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RESEARCH

Approximate prediction of life expectancy in the older people using a revised equation for estimating somatic telomere length from clinical blood data

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Abstract

We previously proposed an equation for estimating somatic telomere length (TL) from peripheral blood test values. Here, we reexamined data from a larger number of individuals and found that the hemoglobin levels in men and serum albumin levels in women were well correlated with the measured TL values. We developed a new simplified estimated TL (eTL) equation that incorporates these test values. We analyzed the relationship between eTL derived from this revised equation based on the test values from a single day and life expectancy until death among residents of elderly care facilities, thereby exploring the correlation between eTL and life expectancy. The results revealed that the eTL values exhibited a significant negative correlation with the number of days until death due to senility. This data suggests that the eTL values can also be used as a tool for assessing the progression of senility in the very elderly. Furthermore, this correlation was no longer significant in populations in which the eTL values exceeded the TL values predicted by age-based regression. Therefore, this discrepancy between eTL and life expectancy may be more pronounced in old individuals who do not live in nursing homes. Furthermore, among elderly residents of nursing homes, serum albumin levels and serum cholesterol levels in men with shorter eTLs were positively correlated with eTLs in both men and women. The relationship between TL maintenance and nutritional status in the elderly is a topic that should be investigated further.

Keywords: Aging, life expectancy, telomere, clinical laboratory data, elderly, geriatric health services facility

Introduction

As we age, our bodies undergo progressive changes that ultimately lead to death. Human aging manifests according to the changes in the body's biological characteristics. Progressive shortening of telomeric DNA is among the indicators of aging-related changes in somatic cells [1, 2]. Telomere shortening is accelerated by various pathological conditions and shortened telomeres induce pathological conditions [1]. Considering that the pathological conditions are often reflected in the patients' blood test results, somatic telomere length (TL) may be associated with multiple laboratory test parameters [3-12]. Therefore, we investigated the correlations between various laboratory test parameters and peripheral blood leukocyte TL and developed an equation for estimating peripheral blood leukocyte TL by combining multiple correlated laboratory test parameters [13]. This initial eTL showed a tendency to shorten in relation to factors associated with aging progression, such as worsening care needs, decreased number of remaining teeth, history of cancer, and history of ischemic heart disease among residents of a geriatric health service facility [14]. In this study, we increased the number of study participants and formulated a new TL estimation equation to develop a simpler TL estimation approach. This estimated telomere length (eTL) calculation involves only age and clinical test values, without requiring genomic DNA extraction. Therefore, observational studies using this approach will not require

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the time-consuming ethical review that are warranted for telomere DNA or genome analysis. Furthermore, considering the circumstances wherein genomic DNA extraction is not possible, current TL can be estimated using past test data alone. This approach pose potential to facilitate more extensive research on physiological and pathological changes associated with aging, as well as telomere shortening, a key genomic aging indicator [14].

The elderly care facility in which the present study was conducted is not a hospital, and residents with serious health problems are admitted to a nearby hospital. Therefore, deaths within the facility are limited to those who would succumb to senility that cannot be treated in a hospital.

We proposed employing eTL as a biomarker for evaluating the aging status of residents in this elderly care facility, emphasizing particular on the eTL progressive change that led to death in residents due to senility within the facility. By observing the process of natural death of these residents, we can monitor the progression of aging that leads to natural death, rather than death resulting from illness, as is the case with hospitalized patients. Although clinical research on various diseases is possible at university hospitals, it is difficult to observe the natural progression leading to death from senility. However, such observation is possible at elderly care facilities. Accordingly, we hypothesized that eTL may serve as a biomarker for evaluating the progression of aging in elderly care facility residents.

Given that TL is inversely correlated with aging, TL should shorten as life expectancy decreases or death approaches. Therefore, by tracking eTL retroactively from the date of death, it is possible to observe the TL shortening as natural death approaches. Therefore, in the present study, we aimed to examine whether eTL, calculated from the routine test results of elderly care facility residents, is

Table 1. Correlations of blood test data with telomere length (MspI TL).

