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# Coffee Consumption Is Positively Associated with Longer Leukocyte Telomere Length in the Nurses' Health Study[1,2]

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## Abstract

**Background:** Coffee is an important source of antioxidants, and consumption of this beverage is associated with many health conditions and a lower mortality risk. However, no study, to our knowledge, has examined whether varying coffee or caffeine consumption levels are associated with telomere length, a biomarker of aging whose shortening can be accelerated by oxidative stress.

**Objective:** We performed a large comprehensive study on how coffee consumption is associated with telomere length.

**Methods:** We used data from the Nurses' Health Study (NHS), a prospective cohort study of female nurses that began in 1976. We examined the cross-sectional association between coffee consumption and telomere length in 4780 women from the NHS. Coffee consumption information was obtained from validated food-frequency questionnaires, and relative telomere length was measured in peripheral blood leukocytes by the quantitative real-time polymerase chain reaction. Unconditional logistic regression was used to obtain ORs when the telomere length outcome was dichotomized at the median. Linear regression was used for tests of trend with coffee consumption and telomere length as continuous variables.

**Results:** Higher total coffee consumption was significantly associated with longer telomeres after potential confounding adjustment. Compared with non-coffee drinkers, multivariable ORs for those drinking 2 to <3 and ≥3 cups of coffee/d were, respectively, 1.29 (95% CI: 0.99, 1.68) and 1.36 (95% CI: 1.04, 1.78) ($P$-trend = 0.02). We found a significant linear association between caffeine consumption from all dietary sources and telomere length ($P$-trend = 0.02) after adjusting for potential confounders, but not after additionally adjusting for total coffee consumption ($P$-trend = 0.37).

**Conclusions:** We found that higher coffee consumption is associated with longer telomeres among female nurses. Future studies are needed to better understand the influence of coffee consumption on telomeres, which may uncover new knowledge of how coffee consumption affects health and longevity. *J Nutr* 2016;146:1373–8.

**Keywords:** coffee, decaffeinated coffee, caffeine, telomere, telomere length, epidemiology

## Introduction

Coffee consumption is associated with many health conditions and lower mortality risk (1–4). Coffee contains many antioxidants, including caffeine, chlorogenic acid, diterpenes, melanoidins, and polyphenols. In populations that regularly consume coffee, coffee is a major source of antioxidant intake and constitutes a high percentage of dietary total antioxidant capacity (5, 6). Studies have shown that coffee and its component compounds can protect against DNA damage (7–19). Although caffeine has antioxidant properties (19), it can also act as a pro-oxidant (19) and inhibit DNA repair (20, 21) and can shorten telomeres in yeast (22). Few studies, to our knowledge, have examined the association between coffee consumption and telomere length (23, 24).

Telomeres are repetitive DNA sequences that protect the ends of linear chromosomes from chromosomal fusion and loss of critical genetic information during DNA replication (25). Telomeres shorten in somatic cells from each round of cell division because DNA polymerases are not able to fully replicate linear chromosomes, which is also known as the end-replication problem (26). Although somatic cell telomeres shorten with age

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because of the end-replication problem, oxidative stress accelerates their shortening (27, 28). Shorter telomeres have been associated with lower life expectancy and higher risks of age-related chronic diseases (29–33). Because coffee consumption can reduce oxidative stress and affect DNA integrity, it is plausible that coffee consumption may be associated with telomere length.

Previous studies on coffee consumption and telomere length have provided inconsistent findings (23, 24). An intervention study of 40 chronic hepatitis C patients found that coffee consumption resulted in significantly longer telomeres (23). However, a cross-sectional study of 840 predominantly black and Hispanic participants found no significant association between coffee consumption and telomere length (24). These studies did not examine whether decaffeinated coffee consumption or varying coffee consumption levels were associated with telomere length.

We present here our findings from the largest study, to our knowledge, to date on coffee consumption and telomere length, involving 4780 participants of the Nurses' Health Study (NHS). We used validated FFQs to capture the participants' coffee and caffeine consumption levels before they provided blood samples that were used for relative peripheral blood leukocyte telomere length measurements. To our knowledge, this is the first study to examine telomere length associations with decaffeinated coffee consumption or varying coffee consumption levels and also the first to examine the association between caffeine consumption from all dietary sources and telomere length in humans.

