quintiles of adherence to the *a priori* defined Mediterranean diet pattern (MedDietScore)[a]

		Quintile of MedDietScore[a]					
Characteristic	**Total**	**1**	**2**	**3**	**4**	**5**	***P* value[b]**
				n (%)			
Participants	339,013	62,470 (18.4)	60,184 (17.8)	78,298 (23.1)	71,551 (21.1)	66,510 (19.6)	
				mean (SD)			
z-LTL[c]	−0.005 (0.998)	−0.030 (1.009)	−0.006 (0.995)	0.001 (0.997)	0.001 (0.993)	0.008 (0.995)	8.35×10^{-11}
Age (y)	56.6 (8.0)	56.2 (8.1)	56.1 (8.1)	56.4 (8.0)	56.8 (7.9)	57.4 (7.8)	1.90×10^{-229}
				n (%)			
Male sex	164,087 (48.4)	35,108 (56.2)	31,997 (53.2)	38,357 (49.0)	31,524 (44.1)	27,101 (40.8)	$< 1.00\times10^{-300}$
Ethnic background[d]							$< 1.00\times10^{-300}$
White	323,084 (95.3)	56,742 (90.8)	57,467 (95.5)	75,432 (96.3)	69,252 (96.8)	64,191 (96.5)	
Black	4,332 (1.3)	1,255 (2.0)	757 (1.3)	810 (1.0)	705 (1.0)	805 (1.2)	
Asian	6,224 (1.8)	2,923 (4.7)	1,026 (1.7)	1,004 (1.3)	697 (1.0)	574 (0.9)	
Mixed	1,892 (0.6)	469 (0.8)	341 (0.6)	418 (0.5)	343 (0.5)	321 (0.5)	
Chinese	840 (0.3)	319 (0.5)	141 (0.2)	180 (0.2)	120 (0.2)	80 (0.1)	
Other	2,641 (0.8)	762 (1.2)	452 (0.8)	454 (0.6)	434 (0.6)	539 (0.8)	
White blood cells (cells/mm^3)	6,840 (1,714)	7,044 (1,820)	6,880 (1,724)	6,809 (1,692)	6,768 (1,671)	6,725 (1,656)	5.30×10^{-225}
Smoking status							3.35×10^{-263}
Never	182,281 (53.8)	31,500 (50.4)	31,711 (52.7)	42,371 (54.1)	39,618 (55.4)	37,081 (55.8)	
Previous	121,702 (35.9)	20,755 (33.2)	21,532 (35.8)	28,373 (36.2)	26,157 (36.6)	24,885 (37.4)	
Current	34,071 (10.1)	10,021 (16.0)	6,795 (11.3)	7,327 (9.4)	5,591 (7.8)	4,337 (6.5)	
Missing	959 (0.3)						
Physical activity							$< 1.00\times10^{-300}$
Low	51,457 (15.2)	11,918 (19.1)	10,119 (16.8)	12,145 (15.5)	9,740 (13.6)	7,535 (11.3)	
Moderate	115,358 (34.0)	20,475 (32.8)	21,039 (35.0)	27,250 (34.8)	24,833 (34.7)	21,761 (32.7)	
Vigorous	114,493 (33.8)	17,904 (28.7)	18,690 (31.1)	25,944 (33.1)	25,347 (35.4)	26,608 (40.0)	
Missing	57,705 (17.0)						
Body mass index classification							2.21×10^{-150}
Normal weight[e]	114,151 (33.7)	18,978 (30.4)	19,660 (32.7)	26,859 (34.3)	25,237 (35.3)	23,417 (35.2)	
Overweight	146,442 (43.2)	26,413 (42.3)	26,264 (43.6)	34,227 (43.7)	30,998 (43.3)	28,540 (42.9)	

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Table 5. UK Biobank participants' demographic, lifestyle, and clinical characteristics collected during 2006-10, by quintiles of adherence to the *a priori* defined Mediterranean diet pattern (MedDietScore)[a] (*continued*)

		Quintile of MedDietScore[a]					
Characteristic	**Total**	**1**	**2**	**3**	**4**	**5**	***P* value[b]**
Obesity	77,199 (22.8)	16,737 (26.8)	14,020 (23.3)	16,969 (21.7)	15,120 (21.1)	14,353 (21.6)	
Missing	1,221 (0.4)						
Highest education[f]							3.95×10^{-199}
None	51,138 (15.1)	12,394 (19.8)	9,010 (15.0)	10,781 (13.8)	9,725 (13.6)	9,228 (13.9)	
Statutory/ compulsory education	55,637 (16.4)	10,794 (17.3)	9,744 (16.2)	12,671 (16.2)	11,512 (16.1)	10,916 (16.4)	
Advanced education	111,709 (33.0)	20,032 (32.1)	19,924 (33.1)	26,049 (33.3)	23,773 (33.2)	21,931 (33.0)	
University/college degree	117,768 (34.7)	18,591 (29.8)	21,021 (34.9)	28,203 (36.0)	26,026 (36.4)	23,927 (36.0)	
Missing	2,761 (0.8)						
Insomnia							$8.79\times10-^{14}$
Never/rarely	83,859 (24.7)	15,259 (24.4)	14,971 (24.9)	19,548 (25.0)	17,610 (24.6)	16,471 (24.8)	
Sometimes	161,832 (47.7)	28,507 (45.6)	28,677 (47.7)	37,771 (48.2)	34,851 (48.7)	32,026 (48.2)	
Usually	93,123 (27.5)	18,649 (29.9)	16,504 (27.4)	20,946 (26.8)	19,049 (26.6)	17,975 (27.0)	
Missing	199 (0.1)						
Fed-up feelings							5.24×10^{-269}
No	202,445 (59.7)	33,757 (54.0)	35,205 (58.5)	47,074 (60.1)	44,354 (62.0)	42,055 (63.2)	
Yes	130,006 (38.4)	27,284 (43.7)	23,797 (39.5)	29,795 (38.1)	25,895 (36.2)	23,235 (34.9)	
Missing	6,562 (1.9)						
LDL[g] cholesterol (mg/dL)	137.5 (33.0)	136.6 (33.6)	137.4 (32.9)	137.9 (32.8)	138.0 (32.8)	137.5 (32.8)	1.48×10^{-07}
Missing	14,821 (4.4)						
CRP[h] (μg/mL)	2.426 (3.597)	2.797 (3.968)	2.492 (3.649)	2.364 (3.523)	2.273 (3.415)	2.257 (3.430)	1.00×10^{-300}
Missing	14,872 (4.4)						
eGFR[i] (μmol/L)	0.84 (0.85)	0.70 (0.84)	0.76 (0.84)	0.83 (0.85)	0.91 (0.84)	0.96 (0.84)	$< 1.00\times10^{-300}$
Missing	14,404 (4.2)						
Diabetes[j]							4.50×10^{-72}
No	322,058 (95.0)	58,202 (93.2)	57,092 (94.9)	74,799 (95.5)	68,475 (95.7)	63,490 (95.5)	
Yes	16,144 (4.8)	4,010 (6.4)	2,929 (4.9)	3,351 (4.3)	2,957 (4.1)	2,897 (4.4)	
Missing	811 (0.2)						

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Table 5. UK Biobank participants' demographic, lifestyle, and clinical characteristics collected during 2006-10, by quintiles of adherence to the *a priori* defined Mediterranean diet pattern (MedDietScore)[a] (*continued*)

		Quintile of MedDietScore[a]					
Characteristic	**Total**	**1**	**2**	**3**	**4**	**5**	***P* value[b]**
Cancer[j]							1.10×10^{-21}
No	312,760 (92.3)	57,828 (92.6)	55,747 (92.6)	72,520 (92.6)	65,780 (91.9)	60,885 (91.5)	
Yes	25,349 (7.5)	4,407 (7.1)	4,268 (7.1)	5,593 (7.1)	5,613 (7.8)	5,468 (8.2)	
Missing	904 (0.3)						
Hypertension[j]							5.91×10^{-24}
No	248,215 (73.2)	44,109 (70.6)	44,033 (73.2)	58,327 (74.5)	53,166 (74.3)	48,580 (73.0)	
Yes	90,258 (26.6)	18,209 (29.2)	16,044 (26.7)	19,874 (25.4)	18,305 (25.6)	17,826 (26.8)	
Missing	540 (0.2)						
Vascular disease[j]							1.50×10^{-26}
No	319,831 (94.3)	58,097 (93.0)	56,821 (94.4)	74,186 (94.8)	67,934 (94.9)	62,793 (94.4)	
Yes	18,642 (5.5)	4,221 (6.8)	3,256 (5.4)	4,015 (5.1)	3,537 (4.9)	3,613 (5.4)	
Missing	540 (0.2)						