	Men		**Women**	
	β (95% CI)	***P*-value**	**β (95% CI)**	***P*-value**
AST (U/L)	-0.949 (-3.823–1.926)	0.516	-2.139 (-4.639–0.361)	0.093
ALT (U/L)	-0.775 (-4.286–2.735)	0.664	1.112 (-1.135–3.359)	0.330
BUN (mg/dL)	-1.338 (-2.796–0.121)	0.072	-2.556 (-3.865–1.248)	$\underline{< 0.001}^{***}$
Crnn (mg/dL)	-0.066 (-0.153–0.022)	0.140	-0.059 (-0.130–0.012)	0.101
T-Chol (mg/dL)	3.706 (-2.586–9.999)	0.247	2.591 (-4.382–9.565)	0.464
LDL (mg/dL)	6.104 (-0.375–12.583)	0.065	0.624 (-6.831–8.080)	0.869
HDL (mg/dL)	-1.505 (-4.671–1.661)	0.349	1.902 (-2.211–6.016)	0.362
TG (mg/dL)	5.751 (-8.722–20.223)	0.433	-4.524 (-17.991–8.944)	0.507
Na (mEq/L)	-0.224 (-0.702–0.254)	0.357	1.120 (0.434–1.805)	0.002^{**}
K (mEq/L)	0.015 (-0.058–0.088)	0.678	-0.014 (-0.109–0.080)	0.766
Cl (mEq/L)	-0.526 (-1.268–0.215)	0.163	1.604 (0.687–2.521)	0.001^{**}
Albumin (g/dL)	0.064 (-0.037–0.165)	0.214	0.237 (0.148–0.327002	$\underline{< 0.001}^{***}$
TP (g/dL)	0.018 (-0.123–0.159)	0.802	0.102 (-0.039–0.244)	0.153
Glo (g/dL)	-0.062 (-0.162–0.038)	0.222	-0.154 (-0.317–0.010)	0.066
WBC(/mm^3)	-9.905 (-339.444–319.635)	0.953	-18.856 (-332.506–294.793)	0.906
RBC (× 10^4/mm^3)	17.517 (5.996–29.038)	0.003^{**}	17.363 (9.247–25.479)	$\underline{< 0.001}^{***}$
Hb (g/dL)	0.554 (0.204–0.905)	$\underline{0.002}^{**}$	0.389 (0.135–0.644)	0.003^{**}
Ht (%)	1.709 (0.458–2.960)	0.008^{**}	1.526 (0.606–2.447)	$\underline{0.001}^{**}$
plt (x10^4/mm^3)	-0.147 (-1.120–0.825)	0.765	0.676 (-0.387–1.740)	0.211

Note: β, regression coefficient; CI, confidence interval; ETL, estimated telomere length; AST, aspartate transaminase; ALT, alanine transaminase; BUN, blood urea nitrogen; Crnn, creatinine; T-Chol, total cholesterol; HDL, high-density lipoprotein cholesterol; LDL, low-density lipoprotein cholesterol; TG, triglyceride; Na, sodium ion; K, potassium ion; Cl, chloride ion, Alb, albumin; TP, total protein; Glo, globulin; WBC, white blood cell; RBC, red blood cell; Hb, hemoglobin; Ht, hematocrit; Plt, platelet. $^*P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$. Underlined significant *P*-values remained significant after Bonferroni correction.

Table 2. Correlations of blood test data with longer and shorter eTLs.

