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Associations of leukocyte telomere length with body anthropometric indices and weight change in Chinese women

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Abstract

Objective—Telomeres are specialized chromatin structures essential for maintenance of chromosomal integrity and stability. Obesity has been proposed to be associated with telomere shortening; however, epidemiologic evidence has been conflicting. We conducted a study to evaluate the associations of telomere length with various anthropometric indices of general and abdominal obesity, as well as weight change.

Design and Methods—The study included 2,912 Chinese women ages 40–70 years. Monochrome multiplex quantitative PCR was applied to measure relative telomere length. ANOVA and the Dunnett test were used to compare log-transformed relative telomere length. Tests for linear trend were performed by entering the ordinal exposure as continuous parameters in the models.

Results—There is an inverse association between telomere length and body mass index (BMI) ($P_{\text{trend}} = 0.005$), waist circumference ($P_{\text{trend}} = 0.004$), waist-to-height ratio (WHtR) ($P_{\text{trend}} = 0.004$), weight ($P_{\text{trend}} = 0.010$), and hip circumference ($P_{\text{trend}} = 0.026$), but not waist-to-hip ratio (WHR) ($P_{\text{trend}} = 0.116$) or height ($P_{\text{trend}} = 0.675$). Weight change since age 50 was further evaluated among women over age 55. Women who maintained their weight within $\pm 5\%$ since age 50, particularly within a normal range (BMI = 18.5–24.9 kg/m²), or reduced their weight from overweight (BMI = 25–29.9 kg/m²) or obesity (BMI ≥ 30 kg/m²) to normal range, had a longer mean of current telomere length than women who gained weight since age 50 ($P_{\text{trend}} = 0.025$), particularly those who stayed in obesity or gained weight from normal range or overweight to obesity ($P = 0.023$).

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Conclusion—Our findings provide strong evidence supporting the hypothesis that telomere shortening is associated with obesity and that maintaining body weight within a normal range helps maintain telomere length.

Introduction

Telomeres are the specific DNA-protein complex located at the ends of chromosomes, consisting of highly conserved tandem hexameric nucleotide repeats (TTAGGG)_n. Telomeres are essential for the complete replication of DNA, protecting chromosomes from nuclease degradation, end-to-end fusion, and cellular senescence, thus playing a key role in promoting chromosome integrity and stability (1,2). In the normal cellular process, telomeres undergo progressive shortening with each mitotic cell division due partly to incomplete replication of the lagging strand during DNA synthesis. When telomeres shorten to a critical length, the signal for replicative senescence is triggered, leading to cell-cycle arrest or apoptosis (3). In human peripheral leukocytes, a slow and gradual loss of telomere length with increasing age has been demonstrated (4,5). Furthermore, shortening of leukocyte telomere length has been associated with systemic inflammation, oxidative stress, certain unhealthy habits (e.g., cigarette smoking), and many aging-related diseases (6). Leukocyte telomere length, therefore, has been proposed as a key marker of cellular and biologic aging, rather than chronological age, reflecting the cumulative burden of oxidative stress and inflammation, as well as a potential biomarker of age-related diseases (7,8).

Obesity is a major risk factor for many aging-related chronic diseases — including cardiovascular diseases, diabetes, and certain cancers — and is the leading cause of preventable death globally (9). Cumulative evidence has shown that pathways through which obesity promotes such diseases include increasing systemic inflammation and oxidative stress; thus, it has been proposed that obesity may adversely influence telomere length and function (10). A number of epidemiologic studies examining the association between leukocyte telomere length and obesity have yielded equivocal results; some studies have observed an inverse association of telomere length with obesity (11–16), whereas others have not (16–21). To date, the relationship between telomere length and obesity has not been clearly established (10).

To better understand the relationship between telomere length and obesity, we examined the associations of leukocyte telomere length with commonly used body anthropometric measures and indices and further evaluated telomere length in relation to weight change since age 50 in a sub-cohort of women from the Shanghai Women's Health Study (SWHS) (22). We hypothesize that telomere length is inversely associated with obesity, and maintaining body weight within a normal range helps maintain telomere length.