[a]MedDietScore was a possible 0 to 37. Quintile 1 = score ≤16, quintile 2 = score 17 to 18, quintile 3 = 19 to 20, quintile 4 = 21 to 22, quintile 5 = ≥23.
[b]*P* values are estimated using the Jonckheere-Terpstra test for trend for both continuous and categorical variables.
[c]zLTL = *z*-standardized leucocyte $\log_e$ telomere length.
[d]Ethnic background is presented as reported through UK Biobank data collection. White ethnic background also includes British, Irish, and any other White background. Asian ethnic background also includes Asian or Asian British, Indian, Pakistani, Bangladeshi, and any other Asian background. Black ethnic background also includes Black or Black British, Caribbean, African, and any other Black background. Mixed ethnic background also includes White and Black African, White and Black Caribbean, White and Asian, and any other Mixed background.
[e]Normal weight category also includes 2,155 participants with body mass index <18.5.
[f]Statutory/compulsory education is equivalent to "O-levels/CSE/GCSE" of the UK educational system, Advanced education is equivalent to the "A-levels/Non-vocational qualifications/ Other professional educational qualifications" of the UK educational system.
[g]LDL = low-density lipoprotein. To convert mg/dL cholesterol to mmol/L, multiply by 0.0259.
[h]CRP = C-reactive protein.
[i]eGFR = estimated glomerular filtration rate. To convert mg/dL to μmol/L, multiply by 88.496.
[j]Diseases are self-reported as diagnosed by a doctor.

Table 6. UK Biobank participants' demographic, lifestyle, and clinical characteristics, collected during 2006-10, by quintiles of adherence to the *a posteriori* defined Prudent pattern

		Quintile of adherence to Prudent pattern					
Dietary pattern	**Total**	**1 (low)**	**2**	**3**	**4**	**5 (high)**	***P* value**[a]
	← *n (%)* →						
Participants	339,013	66,184 (19.5)	67,746 (20.0)	68,439 (20.2)	68,677 (20.3)	67,967 (20.1)	
	← *mean (SD)* →						
z-LTL[b]	−0.005 (0.998)	0.001 (1.000)	−0.002 (0.997)	−0.009 (0.992)	−0.007 (0.997)	−0.006 (1.004)	0.054
Age (y)	56.6 (8.0)	54.8 (8.2)	55.9 (8.1)	56.7 (7.9)	57.4 (7.8)	58.1 (7.6)	$<1.00\times10^{-300}$
	← *n (%)* →						
Male sex	164,087 (48.4)	38,931 (58.8)	35,350 (52.2)	32,854 (48.0)	29,937 (43.6)	27,015 (39.8)	$<1.00\times10^{-300}$
Ethnic background[c]							1.38×10^{-32}
White	323,084 (95.3)	63,123 (95.4)	64,839 (95.7)	65,616 (95.9)	65,706 (95.7)	63,800 (93.9)	
Black	4,332 (1.3)	587 (0.9)	647 (1.0)	728 (1.1)	861 (1.3)	1,509 (2.2)	
Asian	6,224 (1.8)	1,640 (2.5)	1,338 (2.0)	1,131 (1.7)	989 (1.4)	1,126 (1.7)	
Mixed	1,892 (0.6)	386 (0.6)	358 (0.5)	350 (0.5)	367 (0.5)	431 (0.6)	
Chinese	840 (0.3)	97 (0.2)	137 (0.2)	155 (0.2)	199 (0.3)	252 (0.4)	
Other	2,641 (0.8)	351 (0.5)	427 (0.6)	459 (0.7)	555 (0.8)	849 (1.3)	
White blood cells (cells/mm^3)	6,840 (1,714)	6,991 (1,792)	6,870 (1,719)	6,832 (1,697)	6,782 (1,676)	6,729 (1,675)	8.03×10^{-169}
Smoking status							6.61×10^{-78}
Never	182,281 (53.8)	34,366 (51.9)	36,723 (54.2)	37,377 (54.6)	37,256 (54.3)	36,559 (53.8)	
Previous	121,702 (35.9)	21,633 (32.7)	23,621 (34.9)	24,547 (35.9)	25,741 (37.5)	26,160 (38.5)	
Current	34,071 (10.1)	10,003 (15.1)	7,237 (10.7)	6,352 (9.3)	5,463 (8.0)	5,016 (7.4)	
Missing	959 (0.3)						
Physical activity							$<1.00x10^{-300}$
Low	51,457 (15.2)	13,388 (20.2)	11,610 (17.1)	10,380 (15.2)	8,915 (13.0)	7,164 (10.5)	
Moderate	115,358 (34.0)	22,304 (33.7)	23,915 (35.3)	24,067 (35.2)	23,729 (34.6)	21,343 (31.4)	
Vigorous	114,493 (33.8)	18,146 (27.4)	20,367 (30.1)	22,435 (32.8)	24,798 (36.1)	28,747 (42.3)	
Missing	57,705 (17.0)						
Body mass index classification							1.15×10^{-09}
Normal weight[d]	114,151 (33.7)	22,587 (34.1)	23,163 (34.2)	23,221 (33.9)	23,104 (33.6)	22,076 (32.5)	
Overweight	146,442 (43.2)	28,003 (42.3)	29,342 (43.3)	29,695 (43.4)	29,863 (43.5)	29,539 (43.5)	

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Table 6. UK Biobank participants' demographic, lifestyle, and clinical characteristics, collected during 2006-10, by quintiles of adherence to the *a posteriori* defined Prudent pattern (*continued*)

		Quintile of adherence to Prudent pattern					
Dietary pattern	**Total**	**1 (low)**	**2**	**3**	**4**	**5 (high)**	***P* value**[a]
Obesity	77,199 (22.8)	15,313 (23.1)	15,017 (22.2)	15,305 (22.4)	15,465 (22.5)	16,099 (23.7)	
Missing	1,221 (0.4)						
Highest education[e]							2.78×10^{-19}
None	51,138 (15.1)	10,965 (16.6)	9,834 (14.5)	9,761 (14.3)	9,964 (14.5)	10,614 (15.6)	
Statutory/ compulsory education	55,637 (16.4)	11,586 (17.5)	11,022 (16.3)	11,022 (16.1)	10,984 (16.0)	11,023 (16.2)	
Advanced education	111,709 (33.0)	21,713 (32.8)	22,530 (33.3)	22,700 (33.2)	22,488 (32.7)	22,278 (32.8)	
University/college degree	117,768 (34.7)	21,413 (32.4)	23,888 (35.3)	24,474 (35.8)	24,659 (35.9)	23,334 (34.3)	
Missing	2,761 (0.8)						
Insomnia							1.32×10^{-06}
Never/rarely	83,859 (24.7)	16,903 (25.5)	17,139 (25.3)	16,848 (24.6)	16,455 (24.0)	16,514 (24.3)	
Sometimes	161,832 (47.7)	30,811 (46.6)	32,182 (47.5)	33,096 (48.4)	33,265 (48.4)	32,478 (47.8)	
Usually	93,123 (27.5)	18,420 (27.8)	18,387 (27.1)	18,462 (27.0)	18,925 (27.6)	18,929 (27.9)	
Missing	199 (0.1)						
Fed-up feelings							$< 1.00\times10^{-300}$
No	202,445 (59.7)	35,110 (53.1)	39,354 (58.1)	41,690 (60.9)	42,812 (62.3)	43,479 (64.0)	
Yes	130,006 (38.4)	29,740 (44.9)	27,052 (39.9)	25,459 (37.2)	24,581 (35.8)	23,174 (34.1)	
Missing	6,562 (1.9)						
LDL[f] cholesterol (mg/dL)	137.5 (33.0)	136.8 (32.5)	137.7 (32.7)	137.7 (32.9)	138.0 (33.2)	137.2 (33.5)	0.039
Missing	14,821 (4.4)						
CRP[g] (μg/mL)	2.426 (3.597)	2.578 (3.749)	2.448 (3.602)	2.434 (3.613)	2.362 (3.538)	2.313 (3.476)	9.38×10^{-83}
Missing	14,872 (4.4)						
eGFR[h] (mg/dL)	0.84 (0.85)	0.67 (0.83)	0.78 (0.85)	0.85 (0.85)	0.92 (0.85)	0.97 (0.83)	$< 1.00\times10^{-300}$
Missing	14,404 (4.2)						
Diabetes[i]							6.89×10^{-17}
No	322,058 (95.0)	62,974 (95.2)	64,566 (95.3)	65,201 (95.3)	65,239 (95.0)	64,078 (94.3)	
Yes	16,144 (4.8)	3,016 (4.6)	3,018 (4.5)	3,102 (4.5)	3,294 (4.8)	3,714 (5.5)	
Missing	811 (0.2)						