	Men						Women					
	eTL		Longer eTL		Shorter eTL		eTL		Longer eTL		Shorter eTL	
	β (95% CI)	*P*-value	β (95% CI)	*P*-value	β (95% CI)	*P*-value	β (95% CI)	*P*-value	β (95% CI)	*P*-value	β (95% CI)	*P*-value
AST	-0.009 (-0.027–0.009)	0.322	-0.023 (-0.050–0.004)	0.087	-0.002 (-0.027–0.023)	0.878	-0.005 (-0.0096–-0.0007)	0.025*	-0.006 (-0.012–-0.001)	0.022*	-0.006 (-0.014–0.003)	0.208
ALT	-0.005 (-0.024–0.014)	0.623	-0.011 (-0.044–0.023)	0.524	-0.004 (-0.028–0.021)	0.765	-0.003 (-0.0067–-0.0007)	0.115	-0.005 (-0.008–0.002)	0.004**	0.002 (-0.006–0.011)	0.621
Crnn	-0.0001 (-0.0005–0.0004)	0.702	0.0001 (-0.0003–0.0005)	0.544	-0.0002 (-0.0009–0.0005)	0.617	-0.0001 (-0.0003–0.0001)	0.321	-0.0001 (-0.0003–0.0001)	0.420	-0.0002 (-0.00068–0.00021)	0.292
TChol	0.039 (0.012–0.066)	0.006**	0.032 (-0.055–0.118)	0.453	0.041 (0.017–0.067)	0.001**	0.007 (-0.011–0.025)	0.419	-0.006 (-0.028–0.017)	0.620	0.010 (-0.022–0.043)	0.525
Na	0.0004 (-0.0054–0.0063)	0.884	0.0005 (-0.0092–0.0102)	0.914	0.001 (-0.008–0.009)	0.829	0.002 (-0.001–0.005)	0.214	0.002 (-0.002–0.005)	0.323	0.00005 (-0.0058–0.0059)	0.986
K	-0.0004 (-0.0011– 0.0004)	0.333	-0.0006 (-0.0016–0.0004)	0.214	0.0001 (-0.0011–0.0012)	0.888	-0.0004 (-0.007–-0.0001)	0.009**	-0.0004 (-0.0008–0.000004)	0.048*	-0.0003 (-0.0008–0.0002)	0.235
Cl	0.003 (-0.002–0.009)	0.229	0.0022 (-0.0007–0.0110)	0.607	0.005 (-0.003–0.013)	0.205	0.002 (-0.001–0.005)	0.242	0.002 (-0.002–0.005)	0.390	0.001 (-0.0052–0.0075)	0.718
Alb	0.0007 (0.0003–0.0011)	< 0.001***	0.0005 (-0.00025–0.00133)	0.172	0.0008 (0.0003–0.0012)	0.0011**	0.0005 (0.0003–0.0008)	< 0.001***	0.0001 (0.00006–0.00027)	0.201	0.0003 (0.00005–0.00056)	0.020*
WBC	-4.250 (-8.809–0.309)	0.067	-7.184 (-14.909–0.542)	0.067	-3.379 (-9.109–2.350)	0.243	-0.425 (-1.531–0.680)	0.448	-0.411 (-1.773–0.952)	0.550	0.337 (-1.790–2.463)	0.752
RBC	0.119 (0.037–0.202)	0.005**	0.075 (-0.015–0.164)	0.100	0.063 (-0.031–0.156)	0.183	-0.002 (-0.029–0.024)	0.868	-0.009 (-0.044–0.027)	0.626	-0.008 (-0.053–0.037)	0.720
Hb	0.0015 (0.0002–0.0028)	0.021*	0.0006 (-0.0007–0.0019)	0.341	0.0007 (-0.0003– 0.0017)	0.195	0.0001 (-0.0007–0.0008)	0.856	0.0002 (-0.0008–0.0012)	0.683	-0.001 (-0.0018–0.0007)	0.420

Table 2 continued.

	Men						Women					
	eTL		Longer eTL		Shorter eTL		eTL		Longer eTL		Shorter eTL	
	β (95% CI)	*P*-value	β (95% CI)	*P*-value	β (95% CI)	*P*-value	β (95% CI)	*P*-value	β (95% CI)	*P*-value	β (95% CI)	*P*-value
Ht	0.009 (0.001–0.017)	0.028*	0.006 (-0.010–0.021)	0.461	0.005 (-0.002–0.012)	0.174	0.0008 (-0.0016–0.0032)	0.518	0.0003 (-0.00029–0.0036)	0.839	-0.0004 (-0.0043–0.0035)	0.834
Plt	-0.013 (-0.025–0.00009)	0.052	-0.013 (-0.030–0.004)	0.130	-0.011 (-0.030–0.007)	0.219	0.001 (-0.003–0.005)	0.569	-0.001 (-0.006–0.005)	0.820	0.006 (-0.0004–0.0128)	0.066

Note: β, regression coefficient; CI, confidence interval; ETL, estimated telomere length; AST, aspartate transaminase; ALT, alanine transaminase; BUN, blood urea nitrogen; Crnn, creatinine; T-Chol, total cholesterol; HDL, high-density lipoprotein cholesterol; LDL, low-density lipoprotein cholesterol; TG, triglyceride; Na, sodium ion; K, potassium ion; Cl, chloride ion, Alb, albumin; TP, total protein; Glo, globulin; WBC, white blood cell; RBC, red blood cell; Hb, hemoglobin; Ht, hematocrit; Plt, platelet. $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$. Underlined significant *P*-values remained significant after Bonferroni correction.

correlated with the time interval from the date of testing to death due to senility.