Methods and Procedures

Study population

The SWHS is an ongoing prospective cohort study among Chinese women to investigate environmental and genetic risk factors for cancer and other chronic diseases. A detailed description of the rationale and methods for the SWHS has been reported elsewhere (22).

Briefly, from December 1996 through May 2000, 74,942 Chinese women ages 40–70 years who were permanent residents in the study communities were enrolled in the cohort study with a participation rate of 92.7%. More than 98% of Chinese women living in Shanghai belong to a single ethnic group (Han Chinese). The baseline survey included an in-person interview and self-administered questionnaires which collected information regarding socio-demographic characteristics, lifestyle-related factors, and medical history. Anthropometric measurements were taken by trained interviewers using standardized protocols at enrollment. Of the study participants, 56,831 (75.8%) provided a blood sample. The cohort was followed through biennial home visits and annual record linkage to cancer incidence and mortality data from the Shanghai Cancer Registry and death certificate data from the Shanghai Vital Statistics Unit. For cohort members who were diagnosed with cancer, medical charts were reviewed to verify the diagnosis, and detailed information regarding pathologic characteristics of the cancer was obtained. All participants provided written informed consent at enrollment, and study protocols were approved by the relevant Institutional Review Boards for human research.

This nested case-control study investigating the association of telomere length with cancer risk included 2,912 SWHS participants. Blood samples were collected from these women prior to any cancer diagnosis.

Measurements of anthropometrics and weight change

Anthropometric measurement data were obtained at enrollment by trained interviewers (23). Briefly, participants were asked to wear light indoor clothing when they were measured for body weight, height, and circumferences of the waist and hips. Measurements were conducted uniformly according to a standard protocol. Waist circumference was measured at 2.5 cm above the umbilicus. Hip circumference was measured at the maximum width of the buttocks while the subject was standing. Circumferences and heights were measured to the nearest 0.1 cm. Weight was measured to the nearest 0.1 kg using a digital scale which was calibrated every 6 months. All measurements were taken twice. A tolerance limit of 1 kg was set for weight measurement and 1 cm for height and circumference measurements. A third measurement was taken if the difference of the first two measurements was greater than the tolerance limit. Using the average of the two closest measurements, body mass index (BMI), waist-to-hip ratio (WHR), and waist-to-height ratio (WHtR) were then calculated for the analysis.

BMI was calculated as body weight in kilograms divided by height in meters squared (kg/m^2). WHR was calculated as waist circumference (cm) divided by hip circumference (cm). WHtR was calculated as waist circumference (cm) divided by height (cm). BMI was categorized based on the World Health Organization's (WHO) definitions as underweight ($<18.5 \text{ kg}/\text{m}^2$), normal weight ($18.5\text{--}24.9 \text{ kg}/\text{m}^2$), overweight ($25\text{--}29.9 \text{ kg}/\text{m}^2$), and obesity ($\geq 30 \text{ kg}/\text{m}^2$) (24). Waist circumference was categorized based on the American Diabetes Association criteria for abdominal obesity as normal ($<80 \text{ cm}$), action level 1 ($80\text{--}87.9 \text{ cm}$), or action level 2 ($\geq 88 \text{ cm}$) (25). Additional anthropometric variables (WHR, WHtR, weight, height, and hip circumference) without standard classification criteria were categorized into quartiles.

During the baseline survey at enrollment, participants older than 50 years ($n = 1,850$) also were asked about their weight at age 50, and 1,670 (90.3%) reported their weight at age 50. Of them, 1,295 were older than 55 years. The self-reported weight at age 50 was used as baseline for assessing weight change since age 50 among women over 55 years. Percentage of weight change was calculated as $100 \times (\text{weight at enrollment} - \text{weight at age 50}) / \text{weight at age 50}$.