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Table 6. UK Biobank participants' demographic, lifestyle, and clinical characteristics, collected during 2006-10, by quintiles of adherence to the *a posteriori* defined Prudent pattern (*continued*)

		Quintile of adherence to Prudent pattern					
Dietary pattern	**Total**	**1 (low)**	**2**	**3**	**4**	**5 (high)**	***P* value**[a]
Cancer[i]							3.17×10^{-73}
No	312,760 (92.3)	61,837 (93.4)	62,901 (92.9)	63,111 (92.2)	62,963 (91.7)	61,948 (91.1)	
Yes	25,349 (7.5)	4,154 (6.3)	4,665 (6.9)	5,143 (7.5)	5,556 (8.1)	5,831 (8.6)	
Missing	904 (0.3)						
Hypertension[i]							2.80×10^{-138}
No	248,215 (73.2)	50,065 (75.7)	50,662 (74.8)	50,269 (73.5)	49,483 (72.1)	47,736 (70.2)	
Yes	90,258 (26.6)	16,024 (24.2)	16,989 (25.1)	18,066 (26.4)	19,077 (27.8)	20,102 (29.6)	
Missing	540 (0.2)						
Vascular disease							3.47×10^{-34}
No	319,831 (94.3)	62,749 (94.8)	64,241 (94.8)	64,700 (94.5)	64,655 (94.1)	63,486 (93.4)	
Yes	18,642 (5.5)	3,340 (5.1)	3,410 (5.0)	3,635 (5.3)	3,905 (5.7)	4,352 (6.4)	
Missing	540 (0.2)						

[a]*P* values are estimated using the Jonckheere-Terpstra test for trend for both continuous and categorical variables.
[b]zLTL = *z*-standardized leucocyte $\log_e$ telomere length.
[c]Ethnic background is presented as reported through UK Biobank data collection. White ethnic background also includes British, Irish, and any other White background. Asian ethnic background also includes Asian or Asian British, Indian, Pakistani, Bangladeshi, and any other Asian background. Black ethnic background also includes Black or Black British, Caribbean, African, and any other Black background. Mixed ethnic background also includes White and Black African, White and Black Caribbean, White and Asian, and any other Mixed background.
[d]Normal weight category also includes 2,155 participants with body mass index <18.5.
[e]Statutory/compulsory education is equivalent to "O-levels/CSE/GCSE" of the UK educational system, Advanced education is equivalent to the "A-levels/Non-vocational qualifications/ Other professional educational qualifications" of the UK educational system.
[f]LDL = low-density lipoprotein. To convert mg/dL cholesterol to mmol/L, multiply 0.0259.
[g]CRP = C-reactive protein.
[h]eGFR = estimated glomerular filtration rate. To convert mg/dL to μmol/L, multiply by 88.496.
[i]Diseases are self-reported as diagnosed by a doctor.

Table 7. UK Biobank participants' demographic, lifestyle, and clinical characteristics,[a] collected during 2006-10, by quintiles of adherence to the *a posteriori* defined Meat intake pattern

		Quintile of adherence to Meat intake dietary pattern					
Characteristic	**Total**	**1 (low)**	**2**	**3**	**4**	**5 (high)**	***P* value[a]**
	←			*n (%)*			→
Participants	339,013	62,380 (18.4)	65,563 (19.3)	68,169 (20.1)	70,341 (20.8)	72,560 (21.4)	
	←			*mean (SD)*			→
z-LTL[b]	−0.005 (0.998)	0.068 (0.997)	0.005 (0.998)	−0.005 (0.992)	−0.027 (1.002)	−0.054 (0.997)	1.27×10^{-109}
Age (y)	56.6 (8.0)	56.1 (8.1)	56.9 (7.9)	56.6 (8.0)	56.6 (8.0)	56.8 (8.0)	2.76×10^{-26}
	←			*n (%)*			→
Male sex	164,087 (48.4)	18,874 (30.3)	25,944 (39.6)	33,268 (48.8)	38,900 (55.3)	47,101 (64.9)	$<1.00\times10^{-300}$
Ethnic background[c]							$<1.00\times10^{-300}$
White	323,084 (95.3)	55,781 (89.4)	62,585 (95.5)	65,932 (96.7)	68,350 (97.2)	70,436 (97.1)	
Black	4,332 (1.3)	1,328 (2.1)	863 (1.3)	667 (1.0)	681 (1.0)	793 (1.1)	
Asian	6,224 (1.8)	3,696 (5.9)	1,045 (1.6)	656 (1.0)	447 (0.6)	380 (0.5)	
Mixed	1,892 (0.6)	474 (0.8)	351 (0.5)	351 (0.5)	332 (0.5)	384 (0.5)	
Chinese	840 (0.3)	168 (0.3)	168 (0.3)	139 (0.2)	180 (0.3)	185 (0.3)	
Other	2,641 (0.8)	933 (1.5)	551 (0.8)	424 (0.6)	351 (0.5)	382 (0.5)	
White blood cell (cells/mm^3)	6,840 (1,714)	6,700 (1,690)	6,792 (1,702)	6,832 (1,702)	6,881 (1,719)	6,970 (1,741)	3.11×10^{-202}
Smoking status							$<1.00\times10^{-300}$
Never	182,281 (53.8)	36,575 (58.6)	36,492 (55.7)	36,897 (54.1)	36,927 (52.5)	35,390 (48.8)	
Previous	121,702 (35.9)	20,706 (33.2)	23,245 (35.5)	24,619 (36.1)	25,763 (36.6)	27,369 (37.7)	
Current	34,071 (10.1)	4,894 (7.9)	5,642 (8.6)	6,469 (9.5)	7,446 (10.6)	9,620 (13.3)	
Missing	959 (0.3)						
Physical activity							7.19×10^{-95}
Low	51,457 (15.2)	8,175 (13.1)	9,572 (14.6)	10,574 (15.5)	11,317 (16.1)	11,819 (16.3)	
Moderate	115,358 (34.0)	20,270 (32.5)	22,133 (33.8)	23,609 (34.6)	24,520 (34.9)	24,826 (34.2)	
Vigorous	114,493 (33.8)	23,089 (37.0)	22,231 (33.9)	22,274 (32.7)	22,732 (32.3)	24,167 (33.3)	
Missing	57,705 (17.0)						
Body mass index classification							$< 1.00\times10^{-300}$
Normal weight[d]	114,151 (33.7)	27,041 (43.4)	23,556 (35.9)	22,465 (33.0)	21,503 (30.6)	19,586 (27.0)	
Overweight	146,442 (43.2)	23,794 (38.1)	27,999 (42.7)	30,052 (44.1)	31,625 (45.0)	32,972 (45.4)	

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Table 7. UK Biobank participants' demographic, lifestyle, and clinical characteristics,[a] collected during 2006-10, by quintiles of adherence to the *a posteriori* defined Meat intake pattern (*continued*)