Methods

Study population

The present study included 340 participants including patients who visited the Department of Internal Medicine at Kyushu University Beppu Hospital between 2012 and 2016, and hospital staff, who agreed to participate in this research. The study cohort comprised 196 men (67.8 ± 13.3 years) and 144 women (72.7 ± 14.4 years), all of whom provided informed consent by signing a form approved by the Conjoint Health Research Ethics Board of Kyushu University (Approval number 203). We excluded patients with acute infections and cancer patients undergoing anticancer drug treatment. However, patients taking analgesics, antihypertensives, hypnotics, antidiabetics, antihyperlipidemics, and anticoagulants were included in the analyses. This suggests that the revised eTL values can also be applied to populations taking medications commonly used in the elderly. Apart from the individuals initially analyzed to establish the revised eTL, we analyzed elderly deaths among 663 residents (275 men and 388 women) who entered the geriatric health services facility Tabaru between August 1, 2020, and July 31, 2025. At this facility, blood tests are conducted after obtaining comprehensive consent for the use of personal information for medical research purposes. Informed consent was also obtained from the individuals or their families at the time of admission. The patients were categorized into a survival group, consisting of those who did not die during their stay (391 residents; 145 men and 246 women) and a death group, comprising those who died of senility (272 residents, 130 men and 142 women). The data of the two groups were analyzed and compared. The mean age at death was 90.3 ± 7.5 years) for all residents, 87.3 ±7.5 years for men, and 92.6 years ± 6.9 years) for women. These deaths were diagnosed as deaths due to senility after the facility's full-time physician, who was present at the time of the resident's death, confirmed that no other causes of death were found. The mean ages of the survival group at the time of blood test were 87.0 ± 8.0 years and 82.9 ± 9.7 years for men and women, respectively. The mean ages of the death group at the time of blood test were 85.6 ± 7.3 years and 91.8 ± 6.5 years for men and women, respectively.

Laboratory data

Biochemical and hematological analysis of blood samples was performed by Bio Majesty JCA-BM1650 (JEOL Ltd., Tokyo, Japan) and Sysmex XE-2100 (Sysmex Corporation, Kobe, Japan) at the laboratory of Kyushu University Beppu Hospital for the construction of the eTL estimation equation. The analysis of blood samples collected from the geriatric health services facility Tabaru was outsourced to RINTEK Co., Ltd. Oita branch.

TL measurement

TL was measured according to a previously reported method [13]. Briefly, peripheral blood samples were collected, genomic DNA was extracted from leukocytes, and telomere fragments containing telomere sequences were analyzed through a Southern blot analysis using a tetranucleotide-recognizing restriction enzyme (MspI). The mean leukocyte TL was calculated by integrating and averaging the density distribution obtained by densitometry of the smear images of the sections. All samples were measured in triplicate, and the resulting mean values were used for the subsequent analysis.

Statistical analysis

Using linear regression analysis, I explored optimal candidate test items for inclusion in the eTL estimation formula [13] (Table 1). Furthermore, in formulating an equation that includes these optimal test items, we used linear regression analysis and polynomial regression analysis to construct a simple equation that estimates the eTL closest to the measured TL (Table 2).