Measurement of telomere length

Genomic DNA was extracted from buffy coats using QIAamp DNA kit (Qiagen) following manufacturer protocol. Relative telomere length was measured using a monochrome multiplex quantitative PCR method described recently by Cawthon (26) with minor modifications (27). Briefly, telomere length assay was carried out in a 15 μl PCR reaction consisting of 1 \times QuantiFast SYBR Green PCR Master Mix (Qiagen), 700 nM telomere primers telg and telc, 200 nM albumin primers albugcr1 and albdgcr1, and 5 ng DNA. A multistep thermal cycling procedure was performed on a Bio-Rad CFX384 Real-Time System. Following amplification, a dissociation curve was performed to confirm the specificity of the reaction. In our assays, for each standard curve, two-fold serial dilutions of a reference DNA sample were used to produce a 6-point standard curve between 20 ng and 0.625 ng DNA in each reaction. Standard curve with linearity (R^2) > 0.98 and amplification efficiency between 90–105% were accepted. Additionally, a calibrator DNA (same as the reference DNA), two negative controls, and two commercially available DNA samples, one with a relatively long (10.5kb), and one with a relatively short telomere length (3.9kb) (Roche, Telo TAGGG Telomere Length Assay kit), were included in each of the 384-well assay plates. Bio-Rad CFX manager software (version 1.6) was used to determine relative telomere length through a two-step relative quantification. In the first step, the ratio of telomere repeat copy number to single-copy gene copy number (T/S), as a measure of relative telomere length, was determined for each sample based on the standard curve. In the second step, the T/S ratio for each sample was normalized to the calibrator DNA to standardize sample values across all reaction plates.

The coefficient of variations (CVs) of the inter-plate T/S were 15.6%, and 16.2% for the long and short telomere QC samples, respectively. Inter- and intra-plate CVs of calibrator DNA samples were 12.2%, and 5.3%, respectively. Mean ratio of long to short telomere QC samples in our assays was 2.9 with 7.5% CV, which is very close to the ratio of 2.7 (10.5/3.9) of Southern Blot provided by Roche (Roche, Telo TAGGG Telomere Length Assay kit). All samples in our study were assayed in triplicate, and the results were consistent. Less than 12% of samples had a T/S CV more than 10%.

Statistical Analyses

Relative telomere length was log-transformed to achieve better normal distribution conformation. The general linear model was used to estimate mean relative telomere length and 95% confidence interval (CI) according to anthropometric characteristics, controlling for age at blood collection, educational level, cigarette smoking status, regular alcohol consumption, case/control status, and comorbidities (e.g., diabetes, hypertension, ischemic heart disease, cardiomyopathy, chronic rheumatic heart disease, heart failure, lipid

metabolism disorders, atherosclerosis, chronic obstructive pulmonary disease and allied conditions, disorders of thyroid gland, chronic renal disease, cerebrovascular disease, chronic liver disease and cirrhosis, inflammatory disease of female pelvic organs, immune-related disorders, vitamin deficiency). ANOVA was applied to compare log-transformed relative telomere length among different categories/groups of each anthropometric characteristic for difference. The Dunnett test was used to compare each of categories/groups with the reference group. Tests for linear trend were performed by entering the ordinal exposure as continuous parameters in the models. Statistical analyses were performed using Statistical Analysis Software (version 9.2; SAS Institute, Cary, NC). The significance level for all analyses was set at $\alpha = 0.05$. All statistical tests were two-sided.

Results

Table 1 summarizes the socio-demographic characteristics of the 2,192 women in this study by telomere length. Mean age of participants at blood collection was 55 years with a range of 40–70 years. More than one-fourth of participants had higher than a high-school education; 70% had a middle or higher annual household income; the vast majority (85.9%) were married or living with a partner; and more than 50% were manual workers. As expected, a significant inverse association between age at blood collection and telomere length was observed ($P_{\text{trend}} < 0.001$). Educational level was positively associated with telomere length ($P = 0.042$).

The associations of telomere length with seven common anthropometric variables, including weight, waist circumference, hip circumference, height, BMI, WHR, and WHtR are presented in Table 2 with adjustment for age (at blood collection), educational level, and comorbidities. Inverse associations were observed between telomere length and weight ($P_{\text{trend}} = 0.010$), waist circumference ($P_{\text{trend}} = 0.004$), hip circumference ($P_{\text{trend}} = 0.026$), BMI ($P_{\text{trend}} = 0.005$), or WHtR ($P_{\text{trend}} = 0.004$). No significant linear associations were detected between telomere length and WHR ($P_{\text{trend}} = 0.116$) or height ($P_{\text{trend}} = 0.675$).