		Quintile of adherence to Meat intake dietary pattern					
Characteristic	**Total**	**1 (low)**	**2**	**3**	**4**	**5 (high)**	***P* value[a]**
Obesity	77,199 (22.8)	11,181 (17.9)	13,793 (21.0)	15,442 (22.7)	17,010 (24.2)	19,773 (27.3)	
Missing	1,221 (0.4)						
Highest education[e]							2.76×10^{-21}
None	51,138 (15.1)	9,304 (14.9)	10,151 (15.5)	10,155 (14.9)	10,354 (14.7)	11,174 (15.4)	
Statutory/ compulsory education	55,637 (16.4)	9,679 (15.5)	11,481 (17.5)	11,619 (17.0)	11,639 (16.6)	11,219 (15.5)	
Advanced education	111,709 (33.0)	18,410 (29.5)	21,143 (32.3)	22,918 (33.6)	24,130 (34.3)	25,108 (34.6)	
University/college degree	117,768 (34.7)	24,327 (39.0)	22,254 (33.9)	22,967 (33.7)	23,723 (33.7)	24,497 (33.8)	
Missing	2,761 (0.8)						
Insomnia							1.05×10^{-14}
Never/rarely	83,859 (24.7)	15,257 (24.5)	15,614 (23.8)	16,802 (24.7)	17,519 (24.9)	18,667 (25.7)	
Sometimes	161,832 (47.7)	29,374 (47.1)	31,785 (48.5)	32,708 (48.0)	33,832 (48.1)	34,133 (47.0)	
Usually	93,123 (27.5)	17,712 (28.4)	18,137 (27.7)	18,606 (27.3)	18,947 (26.9)	19,721 (27.2)	
Missing	199 (0.1)						
Fed-up feelings							0.995
No	202,445 (59.7)	36,910 (59.2)	39,539 (60.3)	40,634 (59.6)	42,242 (60.1)	43,120 (59.4)	
Yes	130,006 (38.4)	24,125 (38.7)	24,849 (37.9)	26,249 (38.5)	26,789 (38.1)	27,994 (38.6)	
Missing	6,562 (1.9)						
LDL[f] cholesterol (mg/dL)	137.5 (33.0)	135.2 (32.7)	137.6 (33.0)	138.1 (33.0)	138.1 (32.9)	138.3 (33.2)	5.07×10^{-61}
Missing	14,821 (4.4)						
CRP[g] (μg/mL)	2.426 (3.597)	2.213 (3.468)	2.361 (3.552)	2.427 (3.591)	2.480 (3.612)	2.615 (3.723)	$< 1.00\times10^{-300}$
Missing	14,872 (4.4)						
eGFR[h] (mg/dL)	0.84 (0.85)	1.11 (0.79)	0.99 (0.84)	0.84 (0.85)	0.74 (0.85)	0.58 (0.81)	$< 1.00\times10^{-300}$
Missing	14,404 (4.2)						
Diabetes[i]							4.97×10^{-22}
No	322,058 (95.0)	59,406 (95.2)	62,518 (95.4)	64,966 (95.3)	66,820 (95.0)	68,348 (94.2)	
Yes	16,144 (4.8)	2,812 (4.5)	2,902 (4.4)	3,056 (4.5)	3,363 (4.8)	4,011 (5.5)	
Missing	811 (0.2)						
Cancer[i]							0.005

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Table 7. UK Biobank participants' demographic, lifestyle, and clinical characteristics,[a] collected during 2006-10, by quintiles of adherence to the *a posteriori* defined Meat intake pattern (*continued*)

		Quintile of adherence to Meat intake dietary pattern					
Characteristic	**Total**	**1 (low)**	**2**	**3**	**4**	**5 (high)**	***P* value[a]**
No	312,760 (92.3)	57,415 (92.0)	60,367 (92.1)	62,889 (92.3)	65,020 (92.4)	67,069 (92.4)	
Yes	25,349 (7.5)	4,757 (7.6)	5,013 (7.7)	5,096 (7.5)	5,156 (7.3)	5,327 (7.3)	
Missing	904 (0.3)						
Hypertension[i]							3.93×10^{-127}
No	248,215 (73.2)	47,694 (76.5)	48,433 (73.9)	49,759 (73.0)	51,108 (72.7)	51,221 (70.6)	
Yes	90,258 (26.6)	14,552 (23.3)	17,042 (26.0)	18,316 (26.9)	19,118 (27.2)	21,230 (29.3)	
Missing	540 (0.2)						
Vascular disease[i]							5.35×10^{-20}
No	319,831 (94.3)	59,178 (94.9)	61,879 (94.4)	64,448 (94.5)	66,349 (94.3)	67,977 (93.7)	
Yes	18,642 (5.5)	3,068 (4.9)	3,596 (5.5)	3,627 (5.3)	3,877 (5.5)	4,474 (6.2)	
Missing	540 (0.2)						

[a]*P* values are estimated using the Jonckheere-Terpstra test for trend for both continuous and categorical variables.
[b]zLTL = *z*-standardized leucocyte $\log_e$ telomere length.
[c]Ethnic background is presented as reported through UK Biobank data collection. White ethnic background also includes British, Irish, and any other White background; Asian ethnic background also includes Asian or Asian British, Indian, Pakistani, Bangladeshi, and any other Asian background. Black ethnic background also includes Black or Black British, Caribbean, African, and any other Black background. Mixed ethnic background also includes White and Black African, White and Black Caribbean, White and Asian, and any other Mixed background.
[d]Normal weight category also includes 2,155 participants with body mass index <18.5.
[e]Statutory/compulsory education is equivalent to "O-levels/CSE/GCSE" of the UK educational system, Advanced education is equivalent to the "A-levels/Non-vocational qualifications/ Other professional educational qualifications" of the UK educational system.
[f]LDL = low-density lipoprotein. To convert mg/dL cholesterol to mmol/L, multiply by 0.0259.
[g]CRP = C-reactive protein.
[h]eGFR = estimated glomerular filtration rate. To convert mg/dL to μmol/L, multiply by 88.496.
[i]Diseases are self-reported as diagnosed by doctor.

Table 8. Association of the dietary patterns with leucocyte telomere length (LTL), in the UK Biobank using data collected during 2006-10

	Base model[a]					
	Available data (n = 339,013)[b]			Imputed data (n = 422,797)		
Dietary pattern	Beta[c] (95% CI)	*P* value	Equivalent years of age-related change in LTL[d]	Beta (95% CI)	*P* value	Equivalent years of age-related change in LTL
Quintiles of Mediterranean pattern, vs first (lowest)		9.03×10^{-12}[e]			8.41×10^{-08}[e]	
Second	.020 (.009 to .031)	2.95×10^{-04}	0.87	.015 (.005 to .026)	0.004	0.65
Third	.026 (.016 to .037)	4.88×10^{-07}	**1.13**[f]	.019 (.009 to .029)	2.28×10^{-04}	0.83
Fourth	.028 (.017 to .038)	2.05×10^{-07}	**1.22**	.021 (.011 to .031)	2.05×10^{-05}	0.91
Fifth (highest)	.040 (.030 to .051)	1.93×10^{-13}	**1.74**	.032 (.022 to .042)	1.31×10^{-09}	**1.39**
Quintiles of Prudent pattern, vs first (lowest)		1.87×10^{-05}[e]			2.53×10^{-11}[e]	
Second	.008 (−.002 to .019)	0.123	0.35	.010 (.001 to .020)	0.032	0.43
Third	.012 (.002 to .023)	0.024	0.52	.018 (.009 to .028)	1.61×10^{-04}	0.78
Fourth	.020 (.010 to .031)	1.55×10^{-04}	0.87	0.025 (.015 to .034)	2.84×10^{-07}	**1.09**
Fifth (highest)	.025 (.015 to .036)	2.72×10^{-06}	**1.09**	.034 (.024 to .043)	7.36×10^{-12}	**1.48**
Quintiles of Meat intake pattern, vs first (lowest)		8.84×10^{-09}[e]			1.51×10^{-10}[e]	
Second	−.020 (−.030 to −.009)	3.33×10^{-04}	-0.87	−.019 (−.028 to −.009)	$1.15x10^{-04}$	-0.83

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Table 8. Association of the dietary patterns with leucocyte telomere length (LTL), in the UK Biobank using data collected during 2006-10 (*continued*)