Results

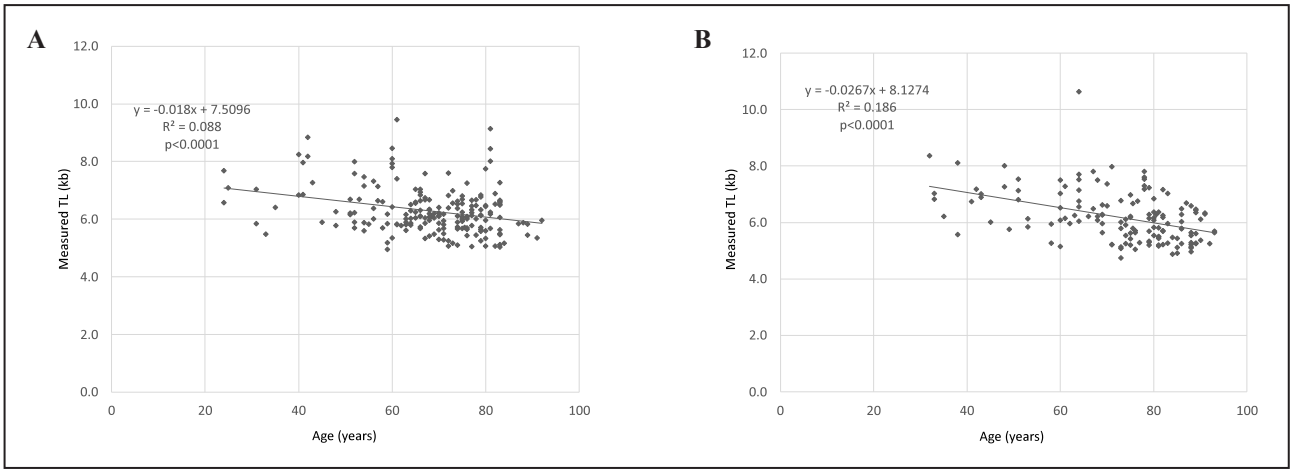

Figure 1. Correlation of age and measured TL. (**A**) Correlation of age and measured TL in men. The equation of the regression line and R-squared, as well as the statistical significance of the correlation, are displayed in the graph. (**B**) Correlation of age and measured TL in women.

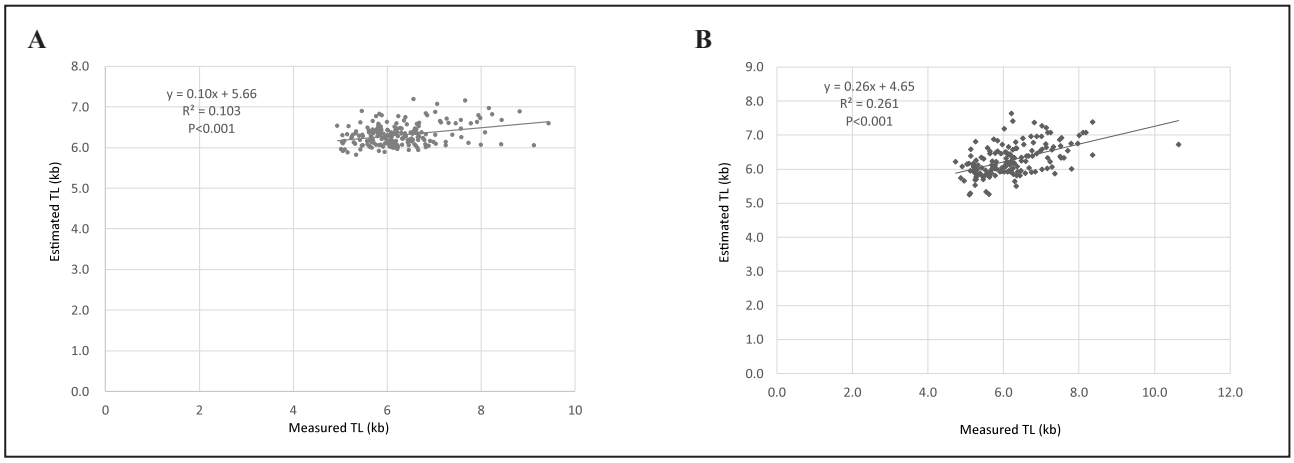

Figure 2. Correlation of eTL and measured TL. (**A**) Correlation of eTL and measured TL in men. The equation of the regression line and R-squared, as well as the statistical significance of the correlation, are displayed in the graph. (**B**) Correlation of eTL and measured TL in women.