We further examined the association between telomere length and weight change since age 50 in a subgroup of study participants older than 55 years who had provided information about their weight at age 50. Weight-change status was grouped into four categories: 1) weight loss $\geq 5\%$ since age 50; 2) stable weight (weight gain or loss within 5% since age 50); 3) weight gain 5–15% since age 50; and 4) weight gain $>15\%$ since age 50. As shown in Table 3, after adjusting for age, education and additionally for cigarette smoking status, alcohol consumption, case/control status, and co-morbidities, weight change was significantly associated with telomere length in general ($P_{\text{trend}} = 0.029$ and 0.025 , respectively). The most marked reduction in telomere length was found among women who gained weight more than 15% since age 50.

We also examined telomere length in relation to weight change based on BMI at age 50 (past BMI) and BMI at enrollment (current BMI). We categorized weight-change status into five groups: 1) Group 1: maintaining a normal BMI between the two time points; 2) Group 2: moving from overweight/obese to normal BMI category, or from obese to overweight category; 3) Group 3: moving from normal to overweight category; 4) Group 4: having

overweight BMI at both time points; and 5) Group 5: having obesity at both time points or moving from normal or overweight to obesity category. As shown in Table 3, women with a normal BMI at both time points (Group 1), and women who reduced their weight from overweight/obesity to normal BMI or from obesity to overweight BMI (Group 2) had a similar telomere length, and they had a longer telomere than those who had obesity at both time points or those who gained weight from normal or overweight BMI to obesity (Groups 5) ($P_{\text{trend}} = 0.023$).

Discussion

In this study, we examined the relationships of leukocyte telomere length with seven commonly used anthropometric measures and indices among Chinese women. We found that telomere length was inversely associated with weight, waist and hip circumferences, BMI and WHtR, but not with WHR or height. Furthermore, we found that women who maintained their weight within $\pm 5\%$ since age 50, and those who had a normal range of BMI ($18.5\text{--}24.9 \text{ kg/m}^2$) (Group 1) or reduced their weight from overweight (BMI = $25\text{--}29.9 \text{ kg/m}^2$) or obesity (BMI $\geq 30 \text{ kg/m}^2$) to normal BMI (Group 2), had a longer telomere than those who gained weight more than 15% since age 50, particularly those who stayed obese or gained weight from normal weight or overweight to obesity (Group 5). To our knowledge, our study is the first to evaluate the relationship of telomere length to body anthropometric indices, obesity, and weight change among Chinese women.

Since Valdes et al. reported that the mean leukocyte telomere length in obese women was shorter than in lean women (14), multiple epidemiologic studies have investigated the association of telomere length with adiposity; however, results have been mixed (6). For instance, Lee et al. reported both total body fat and visceral fat to be inversely associated with leukocyte telomere length among 309 non-Hispanic whites ages 8–80 years (11); whereas Diaz et al. reported no association between leukocyte telomere length and visceral fat among 317 men and women ages 40–64 years and free of diabetes, cardiovascular disease, or cancer (21). Some studies have observed an inverse association of telomere length with body size or obesity status as measured by BMI (11–16), whereas others have failed to find such an association (17–21). The inconsistencies have been attributed to differences in methods of measuring telomere length and sample characteristics in the studies (6,10). In addition, the question whether BMI is a good measure of adiposity in certain subpopulations, such as in elderly, has been raised (15). In our study population, an inverse association between telomere length and BMI was clearly seen, especially among women with BMI $\geq 18.5 \text{ kg/m}^2$, showing that obese women had about 5% shorter telomere length, compared to women at a normal weight.

A few studies have examined the relationships between telomere length and central or abdominal obesity assessed by waist circumference or WHR. Multiple studies reported an inverse association between telomere length and waist circumference and a null association of telomere length with WHR (11,12,16). These findings are in line with our results. Recently, WHtR also has been suggested as an index to reflect central obesity and show better cardiovascular disease prediction than other anthropometric indices (28,29). Therefore, we examined the relationship between telomere length and WHtR. Our study

found WHtR to be inversely associated with telomere length, particularly when WHtR ≥ 0.5 . Our study, combined with previous studies (11,12,16), provides strong evidence indicating that telomere length is inversely associated with central or abdominal obesity, and that waist circumference and WHtR are better measures than WHR to assess such association. In addition, it has been suggested that WHtR be kept within <0.5 to reduce risk for cardiovascular diseases. Our finding supports this notion.