## Methods

*Study population.* The NHS is a prospective cohort study that began in 1976, when 121,700 female registered nurses aged 30–55 who were residing in 11 US states completed an initial questionnaire. Personal information, such as lifestyle and dietary factors, was subsequently updated every 2–4 y through questionnaire responses. From 1989 to 1990, blood was collected from 32,826 participants. Of these blood samples, 97% arrived within 26 h of being drawn and were centrifuged and aliquoted into plasma, white blood cell, and red blood cell components. The cryotubes containing the aliquoted samples were stored in liquid nitrogen freezers.

The analysis population consists of 4780 participants with coffee consumption information from FFQs and telomere length measurements. These participants were controls from nested case-control studies in the NHS (34–39). All of the case-control studies matched cases and controls by age or birth year. However, each of the case-control studies had somewhat different matching schemes, so we performed a sensitivity analysis, which additionally adjusted for the identifier of the case-control studies as an indicator variable in the multivariable model. We found that the adjustment minimally changed the effect estimates, so we did not include the case-control study identifier variable in the final multivariable models. This analysis was restricted to Caucasians, who are the predominant majority of the NHS participants. The NHS protocol was approved by Brigham and Women's Hospital's Human Research Committee.

*Telomere length.* Relative telomere length in genomic DNA extracted from peripheral blood leukocytes was measured by use of quantitative real-time polymerase chain reaction, and the ratio of telomere repeat copy number to a single gene copy number (T:S) was determined as previously described (40). Each sample was assayed in triplicate, and the relative telomere length was the exponentiated T:S corrected for a reference sample. The coefficients of variation were below 4% for the telomere and single-gene assays and below 18% for the exponentiated T:S. In the Nurses' Health Study, the 3- and 10-y intraclass correlations for reliability were determined to be 0.80 and 0.60. Although this assay provides a relative measurement of telomere length, ratios of telomere repeat copy number to a single gene copy number highly correlate with absolute telomere lengths determined by Southern blot ($r = 0.68$; $P < 0.001$) (40).

*Questionnaire information.* Coffee and caffeine consumption levels were obtained from the FFQ administered in 1990. For coffee consumption, categories of 0, <1, 1 to <2, 2 to <3, and ≥3 cups/d were chosen because of sample size consideration and because these are the likely consumption levels for an average person. For caffeine consumption from all dietary sources, we categorized its continuous measurement in mg/d into quartiles, because we are not aware of an established threshold of caffeine consumption level in which caffeine exerts biological effects on DNA in humans. Questionnaire information for potential confounders was also obtained from the 1990 questionnaire, except for physical activity level, which was obtained from the 1988 questionnaire. Smoking amount was indicated by pack-y. Alcohol consumption level was quantified by g/d, in which 14 g alcohol equals 1 drink. Physical activity level was indicated by metabolic equivalent task-h/wk. The Alternate Mediterranean Diet score was derived from the following 9 dietary components: vegetables (excluding potatoes), fruits, nuts, whole grains, legumes, fishes, monounsaturated to saturated fatty acid ratio, red and processed meats, and alcohol. The score ranges from 0 to 9, and a higher score represents greater adherence to the Mediterranean diet (41, 42).

*Statistical analysis.* We performed a cross-sectional analysis examining how coffee and caffeine consumption were associated with telomere length. The extreme studentized deviate many-outlier procedure was used to exclude outlier telomere length values (43), and $z$ scores were derived to standardize the distribution of telomere length values across