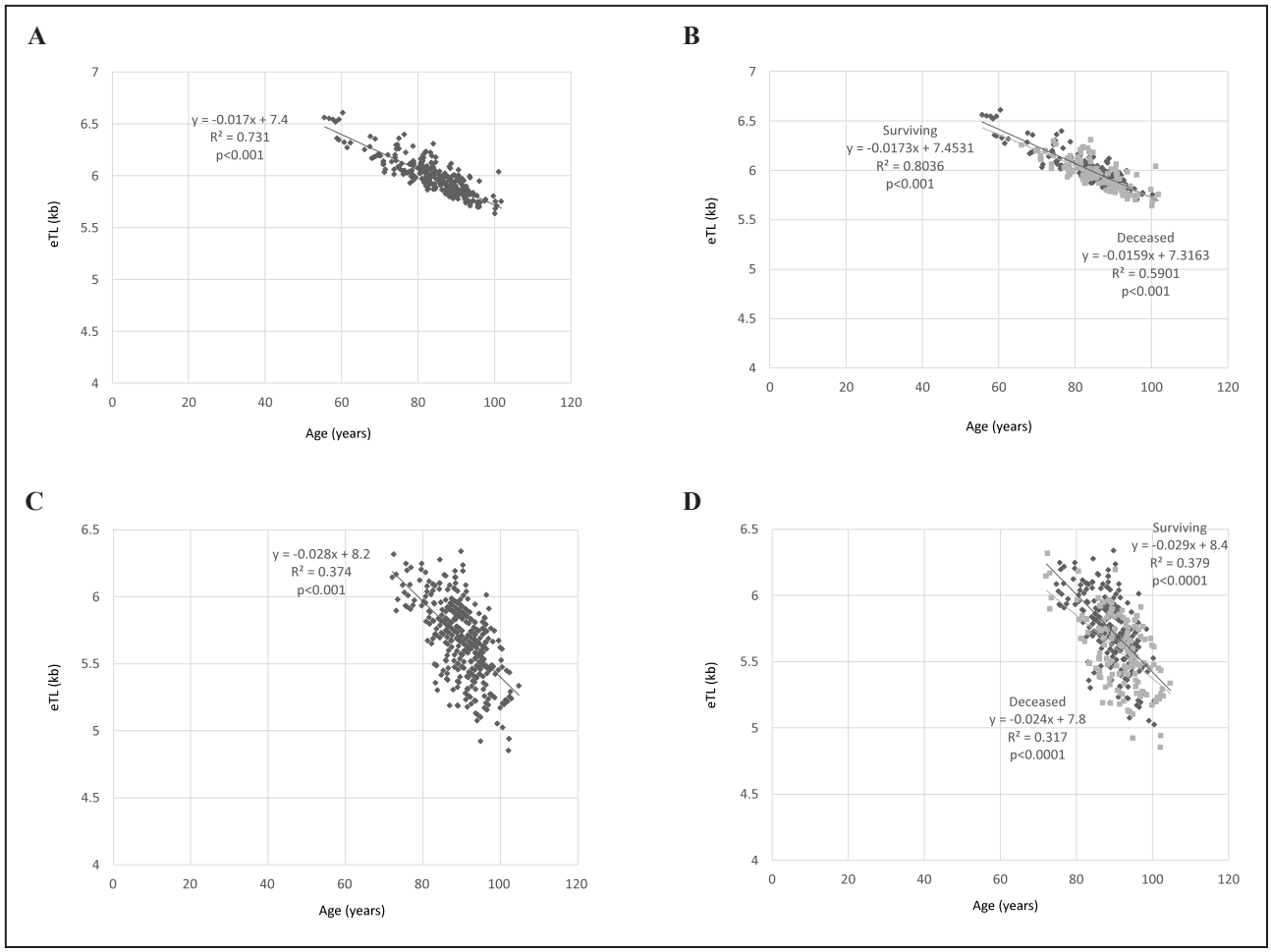

Figure 3. Correlation of age and eTL. (**A**) Correlation of age and eTL in men. (**B**) Correlation of age and eTL among surviving (black) and deceased (gray) male residents of long-term elderly care facilities. (**C**) Correlation of age and eTL in women. (**D**) Correlation of age and eTL among surviving (black) and deceased (gray) female residents of long-term elderly care facilities.

Across all study participants, age and measured TL showed an inverse correlation in both men and women (Figure 1A-B). Regarding the correlation between laboratory test parameters and measured TL, the Hb levels showed a high correlation in men, whereas the serum albumin (Alb) levels showed high correlation in women (Table 1). This supported previous reports on the correlation between laboratory test parameters and measured TL. In the present study, In this study, I established approximation equations for calculating estimated telomere length (eTL) using linear regression analysis and polynomial regression analysis, employing age and Hb levels in men, and age and serum albumin (Alb) levels in women (Figure 2A-B).

For men, the equation was as follows: eTL (kb) = 7.0 − 0.014 × age (years) + 0.036 × (hemoglobin (g/dL) − 5)². For women, eTL was calculated as follows: eTL (kb) = 6.2 − 0.022 × age (years) + 0.45 × serum Alb (g/dL).

Furthermore, using these data, we examined the correlation between age and eTL in nursing home residents. A significant inverse correlation was observed in both men and women (Figure 3A, C). When the analysis was restricted to residents who died of old age within the nursing home, we found no difference in the correlation between age and eTL (Figure 3B, D).