	Base model[a]					
	Available data (n = 339,013)[b]			Imputed data (n = 422,797)		
Dietary pattern	Beta[c] (95% CI)	*P* value	Equivalent years of age-related change in LTL[d]	Beta (95% CI)	*P* value	Equivalent years of age-related change in LTL
Third	−.019	5.90×10^{-04}	-0.83	−.022	8.80×10^{-06}	-0.96
	(−.030 to −.008)			(−.031 to −.012)		
Fourth	−.030	6.89×10^{-08}	**-1.30**	−.031	3.34×10^{-10}	**-1.35**
	(−.040 to −.019)			(−.040 to −.021)		
Fifth (highest)	−.033	1.23×10^{-09}	**-1.43**	−.032	1.90×10^{-10}	**-1.39**
	(−.044 to −.023)			(−.041 to −.022)		
	Full model[g]					
	Available data (n = 259,855)			Imputed data (n = 422,797)		
Quintiles of Mediterranean pattern, vs first (lowest)		0.009[e]			0.015[e]	
Second	.001	0.870	0.04	.007	0.172	0.30
	(−.012 to .014)			(−.003 to .018)		
Third	.008	0.199	0.35	.008	0.119	0.35
	(−.004 to .020)			(−.002 to .018)		
Fourth	.011	0.071	0.48	.008	0.110	0.35
	(−.001 to .023)			(−.002 to .018)		
Fifth (highest)	.020	0.002	0.87	.018	4.59×10^{-04}	0.78
	(.008 to .033)			(.008 to .029)		
Quintiles of Prudent pattern, vs first (lowest)		0.103[e]			3.03×10^{-05}[e]	
Second	.001	0.917	0.04	.003	0.602	0.13
	(−.011 to .013)			(−.007 to .012)		
Third	.001	0.839	0.04	.008	0.121	0.35
	(−.011 to .013)			(−.002 to .017)		
Fourth	.006	0.308	0.26	.013	0.009	0.57
	(−.006 to .018)			(.003 to .022)		

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Table 8. Association of the dietary patterns with leucocyte telomere length (LTL), in the UK Biobank using data collected during 2006-10 (*continued*)

	Base model[a]					
	Available data (n = 339,013)[b]			Imputed data (n = 422,797)		
Dietary pattern	Beta[c] (95% CI)	*P* value	Equivalent years of age-related change in LTL[d]	Beta (95% CI)	*P* value	Equivalent years of age-related change in LTL
Fifth (highest)	.014 (.002 to .027)	0.021	0.61	.022 (.013 to .032)	6.86×10^{-06}	0.96
Quintiles of Meat intake pattern, vs first (lowest)						
		1.03×10^{-04}[e]			5.29×10^{-07}[e]	
Second	−.015 (−.028 to −.003)	0.014	−0.65	−.015 (−.025 to −.006)	0.002	-0.65
Third	−.012 (−.025 to .000)	0.047	−0.52	−.018 (−.027 to −.008)	2.89×10^{-04}	-0.78
Fourth	−.027 (−.039 to −.015)	1.87×10^{-05}	**−1.17**	−.026 (−.036 to −.017)	1.04×10^{-07}	**-1.13**
Fifth (highest)	−.025 (−.038 to −.013)	6.12×10^{-05}	**−1.09**	−.025 (−.035 to −.015)	5.14×10^{-07}	**-1.09**

[a]The base model includes the quintiles of adherence to the specific pattern, and is adjusted for age, sex, ethnic background, and white blood cell count.
[b]Findings are shown for the subset of participants with available data to extract the patterns and for the imputed data in the full cohort.
[c]All beta coefficients are for *z*-standardized LTL (z-LTL) with the comparator groups specified in the table.
[d]Equivalent years of age-related change in LTL is the ratio of the quintiles of adherence beta and the absolute value of age beta (|−0.023|). For example, in the fully adjusted model of the available data, z-LTL is shorter by 0.027 SD in participants classified at the fourth quintile of the meat intake pattern, compared with the first quintile. This means that LTL is shorter by approximately 1.17 years (−.027/0.023) for participants in the fourth quintile of the meat intake pattern compared with those in the first quintile.
[e]A Global *P* value has been estimated using a likelihood ratio test.
[f]Boldface type highlights results with effect ≥1 year (in absolute value) age-related change in LTL.
[g]The full model is additionally adjusted for smoking habits, physical activity, body mass index classification, highest educational qualification, experiencing insomnia, fed-up feelings, low-density lipoprotein cholesterol level, C-reactive protein level, estimated glomerular filtration rate, and self-reported diseases diagnosed by doctor (ie, diabetes, cancer, hypertension, and vascular diseases).

Table 9. Association of the dietary patterns with leucocyte telomere length (LTL), after excluding C-reactive protein from the fully adjusted model, in the UK Biobank using data collected during 2006-10

	Full model[a]					
	Available data[b] (n = 259,855)			Imputed data (n = 422,797)		
Dietary pattern	Beta[c] (95% CI)	*P* value	Equivalent years of age-related change in LTL[d]	Beta (95% CI)	*P* value	Equivalent years of age-related change in LTL
Quintile of Mediterranean pattern, vs first (lowest)		0.004[e]			0.006[e]	
Second	.002 (−.010 to .015)	0.74	0.09	.008 (−.003 to .018)	0.15	0.35
Third	.009 (−.003 to .021)	0.14	0.39	.009 (−.001 to .019)	0.09	0.39
Fourth	.013 (.001 to .025)	0.04	0.57	.009 (−.001 to .019)	0.07	0.39
Fifth (highest)	.022 (.009 to .034)	5.52×10^{-04}	0.96	.020 (.010 to .030)	$1.58\text{x}10^{-04}$	0.87
Quintile of Prudent pattern, vs first (lowest)		0.06[e]			$3.03\text{x}10^{-05}$[e]	
Second	.001 (−.011 to .013)	0.85	0.04	.003 (−.007 to .012)	0.60	0.13
Third	.002 (−.010 to .014)	0.77	0.09	.008 (−.002 to .017)	0.12	0.35
Fourth	.007 (−.005 to .019)	0.25	0.30	.013 (.003 to .022)	0.009	0.57
Fifth (highest)	.016 (.003 to .028)	0.012	0.70	.022 (.013 to .032)	6.86×10^{-06}	0.96
Quintile of Meat intake pattern, vs first (lowest)		4.01×10^{-05}[e]			5.29×10^{-07}[e]	
Second	−.015 (−.028 to −.003)	0.015	-0.65	−.015 (−.025 to −.006)	0.002	−0.65

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Table 9. Association of the dietary patterns with leucocyte telomere length (LTL), after excluding C-reactive protein from the fully adjusted model, in the UK Biobank using data collected during 2006-10 (*continued*)

	Full model[a]					
	Available data[b] (n = 259,855)			Imputed data (n = 422,797)		
Dietary pattern	Beta[c] (95% CI)	*P* value	Equivalent years of age-related change in LTL[d]	Beta (95% CI)	*P* value	Equivalent years of age-related change in LTL
Third	−.013 (−.025 to .000)	0.042	-0.57	−.018 (−.027 to −.008)	2.89×10^{-04}	−0.78
Fourth	−.028 (−.040 to −.015)	1.10×10^{-05}	**-1.22**[f]	−.026 (−.036 to −.017)	1.00×10^{-07}	**−1.13**
Fifth (highest)	−.027 (−.039 to −.014)	2.39×10^{-05}	**-1.17**	−.025 (−.035 to −.015)	5.10×10^{-07}	**−1.09**

[a]The full model includes the quintiles of adherence to the specific pattern, and is adjusted for age, sex, ethnic background, white blood cell count, smoking habits, physical activity, body mass index classification, highest educational qualification, experiencing insomnia, fed-up feelings, low-density lipoprotein cholesterol level, estimated glomerular filtration rate, and self-reported diseases diagnosed by doctor (ie, diabetes, cancer, hypertension, and vascular diseases).

[b]Findings are shown for the subset of participants with available data to extract the patterns and for the imputed data in the full cohort.

[c]All beta coefficients are for *z*-standardized LTL (z-LTL) with the comparator groups specified in the table.

[d]Equivalent years of age-related change in LTL is the ratio of the quintiles of adherence beta and the absolute value of age beta (|−0.023|). For example, in the fully adjusted model of the available data, z-LTL is shorter by 0.028 SD in participants classified at the fourth quintile of the Meat intake pattern, compared with the first quintile. This means that LTL is shorter by approximately 1.22 years (−0.028/0.023) for participants in the fourth quintile of the Meat intake pattern compared with those in the first quintile.