**TABLE 1** Age-standardized characteristics of the Nurses' Health Study participants at the time of blood collection by total coffee consumption levels[1]

| | No coffee ($n$ = 295) | <1 cup/d ($n$ = 658) | 1 to <2 cups/d ($n$ = 854) | 2 to <3 cups/d ($n$ = 1446) | ≥3 cups/d ($n$ = 1527) | $P$ |
|---|---|---|---|---|---|---|
| Age,[2] y | 58.6 ± 7.0 | 59.1 ± 7.0 | 59.8 ± 6.7 | 59.5 ± 6.5 | 58.9 ± 6.3 | 0.76 |
| Smoking,[3] pack-y | 7.3 ± 12.0 | 7.7 ± 14.1 | 10.4 ± 16.0 | 12.0 ± 18.2 | 18.7 ± 21.6 | <0.0001 |
| Percentage of ever smokers, % | 31.9 | 40.3 | 49.4 | 56.2 | 67.0 | |
| BMI, kg/m$^2$ | 25.7 ± 4.1 | 25.3 ± 4.5 | 25.6 ± 4.5 | 25.3 ± 4.3 | 25.0 ± 4.2 | 0.009 |
| Physical activity, MET-h/wk | 15.3 ± 14.4 | 16.1 ± 18.4 | 16.1 ± 19.1 | 17.5 ± 20.0 | 16.9 ± 24.8 | 0.23 |
| Alcohol consumption, g/d | 2.1 ± 5.4 | 3.9 ± 7.8 | 4.6 ± 8.3 | 6.5 ± 9.8 | 6.4 ± 10.3 | <0.0001 |
| *Trans* fat consumption, g/d | 2.6 ± 0.9 | 2.4 ± 1.0 | 2.5 ± 1.0 | 2.6 ± 0.9 | 2.7 ± 1.0 | <0.0001 |
| Alternate Mediterranean Diet Score | 4.0 ± 1.5 | 4.3 ± 1.7 | 4.3 ± 1.8 | 4.2 ± 1.8 | 4.3 ± 1.9 | 0.046 |
| Caffeine consumption, mg/d | 92.5 ± 74.0 | 104 ± 78.6 | 171 ± 87.0 | 283 ± 122 | 447 ± 192 | <0.0001 |

[1] Values are means ± SDs for all variables, except percentage of ever smokers (of which the values are percentages). $P$ values and SDs were standardized by the age distribution of the study population. MET-h, metabolic equivalent task hours.
[2] The $P$ values and SDs involving the age variable were not age-adjusted.
[3] Pack-y of smoking were calculated among ever smokers ($n$ = 2608). The $P$ value for smoking was calculated among ever and never smokers ($n$ = 4767).

**TABLE 2** Age-standardized characteristics of the Nurses' Health Study participants at the time of blood collection by telomere length *z* score quartiles[1]

| | Quartile 1 (*n* = 1195) | Quartile 2 (*n* = 1195) | Quartile 3 (*n* = 1195) | Quartile 4 (*n* = 1195) | *P* |
|---|---|---|---|---|---|
| Age,[2] y | 60.1 ± 6.3 | 59.7 ± 6.4 | 59.0 ± 6.6 | 58.2 ± 6.8 | <0.0001 |
| Smoking,[3] pack-y | 14.4 ± 20.1 | 12.6 ± 18.3 | 12.6 ± 19.5 | 12.2 ± 18.3 | 0.0017 |
| Percentage of ever smokers, % | 57.2 | 55.8 | 53.0 | 52.8 | |
| BMI, kg/m$^2$ | 25.6 ± 4.8 | 25.4 ± 4.5 | 25.2 ± 4.5 | 25.5 ± 4.4 | 0.31 |
| Physical activity, MET-h/wk | 16.1 ± 26.2 | 16.8 ± 20.9 | 16.2 ± 19.1 | 16.6 ± 18.1 | 0.88 |
| Alcohol consumption, g/d | 5.5 ± 9.4 | 5.6 ± 9.5 | 5.4 ± 9.9 | 5.4 ± 8.9 | 0.61 |
| *Trans* fat consumption, g/d | 2.6 ± 1.0 | 2.6 ± 1.0 | 2.6 ± 1.0 | 2.5 ± 1.0 | 0.027 |
| Alternate Mediterranean Diet Score | 4.2 ± 1.8 | 4.2 ± 1.7 | 4.1 ± 1.8 | 4.4 ± 1.8 | 0.042 |
| Caffeine consumption, mg/d | 280 ± 184 | 268 ± 191 | 277 ± 188 | 289 ± 197 | 0.054 |
| Total coffee consumption, cups/d | 2.0 ± 1.4 | 1.9 ± 1.3 | 2.0 ± 1.4 | 2.1 ± 1.5 | 0.050 |