Moreover, for elderly people requiring nursing care who died while in a nursing home, we examined the correlation between the number of days from the date of blood test to death (life expectancy) and eTL calculated from the blood test results. We examined the relationship between age and life expectancy, as well as the correlation between eTL and life expectancy for both men and women. A significant correlation was observed between time to death and age in men, but not in women (Figure 4A-B).

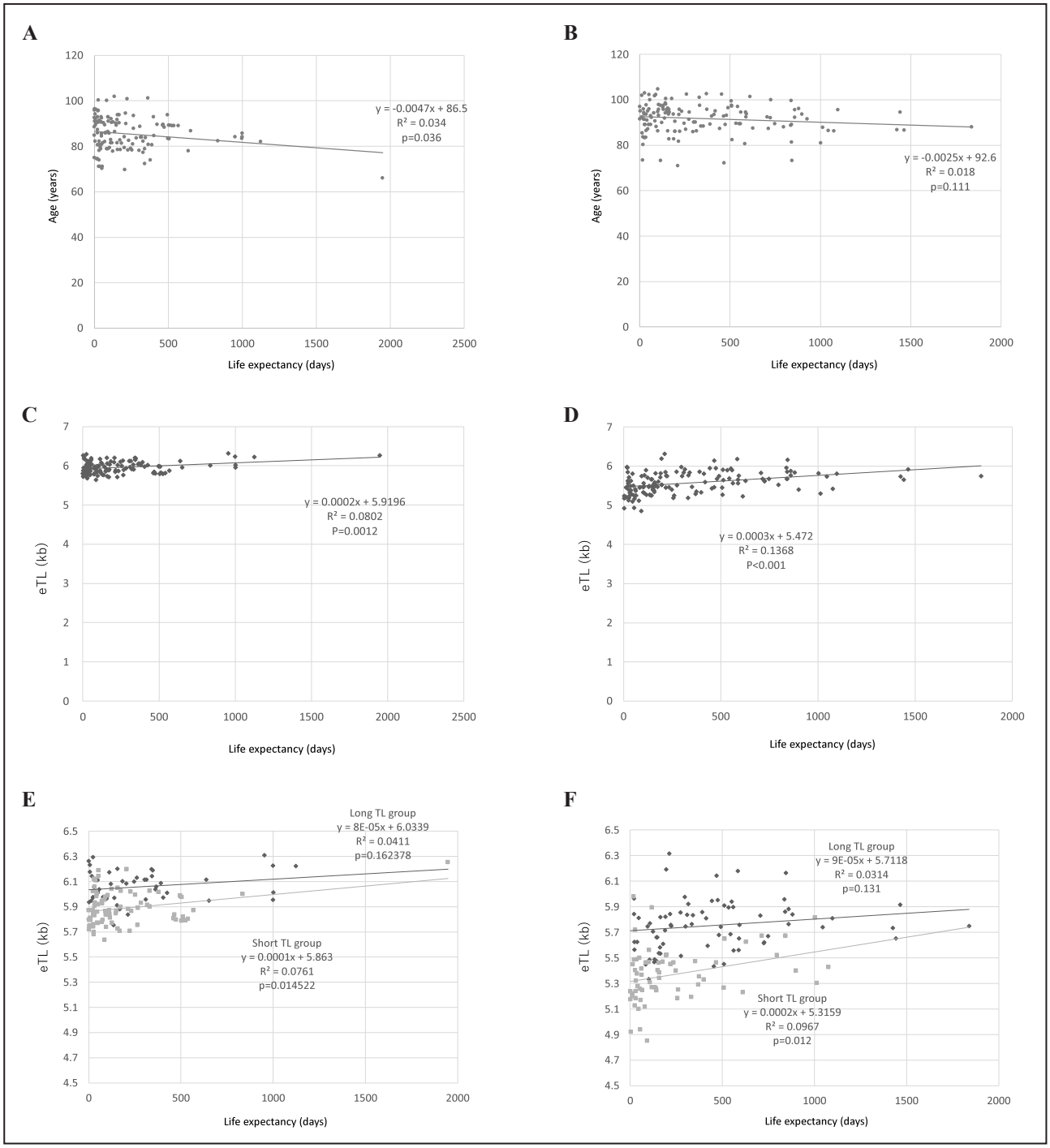

Figure 4. Correlations of age, life expectancy, and eTL. (**A**) Correlation of age and life expectancy in men. (**B**) Correlation of age and life expectancy in women. (**C**) Correlation of eTL and life expectancy in men. (**D**) Correlation of eTL and life expectancy in women. (**E**) Correlation of eTL and life expectancy of the long (black) and short (gray) eTL groups in men. (**F**) Correlation of eTL and life expectancy of the long (black) and short (gray) eTL groups in women.