[e]A Global *P* value has been estimated using a likelihood ratio test.

[f]Boldface type highlights results with effect ≥1 year (in absolute value) age-related change in LTL.

Table 10. Association of the dietary patterns with leucocyte telomere length (LTL), in the UK Biobank using data collected during 2006-10, with the inclusion of continuous covariates for smoking, physical activity, and body mass index instead of categorical

	Full model[a]					
	Available data (n = 219,266)[b]			Imputed data (n = 422,797)		
Dietary pattern	Beta[c] (95% CI)	*P* value	Equivalent years of age-related change in LTL[d]	Beta (95% CI)	*P* value	Equivalent years of age-related change in LTL
Quintile of Mediterranean pattern, vs first (lowest)		0.006[e]			0.002[e]	
Second	3.34×10^{-05} (−.01 to .01)	0.99	0.00	.008 (−.002 to .019)	0.127	0.35
Third	.010 (−.003 to .02)	0.12	0.44	.010 (−.0002 to .020)	0.055	0.43
Fourth	.008 (−.006 to .02)	0.26	0.33	.010 (.0003 to .020)	0.044	0.43
Fifth (highest)	.022 (.009 to.04)	0.001	0.97	.021 (.011 to .031)	2.99×10^{-05}	0.91
Quintile of Prudent pattern, vs first (lowest)		0.09[e]			8.39×10^{-07}[e]	
Second	−.001 (−.01 to .01)	0.83	−0.06	.005 (−.004 to .014)	0.31	0.22
Third	.003 (−.010 to .02)	0.63	0.14	.008 (−.001 to .017)	0.101	0.35
Fourth	.007 (−.006 to.02)	0.28	0.32	.016 (.006 to .025)	0.001	0.70
Fifth (highest)	.016 (.002 to .03)	0.02	0.67	.026 (.016 to.036)	1.54×10^{-07}	**1.13**[f]
Quintile of Meat intake pattern, vs first (lowest)		1.00×10^{-4}[e]			6.89×10^{-8}[e]	
Second	−.001 (−.03 to −.002)	0.03	−0.66	−.015 (−.025 to −.006)	0.002	0.65

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Table 10. Association of the dietary patterns with leucocyte telomere length (LTL), in the UK Biobank using data collected during 2006-10, with the inclusion of continuous covariates for smoking, physical activity, and body mass index instead of categorical (*continued*)

	Full model[a]					
	Available data (n = 219,266)[b]			Imputed data (n = 422,797)		
Dietary pattern	Beta[c] (95% CI)	*P* value	Equivalent years of age-related change in LTL[d]	Beta (95% CI)	*P* value	Equivalent years of age-related change in LTL
Third	−.013	0.06	−0.56	−.018	1.88×10^{-4}	0.78
	(−.026 to .00)			(−.028 to −.009)		
Fourth	−.030	1.23×10^{-05}	**−1.30**	−.027	2.98×10^{-8}	**-1.17**
	(−.043 to −.02)			(−.037 to −.018)		
Fifth (highest)	−.025	2.30×10^{-04}	**−1.10**	−.027	8.39×10^{-8}	**-1.17**
	(−.039 to −.01)			(−.036 to −.017)		

[a]Compared to the fully adjusted model shown in Table 7 (available at www.jandonline.org), the full model shown here is adjusted for age, sex, ethnic background, white blood cell count, packs of years of smoking (UK Biobank field "20161"), metabolic equivalents of task minutes per week for all activity ("22040"), body mass index ("21001"), highest educational qualification, experiencing insomnia, fed-up feelings, low-density lipoprotein cholesterol level, C-reactive protein level, estimated glomerular filtration rate, and self-reported diseases diagnosed by a doctor (ie, diabetes, cancer, hypertension, and vascular diseases).

[b]Findings are shown for the subset of participants with available data to extract the patterns and for the imputed data in the full cohort.

[c]All beta coefficients are for *z*-standardized leucocyte telomere length (z-LTL) with the comparator groups specified in the table.

[d]Equivalent years of age-related change in LTL is the ratio of the quintiles of adherence beta and the absolute value of age beta (|−0.023|). For example, in the fully adjusted model of the available data, z-LTL is shorter by 0.030 SD in participants classified at the fourth quintile of the Meat intake pattern, compared with the first quintile. This means that LTL is shorter by approximately 1.30 years (−0.030/0.023) for participants in the fourth quintile of the Meat intake pattern compared with those in the first quintile.

[e]A Global *P* value has been estimated using a likelihood ratio test.

[f]Boldface type highlights results with effect ≥1 year (in absolute value) age-related change in LTL.

Table 11. UK Biobank participants' demographic, lifestyle, and clinical characteristics, collected during 2006-10, by adherence to a certain dietary practice

		Vegetarian			Eating five-a-day of fruit and vegetables			Abstaining from eggs/dairy/wheat/sugar		
Characteristic	**Total**	**Yes**	**No**	***P* value**[a]	**Yes**	**No**	***P* value**	**Yes**	**No**	***P* value**
	←——*n (%)*——→				←——*n (%)*——→			←——*n (%)*——→		
Participants	420,919	7,680 (1.8)	413,239 (98.2)		75,223 (17.9)	345,696 (82.1)		95,850 (22.8)	325,069 (77.2)	
	←——*mean (SD)*——→				←——*mean (SD)*——→			←——*mean (SD)*——→		
z-LTL[b]	−0.0003 (1.000)	0.129 (0.993)	−0.003 (1.000)	2.38×10^{-30}	0.025 (0.999)	−0.006 (1.000)	9.93×10^{-15}	−0.070 (1.002)	0.020 (0.999)	8.16×10^{-133}
Age (y)	56.6 (8.0)	53.3 (7.9)	56.6 (8.0)	1.13×10^{-286}	57.5 (7.7)	56.3 (8.1)	2.84×10^{-297}	58.6 (7.4)	56.0 (8.1)	$< 1.00\times10^{-300}$
	←——*n (%)*——→				←——*n (%)*——→			←——*n (%)*——→		
Male sex	194,186 (46.1)	2,616 (34.1)	191,570 (46.4)	9.2×10^{-102}	28,184 (37.5)	166,002 (48.0)	$<1.00\times10^{-300}$	44,621 (46.6)	149,565 (46.0)	0.003
Ethnic background[c]				$<1.00\times10^{-300}$			9.51×10^{-304}			2.15×10^{-14}
White	398,663 (94.7)	6,167 (80.3)	392,496 (95.0)		69,302 (92.1)	329,361 (95.3)		90,641 (94.6)	308,022 (94.8)	
Black	6,455 (1.5)	42 (0.6)	6,413 (1.6)		1,563 (2.1)	4,892 (1.4)		1,555 (1.6)	4,900 (1.5)	
Asian	8,113 (1.9)	1,312 (17.1)	6,801 (1.7)		2,291 (3.1)	5,822 (1.7)		2,042 (2.1)	6,071 (1.9)	
Mixed	2,497 (0.6)	63 (0.8)	2,434 (0.6)		491 (0.7)	2,006 (0.6)		495 (0.5)	2,002 (0.6)	
Chinese	1,356 (0.3)	15 (0.2)	1,341 (0.3)		355 (0.5)	1,001 (0.3)		228 (0.2)	1,128 (0.4)	
Other	3,835 (0.9)	81 (1.1)	3,754 (0.9)		1,221 (1.6)	2,614 (0.8)		889 (0.9)	2,946 (0.9)	
White blood cell (cells/mm^3)	6,868 (1,736)	6,753 (1,698)	6,870 (1,737)	3.17×10^{-09}	6,716 (1,688)	6,901 (1,744)	2.87×10^{-158}	6,932 (1,771)	6,849 (1,725)	9.66×10^{-34}
Smoking status				5.23×10^{-62}			1.68×10^{-320}			3.7×10^{-125}
Never	229,553 (54.5)	4,876 (63.8)	224,677 (54.6)		41,969 (56.0)	187,584 (54.5)		49,381 (51.8)	180,172 (55.6)	
Previous	145,860 (34.7)	2,247 (29.4)	143,613 (34.9)		27,965 (37.3)	117,895 (34.2)		36,232 (38.0)	109,628 (33.8)	
Current	44,040 (10.5)	521 (6.8)	43,519 (10.6)		4,997 (6.7)	39,043 (11.3)		9,742 (10.2)	34,298 (10.6)	
Missing	1,466 (0.4)									
Physical activity				5.84×10^{-04}			$<1.00\times10^{-300}$			3.01×10^{-49}
Low	64,521 (15.3)	1,121 (17.5)	63,400 (18.9)		8,005 (12.8)	56,516 (20.3)		14,098 (18.3)	50,423 (19.0)	
Moderate	139,303 (33.1)	2,574 (40.1)	136,729 (40.8)		22,667 (36.2)	116,636 (41.8)		29,994 (39.0)	109,309 (41.3)	
Vigorus	137,855 (32.8)	2,725 (42.5)	135,130 (40.3)		31,869 (51.0)	105,986 (38.0)		32,805 (42.7)	105,050 (39.7)	
Missing	79,240 (18.8)									
Body mass index classification				8.56×10^{-233}			1.76×10^{-10}			1×10^{-300}
Normal weight[d]	138,869 (33.0)	3,814 (50.2)	135,055 (32.8)		25,269 (33.7)	113,600 (33.0)		27,637 (29.0)	111,232 (34.3)	