[1] Values are means ± SDs for all variables, except percentage of ever smokers (of which the values are percentages). The *P* values and SDs were standardized by the age distribution of the study population. Telomere length *z* score quartile-specific means ± SDs are −1.3 ± 0.5 for quartile 1, −0.3 ± 0.2 for quartile 2, 0.3 ± 0.2 for quartile 3, and 1.3 ± 0.5 for quartile 4. MET-h, metabolic equivalent task hours.
[2] The *P* values and SDs involving the age variable were not age-adjusted.
[3] Pack-y of smoking were calculated among ever smokers (*n* = 2608). The *P* value for smoking was calculated among ever and never smokers (*n* = 4767).

the case-control studies. The unconditional logistic regression was used to obtain ORs when the *z* score outcome was dichotomized at the median. The linear regression was used for tests of trend with coffee and caffeine consumption and *z* score as continuous variables. Potential confounders that were adjusted include age (<50, 50–54.9, 55–59.9, 60–64.9, and ≥65 y), smoking (0, 0.1–20, 20.1–40, and >40 pack-y), alcohol consumption (0, 0.1–14, 14.1–28, and >28 g/d), BMI (measured in kg/m$^2$; <25, 25–29.9, 30–34.9, and ≥35), physical activity (nominal quartiles, metabolic equivalent task-h/wk), *trans* fat consumption (continuous, g/d), and Alternate Mediterranean Diet score (continuous). Analyses of caffeinated coffee consumption were adjusted for decaffeinated coffee consumption and vice versa. The SAS version 9.3 software (SAS Institute) was used for the analyses. Quartiles were created by use of the SAS rank procedure. All *P* values were 2-sided, and the α level of 0.05 was used to determine statistical significance.

## Results

**Table 1** presents the age-standardized characteristics of the study population by different coffee consumption levels. Women who drank more coffee had significantly more smoking pack-y ($P < 0.0001$), higher alcohol consumption ($P < 0.0001$), higher *trans* fat consumption ($P < 0.0001$), higher Alternate Mediterranean Diet Score ($P = 0.046$), and lower BMI ($P = 0.009$) (Table 1). Total coffee consumption was not significantly associated with age or physical activity level (Table 1).

**Table 2** shows the age-standardized characteristics by quartiles of telomere length. As expected, older age was significantly associated with shorter telomeres ($P < 0.0001$) (Table 2). Women with shorter telomeres had significantly more smoking pack-y ($P = 0.0017$) higher *trans* fat consumption ($P = 0.027$), and higher Alternate Mediterranean Diet Score ($P = 0.042$) (Table 2). Telomere length was not significantly associated with BMI, physical activity, or alcohol consumption (Table 2).

We examined the categorical and linear associations between total coffee consumption and telomere length, after adjusting for the covariates age, smoking, BMI, physical activity, alcohol consumption, *trans* fat consumption, and Alternate Mediterranean Diet Score (**Table 3**). Compared with non-coffee drinkers, those who drank 2 to <3 and ≥3 cups of coffee/d, respectively, had 1.29 (95% CI: 0.99, 1.68) and 1.36 (95% CI: 1.04, 1.78) times the odds of having above-median telomere length (*P*-trend = 0.02).

We further compared the categorical and linear associations with telomere length for caffeinated coffee and decaffeinated coffee consumption (**Table 4**). We found a significant linear association with longer telomeres for higher caffeinated coffee consumption after adjusting for decaffeinated coffee consumption and the other covariates age, smoking, BMI, physical activity, alcohol consumption, *trans* fat consumption, and Alternate Mediterranean Diet Score (*P*-trend = 0.008). There was no significant linear trend involving decaffeinated coffee consumption after adjusting for caffeinated coffee consumption and the other covariates (*P*-trend = 0.63).