Only two population-based studies have investigated the relationship between telomere length and weight change; however, results are inconsistent (15,16). Njajou et al. examined whether telomere length predicts changes in adiposity traits between baseline and 7-year follow-up in a cohort of 1,958 elderly black and white subjects ages 70–79 years (57.4% women). They reported telomere length to be significantly associated with percentage of change in BMI and with percentage of total body fat, and found mean telomere length to be significantly longer in individuals who gained weight (> 3 Kg), compared with individuals who lost weight (> 3 Kg) during the follow-up period (15). However, among 647 women ages 35 to 74 years selected from the NIEHS Sister Study (16), Kim et al. reported that among women ages 40 years and older, weight gain since their 30s was associated with shorter telomere length. They also reported that women categorized as overweight or obese both currently and when they were in their 30s, or those who were overweight or obese in their 30s but currently are at normal weight, showed a shorter telomere length than women at normal weight both currently and in their 30s. Notably, there are significant differences in age range and gender between these two study populations. In our study of 1,295 women ages 55 to 70 years, weight gain since age 50 was found to be significantly inversely associated with telomere length. Women who gained more than 15% weight had approximately 4% shorter telomere length than those who maintained their weight within $\pm 5\%$ of their weight at age 50. Our data also showed that women who kept their weight within normal range, or reduced their weight from overweight to normal weight, or from obesity to overweight since age 50, had a significantly longer telomere length than those who stayed at obesity, or gained weight from normal range, or from overweight to obesity. Our study provides strong evidence that gaining weight to levels of overweight or obesity is associated with telomere shortening, whereas maintaining body weight within normal range or reducing weight to normal range helps maintain telomere length in adult women.

In conclusion, our study showed telomere length to be inversely associated with both general and abdominal fat assessed by BMI, waist circumference, and WHtR, but not WHR; and showed women who maintained weight in the normal range or reduced their weight to normal range since age 50 had a longer telomere length than those who stayed in obesity or became obese since age 50. These findings confirm the inverse association of telomere length with obesity and support the hypothesis that maintaining body weight within a normal range will help maintain telomere length.

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Table 1

Telomere length by selected socio-demographic characteristics of study participants, the Shanghai Women's Health Study

Socio-demographic Characterist	Telomere Length, N = 2,912				P_ANOVA
	N (%)	α Mean (95% CIs)	b Mean (95% CIs)	P_ANOVA	
Age					
40–45	558(19.2)	0.996(0.980, 1.011)	1.001 (0.984, 1.018)		
46–50	504(17.3)	0.965(0.949,0.981)	0.970 (0.953, 0.986)		
51–55	412(14.1)	0.940 (0.923, 0.957)	0.944 (0.926, 0.962)		
56–60	338(11.6)	0.905 (0.887, 0.925)	0.907 (0.888, 0.926)	<0.001	<0.001
61–65	523(18.0)	0.910(0.896,0.925)	0.906(0.891,0.922)		
66–70	577(19.8)	0.886 (0.873, 0.900)	0.878 (0.863, 0.894)		
		$P_{trend} <0.001$	$P_{trend} <0.001$		
^cEducation					
HS	2,120(72.8)	0.928 (0.920, 0.936)	0.929 (0.920, 0.937)		
>HS	790 (27.2)	0.952 (0.937, 0.966)	0.950 (0.933, 0.966)	0.009	0.042
Income					
Low	872 (30.0)	0.945 (0.933, 0.957)	0.942 (0.930, 0.954)		
Middle	1,169(40.1)	0.933 (0.923, 0.943)	0.933 (0.923, 0.943)	0.080	0.330
High	871 (29.9)	0.925(0.913,0.937)	0.928(0.916,0.941)		
		$P_{trend} <0.027$	$P_{trend} =0.146$		
Marital status					
Married	2,502(85.9)	0.932 (0.925, 0.939)	0.932 (0.925, 0.939)		
Unmarried	410(14.1)	0.948(0.931,0.966)	0.946 (0.928, 0.964)	0.94	0.177
^dOccupation					
Professional	827 (28.5)	0.929(0.917,0.941)	0.936 (0.926, 0.949)		
Clerical	554(19.1)	0.927 (0.912, 0.942)	0.925(0.911,0.940)	0.161	0.369
Manual workers	1,521 (52.4)	0.940 (0.932, 0.949)	0.937 (0.928, 0.947)		

^a Education, household income, marital status and occupation were adjusted for age.