(*continued on next page*)

Table 11. UK Biobank participants' demographic, lifestyle, and clinical characteristics, collected during 2006-10, by adherence to a certain dietary practice (*continued*)

		Vegetarian			Eating five-a-day of fruit and vegetables			Abstaining from eggs/dairy/wheat/sugar		
Characteristic	**Total**	**Yes**	**No**	***P* value**[a]	**Yes**	**No**	***P* value**	**Yes**	**No**	***P* value**
Overweight	178,679 (42.5)	2,665 (35.0)	176,014 (42.8)		31,087 (41.5)	147,592 (42.9)		40,476 (42.5)	138,203 (42.7)	
Obesity	101,781 (24.2)	1,126 (14.8)	100,655 (24.5)		18,529 (24.7)	83,252 (24.2)		27,242 (28.6)	74,539 (23.0)	
Missing	1,590 (0.4)									
Highest education[e]				6.33×10^{-244}			1.95×10^{-52}			$< 1.00\times10^{-300}$
None	70,315 (16.7)	671 (8.9)	69,644 (17.0)		12,612 (17.0)	57,703 (16.9)		22,558 (23.9)	47,757 (14.8)	
Statutory/ compulsory education	70,027 (16.6)	977 (12.9)	69,050 (16.9)		11,629 (15.7)	58,398 (17.1)		15,861 (16.8)	54,166 (16.8)	
Advanced education	137,931 (32.8)	2,102 (27.7)	135,829 (33.2)		23,737 (31.9)	114,194 (33.4)		30,482 (32.3)	107,449 (33.3)	
University/ college degree	138,425 (32.9)	3,828 (50.5)	134,597 (32.9)		26,335 (35.4)	112,090 (32.7)		25,504 (27.0)	112,921 (35.0)	
Missing	4,221 (1.0)									
Insomnia				1.51×10^{-08}			2.24×10^{-08}			8.87×10^{-55}
Never/rarely	101,980 (24.2)	2,082 (27.1)	99,898 (24.2)		18,177 (24.2)	83,803 (24.3)		22,340 (23.3)	79,640 (24.5)	
Sometimes	200,524 (47.6)	3,540 (46.2)	196,984 (47.7)		35,246 (46.9)	165,278 (47.9)		44,621 (46.6)	155,903 (48.0)	
Usually	118,091 (28.1)	2,049 (26.7)	116,042 (28.1)		21,739 (28.9)	96,352 (27.9)		28,796 (30.1)	89,295 (27.5)	
Missing	324 (0.1)									
Fed-up feelings				0.266			4.08×10^{-103}			0.679
No	245,028 (58.2)	4,386 (58.9)	240,642 (59.5)		46,399 (63.1)	198,629 (58.8)		55,768 (59.6)	189,260 (59.5)	
Yes	166,622 (39.6)	3,061 (41.1)	163,561 (40.5)		27,181 (36.9)	139,441 (41.3)		37,831 (40.4)	128,791 (40.5)	
Missing	9,269 (2.2)									
LDL[f] **cholesterol (mg/dL)**	137.3 (33.2)	129.8 (30.7)	137.5 (33.2)	1.46×10^{-86}	135.7 (33.2)	137.7 (33.2)	8.32×10^{-49}	133.4 (34.5)	138.5 (32.7)	$< 1.00\times10^{-300}$
Missing	18,164 (4.3)									
CRP[g] **(μg/mL)**	2.518 (3.690)	2.128 (3.347)	2.525 (3.696)	2.84×10^{-72}	2.330 (3.486)	2.559 (3.732)	1.57×10^{-126}	2.466 (3.630)	2.694 (3.883)	1.09×10^{-100}
Missing	18,276 (4.3)									
eGFR[h] **(mg/dL)**	0.87 (0.85)	1.00 (0.75)	0.87 (0.85)	8.01×10^{-37}	1.00 (0.82)	0.85 (0.85)	$<1.00\times10^{-300}$	0.86 (0.85)	0.88 (0.85)	2.25×10^{-06}
Missing	17,626 (4.2)									
Diabetes[i]				0.043			7.67×10^{-45}			$< 1.00\times10^{-300}$
No	397,855 (94.5)	7,292 (95.3)	390,563 (94.8)		70,320 (93.8)	327,535 (95.0)		83,751 (87.7)	314,104 (96.9)	
Yes	21,890 (5.2)	360 (4.7)	21,530 (5.2)		4,687 (6.3)	17,203 (5.0)		11,737 (12.3)	10,153 (3.1)	

(*continued on next page*)

Table 11. UK Biobank participants' demographic, lifestyle, and clinical characteristics, collected during 2006-10, by adherence to a certain dietary practice (*continued*)

		Vegetarian			Eating five-a-day of fruit and vegetables			Abstaining from eggs/dairy/wheat/sugar		
Characteristic	**Total**	**Yes**	**No**	***P* value**[a]	**Yes**	**No**	***P* value**	**Yes**	**No**	***P* value**
Missing	1,174 (0.3)									
Cancer[i]				1.55×10^{-08}			9.36×10^{-18}			2.02×10^{-35}
No	387,662 (92.1)	7,194 (94.1)	380,468 (92.4)		68,712 (91.6)	318,950 (92.6)		87,286 (91.5)	300,376 (92.7)	
Yes	31,937 (7.6)	452 (5.9)	31,485 (7.6)		6,272 (8.4)	25,665 (7.5)		8,159 (8.6)	23,778 (7.3)	
Missing	1,320 (0.3)									
Hypertension[i]				8.3×10^{-68}			1.31×10^{-15}			$< 1.00\times10^{-300}$
No	306,106 (72.7)	6,252 (81.6)	299,854 (72.7)		53,814 (71.7)	252,292 (73.1)		63,325 (66.3)	242,781 (74.8)	
Yes	113,963 (27.1)	1,407 (18.4)	112,556 (27.3)		21,246 (28.3)	92,717 (26.9)		32,246 (33.7)	81,717 (25.2)	
Missing	850 (0.2)									
Vascular disease[i]				2.69×10^{-27}			0.074			$< 1.00\times10^{-300}$
No	395,838 (94.0)	7,436 (97.1)	388,402 (94.2)		70,627 (94.1)	325,211 (94.3)		87,427 (91.5)	308,411 (95.0)	
Yes	24,231 (5.8)	223 (2.9)	24,008 (5.8)		4,433 (5.9)	19,798 (5.7)		8,144 (8.5)	16,087 (5.0)	
Missing	850 (0.2)									

[a]*P* values are estimated using the Jonckheere-Terpstra test for trend for both continuous and categorical variables.
[b]zLTL = *z*-standardized leucocyte $\log_e$ telomere length.
[c]Ethnic background is presented as reported through UK Biobank data collection. White ethnic background also includes British, Irish, and any other White background. Asian ethnic background also includes Asian or Asian British, Indian, Pakistani, Bangladeshi, and any other Asian background. Black ethnic background also includes Black or Black British, Caribbean, African, and any other Black background. Mixed ethnic background also includes White and Black African, White and Black Caribbean, White and Asian, and any other Mixed background.
[d]Normal weight category also includes 2,155 participants with body mass index <18.5.
[e]Statutory/compulsory education is equivalent to "O-levels/CSE/GCSE" of the UK educational system, Advanced education is equivalent to the "A-levels/Non-vocational qualifications/Other professional educational qualifications" of the UK educational system.
[f]LDL = low-density lipoprotein. To convert mg/dL cholesterol to mmol/L, multiply by 0.026.
[g]CRP = C-reactive protein.
[h]eGFR = estimated glomerular filtration rate. To convert mg/dL to μmol/L, multiply by 88.496.
[i]Diseases are self-reported as diagnosed by a doctor.