We also examined whether caffeine consumption from all dietary sources was associated with telomere length (**Table 5**) and found a significant association after adjusting for age, smoking, BMI, physical activity, alcohol consumption, *trans* fat consumption, and Alternate Mediterranean Diet Score (*P*-trend = 0.02). However, the association was no longer significant after additionally adjusting for total coffee consumption (*P*-trend = 0.37). The Spearman correlation between caffeine and total coffee consumption was 0.66, whereas the Spearman correlation between caffeine and caffeinated coffee consumption was 0.93.

**TABLE 3** Multivariable associations between total coffee consumption levels and telomere length among Nurses' Health Study participants[1]

| | | Adjusted for age | | Adjusted for multiple factors[2] | |
|---|---|---|---|---|---|
| Total coffee | *N* | OR (95% CI) | *P* | OR (95% CI) | *P* |
| No coffee | 295 | Reference | — | Reference | — |
| <1 cup/d | 658 | 1.18 (0.90, 1.56) | 0.24 | 1.23 (0.92, 1.64) | 0.16 |
| 1 to <2 cups/d | 854 | 1.11 (0.85, 1.45) | 0.43 | 1.16 (0.88, 1.53) | 0.3 |
| 2 to <3 cups/d | 1446 | 1.22 (0.95, 1.57) | 0.13 | 1.29 (0.99, 1.68) | 0.06 |
| ≥3 cups/d | 1527 | 1.23 (0.96, 1.58) | 0.10 | 1.36 (1.04, 1.78) | 0.02 |
| *P*-trend | 4780 | 0.13 | | 0.02 | |

[1] To obtain the OR and 95% CI, telomere length was dichotomized at the median, with below-median telomere length as the reference group. To obtain the *P*-trend, total coffee consumption and telomere length were analyzed as continuous variables. The median values for the no coffee and <1, 1 to <2, 2 to <3, and ≥3 cups/d categories are 0, 0.45, 1.45, 2.5, and 4 cups/d, respectively.
[2] Adjusted for age, smoking, BMI, physical activity, alcohol consumption, *trans* fat consumption, and Alternate Mediterranean Diet Score.

**TABLE 4** Multivariable associations between caffeinated and decaffeinated coffee consumption levels and telomere length among Nurses' Health Study participants[1]

| | | Adjusted for age | | Adjusted for multiple factors[2] | |
|---|---|---|---|---|---|
| Total coffee | *N* | OR (95% CI) | *P* | OR (95% CI) | *P* |
| Caffeinated coffee | | | | | |
| No coffee | 802 | Reference | — | Reference | — |
| <1 cup/d | 1150 | 1.23 (1.03, 1.48) | 0.02 | 1.24 (1.02, 1.51) | 0.03 |
| 1 to <2 cups/d | 861 | 1.11 (0.92, 1.35) | 0.28 | 1.13 (0.92, 1.39) | 0.24 |
| 2 to <3 cups/d | 1085 | 1.32 (1.10, 1.59) | 0.003 | 1.41 (1.16, 1.72) | 0.001 |
| ≥3 cups/d | 882 | 1.20 (0.99, 1.46) | 0.06 | 1.32 (1.07, 1.63) | 0.01 |
| *P*-trend | 4780 | 0.08 | | 0.008 | |
| Decaffeinated coffee | | | | | |
| No coffee | 1297 | Reference | — | Reference | — |
| <1 cup/d | 2048 | 1.21 (1.05, 1.39) | 0.0076 | 1.14 (0.98, 1.33) | 0.08 |
| 1 to <2 cups/d | 730 | 1.13 (0.94, 1.36) | 0.19 | 1.13 (0.93, 1.38) | 0.21 |
| 2 to <3 cups/d | 488 | 1.03 (0.83, 1.27) | 0.79 | 1.00 (0.80, 1.26) | 0.99 |
| ≥3 cups/d | 217 | 1.14 (0.86, 1.52) | 0.37 | 1.16 (0.85, 1.59) | 0.36 |
| *P*-trend | 4780 | 0.87 | | 0.63 | |