^b Manually adjusted for variables included in the table and also adjusted for cigarette smoking status and regular alcohol consumption.

Two subjects had data missing on education.
Ten subjects had data missing on occupation.

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Table 2 Associations of telomere length with anthropometric measurements, the Shanghai Women’s Health Study

Anthropometric variables	N	Relative Telomere Length				P
		^a Mean (95% CIs)	^b Mean (95% CIs)	^c Ratio (95% CIs)		
Weight (Kg)						
Q1 (< 54)	754	0.945(0.933,0.958)	0.946 (0.933, 0.959)	Ref. (1.00)		
Q2 (54 – 59.9)	668	0.937(0.923,0.950)	0.938 (0.925, 0.952)	0.992(0.972,1.012)		0.747
Q3 (60–65.9)	726	0.929(0.917,0.943)	0.929 (0.917, 0.942)	0.982(0.963,1.001)		0.170
Q4 (> 66.0)	772	0.924 (0.913, 0.938)	0.924(0.911,0.936)	0.976 (0.957, 0.995)		0.043
P for trend		0.019	0.010			
Height (m)						
Q1(<1.54)	737	0.928(0.915,0.941)	0.927(0.914,0.941)	0.973 (0.954, 0.993)		0.022
Q2 (1.54–1.57)	728	0.933 (0.920, 0.946)	0.933(0.921,0.946)	0.979(0.961,0.999)		0.090
Q3 (1.58–1.60)	693	0.952(0.939,0.966)	0.953 (0.940, 0.966)	Ref. (1.00)		
Q4(>1.60)	754	0.924(0.912,0.938)	0.926 (0.913, 0.939)	0.971(0.952,0.991)		0.011
P for trend		0.842	0.675			
Waist circumference (cm)						
Normal (< 80)	1,547	0.942(0.933,0.951)	0.943 (0.934, 0.953)	Ref. (1.00)		
Action level 1 (80–87.9)	825	0.929(0.917,0.941)	0.929(0.917,0.941)	0.983(0.968,1.000)		0.116
Action level 2 (88)	540	0.920 (0.905, 0.935)	0.917 (0.902, 0.933)	0.971(0.952,0.990)		0.014
P for trend		0.019	0.004			
Hip circumference (cm)						
Q1(91.0)	705	0.937 (0.924, 0.950)	0.938 (0.925, 0.952)	Ref. (1.00)		
Q2 (91.1–96.5)	681	0.942 (0.929, 0.956)	0.943 (0.930, 0.956)	1.005(0.986,1.026)		0.922
Q3 (96.6–102)	640	0.939 (0.927, 0.952)	0.938(0.926,0.951)	0.999(0.980,1.019)		1.000
Q4 (> 102)	740	0.917(0.903,0.930)	0.916 (0.902, 0.929)	0.974 (0.955, 0.994)		0.053
P for trend		0.044	0.026			
BMI (Kg/m²)						
< 18.5	76	0.910 (0.872, 0.949)	0.912 (0.874, 0.952)	0.966(0.925,1.010)		0.331