Table 12. Association of the dietary practices with leucocyte telomere length (LTL), in the UK Biobank using data collected during 2006-10

	Available data (n = 420,919)[a]					
	Base model[b]			Full model[c]		
Dietary practice	Beta[d] (95% CI)	*P* value	Equivalent years of age-related change in LTL[e]	Beta (95% CI)	*P* value	Equivalent years of age-related change in LTL
Follow vegetarian diet vs no	.029	0.011	**1.26**[f]	.006	0.66	0.26
	(.007—.051)			(—.020 to .031)		
Eating five servings of fruit and vegetables each day vs no	.031	5.61×10^{-15}	**1.35**	.027	5.36×10^{-09}	**1.17**
	(.023—.039)			(.018 to .036)		
Abstaining from eggs/dairy/wheat/sugar vs no	—.026	2.57×10^{-13}	**—1.13**	—.016	2.51×10^{-04}	—0.70
	(—.033 to —0.019)			(—.024 to —.007)		
	Imputed data (n = 422,797)					
Follow vegetarian diet vs no	.025	0.027	**1.09**	.009	0.42	0.39
	(.003 to .047)			(—.013 to .031)		
Eating five-a-day of fruit and vegetable vs no	.031	7.83×10^{-15}	**1.35**	.027	9.96×10^{-12}	**1.17**
	(.023 to .038)			(.019 to .035)		
Abstaining from eggs/dairy/wheat/sugar vs no	—.026	2.26×10^{-13}	**—1.13**	—.013	3.18×10^{-04}	—0.57
	(—.034 to —.019)			(—.020 to —.006)		

[a]Findings are shown for the subset of participants with available data on dietary practices and for the imputed data in the full cohort.
[b]The base model includes the adherence to the specific dietary practice and is adjusted for age, sex, ethnic background, and white blood cell count.
[c]The full model is additionally adjusted for smoking habits, physical activity, body mass index classification, highest educational qualification, experiencing insomnia, fed-up feelings, low-density lipoprotein level, C-reactive protein level, estimated glomerular filtration rate, and self-reported diseases diagnosed by a doctor (ie, diabetes, cancer, hypertension, and vascular diseases).
[d]All beta coefficients are for *z*-standardized leucocyte telomere length (z-LTL) with the comparator groups specified in the table.
[e]Equivalent years of age-related change in LTL is the ratio of the adherence beta and the absolute value of age beta (|—0.023|). For example, in the fully adjusted model of the available data, z-LTL is longer by 0.027 SD in participants who adhere to the "eating five-a-day servings of fruit and vegetables" guideline, compared with nonadherents. This means that LTL is longer by approximately 1.17 years (0.027/0.023) for adherents to the guideline of "eating five-a-day" compared to non-adherents.
[f]Boldface type highlights results with effect ≥1 year (in absolute value) age-related change in LTL.

Table 13. Association of the dietary practices with leucocyte telomere length (LTL), after excluding C-reactive protein from the fully adjusted model, in the UK Biobank using data collected during 2006-10

	Full model[a]					
	Available data[b] (n = 420,919)			Imputed data (n = 422,797)		
Dietary practice	Beta[c] (95% CI)	*P* value	Equivalent years of age-related change in LTL[d]	Beta (95% CI)	*P* value	Equivalent years of age-related change in LTL
Follow vegetarian diet vs no	.005	0.72	0.22	.009	0.40	0.39
	(−.021 to .030)			(−.013 to .032)		
Eating five servings of fruit and vegetables each day vs no	.028	1.14×10^{-09}	**1.22**[e]	.028	1.13×10^{-12}	**1.22**
	(.019 to .037)			(.020 to .036)		
Abstaining from eggs/dairy/wheat/sugar vs no	−.015	3.32×10^{-04}	−0.65	−.013	3.72×10^{-04}	−0.57
	(−.024 to −.007)			(−.020 to −.006)		

[a]The full model includes the adherence to the specific dietary practice, and is adjusted for age, sex, ethnic background, white blood cell, smoking habits, physical activity, body mass index classification, highest educational qualification, experiencing insomnia, fed-up feelings, low-density lipoprotein, estimated glomerular filtration rate, and self-reported diseases diagnosed by doctor (ie, diabetes, cancer, hypertension, and vascular diseases).

[b]Findings are shown for the subset of participants with available data to extract the practices and for the imputed data in the full cohort.

[c]All beta coefficients are for *z*-standardized LTL (z-LTL) with the comparator groups specified in the table.

[d]Equivalent years of age-related change in LTL is the ratio of the adherence beta and the absolute value of age beta (|−0.023|). For example, in the fully adjusted model of the available data, z-LTL is longer by 0.028S D in adherents to the "eat five-a-day servings of fruit and vegetables" guideline, compared with nonadherents. This means that LTL is longer by approximately 1.22 years (0.028/0.023) in adherents to the guideline of "eating five-a-day", compared with nonadherents.

[e]Boldface type highlights results with effect ≥1 year (in absolute value) age-related change in LTL.

Table 14. Association of the dietary practices with leucocyte telomere length (LTL), in the UK Biobank using data collected during 2006-10, with the inclusion of continuous covariates for smoking, physical activity, and body mass index instead of categorical

	Full model[a]					
	Available data[b] (n = 385,074)			Imputed data (n = 422,797)		
Dietary practice	Beta[c] (95% CI)	*P* value	Equivalent years of age-related change in LTL[d]	Beta (95% CI)	*P* value	Equivalent years of age-related change in LTL
Follow vegetarian diet vs no	.005	0.71	0.22	.010	0.37	0.44
	(−.02 to .03)			(−.012 to .032)		
Eating five-a-day of fruit and vegetables vs no	.028	2.89×10^{-08}	**1.22**[e]	.029	2.58×10^{-13}	**1.26**
	(.018 to .037)			(.021 to .037)		
Abstaining from eggs/dairy/wheat/sugar vs no	−.015	0.002	−0.65	−.013	3.85×10^{-04}	−0.57
	(−.024 to −.006)			(−.020 to −.006)		

[a]Compared with the fully adjusted model shown in Table 11 (available at www.jandonline.org), the full model shown here is adjusted for age, sex, ethnic background, white blood cell, packs of years of smoking (UK Biobank field "20161"), metabolic equivalents of task minutes per week for all activity ("22040"), body mass index ("21001"), highest educational qualification, experiencing insomnia, fed-up feelings, low-density lipoprotein, C-reactive protein, estimated glomerular filtration rate, and self-reported diseases diagnosed by doctor (ie, diabetes, cancer, hypertension, and vascular diseases).

[b]Findings are shown for the subset of participants with available data to extract the patterns and for the imputed data in the full cohort.

[c]All beta coefficients are for *z*-standardized LTL (z-LTL) with the comparator groups specified in the table.

[d]Equivalent years of age-related change in LTL is the ratio of the quintiles of adherence beta and the absolute value of age beta (|−0.023|). For example, in the fully adjusted model of the available data, z-LTL is longer by 0.028 SD in participants adhering to the "eat five-a-day servings of fruit and vegetables" guideline, compared to non-adherents. This means that LTL is longer by approximately 1.22 years (0.028/0.023) for adherents to the guideline of "eating five-a-day", compared to non-adherents.

[e]Boldface type highlights results with effect ≥1 year (in absolute value) age-related change in LTL.