[1] To obtain the OR and 95% CI, telomere length was dichotomized at the median, with below-median telomere length as the reference group. To obtain the *P*-trend, caffeinated/decaffeinated coffee consumption and telomere length were analyzed as continuous variables. The median values for the no coffee and <1, 1 to <2, 2 to <3, and ≥3 cups/d categories of caffeinated coffee consumption are, respectively, 0, 0.38, 1.5, 2.5, and 3.8 cups/d. The median values for the no coffee and <1, 1 to <2, 2 to <3, and ≥3 cups/d categories of decaffeinated coffee consumption are, respectively, 0, 0.33, 1.43, 2.5, and 3.7 cups/d.
[2] Adjusted for age, smoking, BMI, physical activity, alcohol consumption, *trans* fat consumption, Alternate Mediterranean Diet Score, and caffeinated or decaffeinated coffee consumption.

## Discussion

In this large study of coffee consumption and telomere length in 4780 women from the NHS, we found significant linear associations with longer telomeres for higher total and caffeinated coffee consumption. We did not find significant linear associations with telomere length for decaffeinated coffee consumption.

Coffee consumption has been found to promote DNA integrity in intervention (7–11) and biological studies (12–19). Intervention studies have shown that coffee consumption reduces spontaneous DNA strand breaks (7) and protects against chemical-induced DNA damage (8, 11) and oxidative DNA damage (9, 10). These intervention studies had study periods ranging from 3 d (11) to 4 wk (7) and coffee consumption amount ranging from 600 mL/d (8) to 1 L/d (11). Animal and cell line studies have shown that specific compounds in coffee such as chlorogenic acid (12, 13) and diterpenes (14–16) may protect against DNA damage. The role of caffeine on DNA integrity is complicated. Caffeine has been shown by biological studies to inhibit oxidative DNA breakage (19). However, caffeine can also be a pro-oxidant (19), inhibit DNA repair (20, 21), and shorten telomeres in yeast (22).

Two epidemiologic studies found inconsistent associations between coffee consumption and telomere length (23, 24). In an intervention study of 40 chronic hepatitis C patients, telomere length was found to be significantly longer in patients during the experimental period of consuming 4 cups of coffee/d for 30 d (23). A cross-sectional study found no significant association between coffee consumption and telomere length in 840 white, black, and Hispanic participants of the Multi-Ethnic Study of Atherosclerosis; however, the focus of the study was not specifically on coffee but on dietary patterns and food groups, so coffee consumption level was not clearly described (24). These previous studies did not examine decaffeinated coffee consumption or compare associations with telomere length across different coffee consumption levels.

We found a statistically significant linear trend with longer telomeres for caffeinated coffee consumption but not for decaffeinated coffee consumption, which is consistent with a previous finding that the antioxidant capacity of caffeinated coffee is higher than that of decaffeinated coffee (44). Although statistical power was lower for analyses involving decaffeinated coffee than for those involving caffeinated coffee, the categorical effect estimates for the association with longer telomeres were generally stronger for caffeinated coffee than decaffeinated coffee. Caffeinated and decaffeinated coffee may have different antioxidant concentrations because of the decaffeination process, which not only lowers caffeine concentration but can also lower other antioxidants that form complexes with caffeine, such as polyphenols (45). In addition, a common decaffeination process by use of carbon dioxide was shown to produce melanoidins (46), antioxidants that are also formed during coffee roasting (47–50). We found a significant association between caffeine consumption and telomere length after adjusting for potential confounders but not after additionally adjusting for total coffee consumption (as an indirect adjustment for potential confounding by the other antioxidants in coffee). This finding suggests that compounds in coffee besides caffeine may be responsible for the association between coffee consumption