Anthropometric variables	N	Relative Telomere Length				P
		<i>a</i> Mean (95% CIs)	<i>b</i> Mean (95% CIs)	<i>c</i> Ratio (95% CIs)		
18.5–24.9	1,643	0.942(0.934,0.951)	0.943 (0.935, 0.952)	Ref. (1.00)		
25–29.9	991	0.929 (0.918, 0.940)	0.928(0.917,0.939)	0.983 (0.969, 0.998)	0.102	
30	201	0.903 (0.879, 0.927)	0.899 (0.875, 0.923)	0.951(0.925,0.979)	0.004	
<i>P</i> for trend		0.014	0.005			
WHR						
Q1 (< 0.779)	726	0.938(0.925,0.952)	0.939 (0.926, 0.953)	Ref. (1.00)		
Q2 (0.779–0.813)	725	0.939 (0.926, 0.952)	0.940 (0.927, 0.953)	1.001(0.980,1.020)	1.000	
Q3 (0.814–0.850)	740	0.933 (0.926, 0.945)	0.932 (0.920, 0.945)	0.992(0.973,1.012)	0.797	
Q4 (> 0.850)	720	0.926(0.913,0.940)	0.925 (0.912, 0.939)	0.984(0.965,1.005)	0.349	
<i>P</i> for trend		0.167	0.116			
WHR						
Q1 (< 0.461)	730	0.943 (0.929, 0.956)	0.944(0.931,0.958)	Ref. (1.00)		
Q2 (0.461–0.50)	728	0.945(0.932,0.959)	0.947 (0.934, 0.961)	1.004(0.983,1.024)	0.988	
Q3 (0.51–0.544)	725	0.928(0.915,0.941)	0.928(0.915,0.941)	0.983(0.963,1.003)	0.231	
Q4 (> 0.544)	792	0.921(0.908,0.935)	0.918(0.904,0.932)	0.972 (0.952, 0.993)	0.033	
<i>P</i> for trend		0.013	0.004			

^a Adjusted for age at blood collection and education.

^b Multiple adjustment for age at blood collection, education, cigarette smoking status, regular alcohol consumption, cancer case/control status, and comorbidities.

^c Derived from the results with multiple adjustment.

Table 3

Association between telomere length and weight change since age 50 among women older than 55 years, the Shanghai Women's Health Study

	N (%)	Relative Telomere Length				
		<i>a</i> Mean (95% CIs)	P	<i>b</i> Mean (95% CIs)	<i>c</i> Ratio (95% CIs)	P
Weight change since age 50						
Weight change						
Loss 5% weight since 50 years	154 (11.9)	0.905 (0.876, 0.935)	0.822	0.907 (0.877, 0.937)	0.989 (0.951, 1.027)	0.869
Gain/loss < ± 5% weight since 50 years	429 (33.1)	0.918 (0.900, 0.936)	-	0.917 (0.899, 0.935)	Ref. (1.00)	-
Gain 5–15% weight since 50 years	460 (35.5)	0.889 (0.872, 0.906)	0.053	0.889 (0.872, 0.906)	0.969 (0.942, 0.996)	0.055
Gain >15% weight since 50 years	252 (19.5)	0.883 (0.861, 0.906)	0.051	0.883 (0.861, 0.906)	0.963 (0.932, 0.994)	0.060
<i>P</i> for trend		0.029		0.025		
Groups based on current BMI and BMI at age 50						
Group 1 (Maintained a normal BMI)	501 (41.0)	0.911 (0.895, 0.928)	-	0.912 (0.896, 0.929)	Ref. (1.00)	-
Group 2 (Changed from obesity/overweight to normal BMI or from obesity to overweight)	81 (6.6)	0.914 (0.874, 0.957)	1.000	0.913 (0.872, 0.956)	1.001 (0.952, 1.051)	1.000
Group 3 (Changed from normal to overweight)	268 (21.9)	0.902 (0.880, 0.925)	0.974	0.903 (0.881, 0.926)	0.990 (0.959, 1.021)	0.944
Group 4 (Stayed within the overweight BMI range)	244 (20.0)	0.900 (0.877, 0.924)	0.898	0.899 (0.876, 0.923)	0.986 (0.954, 1.018)	0.872
Group 5 (Changed from normal/overweight to obesity or stayed within the obesity BMI range)	128 (10.5)	0.862 (0.832, 0.894)	0.032	0.860 (0.829, 0.892)	0.943 (0.904, 0.982)	0.023
<i>P</i> for trend		0.025		0.024		

^a Adjusted for age and educational level.^b Multiple adjustment for age, educational level, cigarette smoking status, regular alcohol consumption, cancer case/control status and comorbidities.^c Derived from the results with multiple adjustment