**TABLE 5** Multivariable associations between caffeine consumption levels and telomere length among Nurses' Health Study participants[1]

| | | | Adjusted for age | | Adjusted for multiple factors[2] | | Adjusted for multiple factors, including coffee consumption[3] | |
|---|---|---|---|---|---|---|---|---|
| Caffeine consumption quartiles | *N* | Mean (SD), mg/d | OR (95% CI) | *P* | OR (95% CI) | *P* | OR (95% CI) | *P* |
| Q1 | 1195 | 64.4 (36.7) | Reference | — | Reference | — | Reference | — |
| Q2 | 1195 | 187.7 (37.1) | 0.97 (0.83, 1.14) | 0.73 | 1.03 (0.87, 1.22) | 0.77 | 1.01 (0.85, 1.21) | 0.90 |
| Q3 | 1196 | 321.5 (38.7) | 1.01 (0.86, 1.19) | 0.90 | 1.10 (0.93, 1.30) | 0.28 | 1.06 (0.86, 1.30) | 0.60 |
| Q4 | 1194 | 544.9 (134.1) | 1.15 (0.98, 1.35) | 0.01 | 1.23 (1.03, 1.47) | 0.02 | 1.17 (0.93, 1.47) | 0.18 |
| *P*-trend | | | 0.11 | | 0.02 | | 0.37 | |

[1] To obtain the OR and 95% CI, telomere length was dichotomized at the median, with below-median telomere length as the reference group. To obtain the *P*-trend, caffeine consumption and telomere length were analyzed as continuous variables. Q, quartile.
[2] Adjusted for age, smoking, BMI, physical activity, alcohol consumption, *trans* fat consumption, and Alternate Mediterranean Diet Score.
[3] Adjusted for age, smoking, BMI, physical activity, alcohol consumption, *trans* fat consumption, Alternate Mediterranean Diet Score, and total coffee consumption.

and telomere length. However, the influence of caffeine consumption on telomere length cannot be entirely ruled out, because simultaneous adjustment for both total coffee and caffeine consumption in the model reduced statistical power (given that coffee is a major source of caffeine), which may also have contributed to the lack of statistical significance. Besides the different concentrations of chemicals in caffeinated and decaffeinated coffee, caffeinated coffee drinkers have different personal traits than decaffeinated coffee drinkers (51), and these traits can modify or be potential confounders of the associations between consumption levels and telomere length.

There are several strengths of this analysis examining coffee consumption and telomere length. This is the largest study, to our knowledge, of coffee consumption and telomere length, which allowed us to adequately assess telomere length associations with different coffee consumption levels. To our knowledge, this is the first analysis to examine the association between decaffeinated coffee consumption and telomere length, which allowed us to compare the associations involving caffeinated and decaffeinated coffee consumption. It is also, to our knowledge, the first analysis to examine how caffeine consumption from all dietary sources is associated with telomere length. Besides our study's large sample size and novel analyses, we also had valid and reliable measurements for coffee consumption and telomere length. The FFQ-measured coffee consumption levels were validated in this cohort to correlate well with the actual consumption levels (52). In addition, the telomere length assay was performed in triplicate. Along with the strengths of this analysis, there are some limitations. Because this is a cross-sectional study, the associations do not exhibit temporality. We only had one telomere length measurement for each participant, so we could not assess whether higher coffee consumption was associated with changes in telomere length. Another limitation is that our findings in female Caucasian nurses may not generalize to other populations. Although we accounted for important potential confounders, unmeasured or residual confounding could still be present.

In conclusion, our findings suggest that higher consumption of coffee—especially caffeinated coffee—is associated with longer telomeres, but additional studies are needed to clarify how coffee consumption is involved in telomere biology. Future studies can provide mechanistic understanding by examining how specific compounds in coffee are involved in telomere maintenance. In addition, conducting observational and randomized clinical studies that examine other populations or obtain repeated measurements of telomere length for each participant will further clarify the shape of the dose-response curve for coffee consumption and telomere length. Understanding coffee's effect on telomeres may help us discover new pathways by which coffee consumption influences health and longevity.


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JJL, EG, and IDV planned the analysis; IDV supervised the telomere length data collection; JJL and MC-B analyzed the data; and JJL drafted the manuscript. All authors read and approved the final manuscript.


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