Meanwhile, eTL showed a significant decline as the date of death approached in both sexes (Figure 4C-D). Furthermore, in men, eTL was more strongly correlated with life expectancy than with age. The correlations between annual and daily TL shortening rates and age (Figure 3A, C) and life expectancy rates (Figure 4C-D) in the overall population were −0.017 (kb/year)/0.0002 365 (kb/year) in men and −0.028 (kb/year)/0.0003 365 (kb/year) in women, suggesting that TL shortening accelerates approximately fourfold from old age toward death in elderly care facility residents. In women, eTLs of < 5 kb may be observed within 100 days before death, suggesting that an eTL of ≤ 5 kb may indicate impending end of life.

Additionally, based on the y-axis intercepts in Figure 4C-D, we can estimate the life expectancy (in days) for men with a TL of ≥ 5.9 kb and for women with a TL of ≥ 5.5 kb using the following equation: (eTL − 5.9)/0.0002 for men and (eTL − 5.5)/0.0003 for women. However, this equation is an approximate estimate derived retrospectively from the number of deaths. Although it is useful as a guide, it is not universally applicable with a considerable fact that for some individuals' life expectancy and TL do not correlate. In accordance, few reports have shown that TL and life expectancy do not necessarily correlate in people aged < 80 years [15-17]. In the present analysis, Figure 4C-D also shows a tendency for eTL values to fluctuate more as the date of death approaches, suggesting that TL and life expectancy may not correlate in all individuals. We therefore compared the correlation between life expectancy and eTL between the long and short eTL groups separated by the regression lines shown in Figure 3A, C. Analysis of covariance showed that the long eTL group and the short eTL group are distinct groups (P < 0.001 for both males and females). The results demonstrated that the association with life expectancy was maintained in the short eTL group, whereas it was lost in the long eTL group (Figure 4E-F).

Furthermore, the analysis of the correlation between eTL and laboratory test parameters revealed that in both men and women, a strong positive correlation was observed, particularly between albumin (Alb) and eTL. Furthermore, in the short-TL group of men, a strong positive correlation was observed between eTL and serum cholesterol (Table 2).

Discussion

Telomere length shortening occurs not only as a normal part of aging but also accelerates under various pathological conditions [1]. We have previously reported accelerated TL shortening in various diseases, including hypertension [3], cerebrovascular disease [4, 5], Alzheimer's disease [6], Parkinson's disease [7], sarcoidosis [8], diabetes [9], multiple sclerosis [10], cancer [11], insomnia [12], and decreased physical activity [4, 14, 18]. These diverse findings suggest that TL shortening is influenced by various physiological and pathological factors. This indicates that TL shortening is reflected in related laboratory test parameters. Indeed, several blood test parameters have demonstrated to correlate with TL in both patients and healthy individuals [2, 3, 5]. Therefore, we developed a TL estimation equation incorporating laboratory test parameters correlated with TL [13]. As a next step, the present study expanded the sample size and developed a revised, simplified TL estimation equation. Among elderly care facility residents, a clear inverse correlation between age and eTL was observed for both men and women. Although this revised eTL is simpler than the first version, its correlation with the measured TL is weaker than that of the first version (male $R^2 = 0.234$, female $R^2 = 0.300$) [13]. In particular, the decrease in correlation is noticeable in the male eTL, suggesting that factors other than the previously analyzed items may be influencing the results. In the female eTL, significant correlations were lost with WBC and TChol, which were included in the first version of the eTL. This indicated the need to revise the first version of the eTL.

A clear inverse correlation between age and the revised eTL was observed for both the deceased and surviving elderly groups. Given that this equation includes an age term, eTL is biased toward values likely to be correlated with age, but it is expected to be a parameter that more clearly indicates aging than age. Contrarily, some studies exhibited no correlation between TL and life expectancy in the very elderly population (age ≥ 85 years) [15-17]. In the present study, we attempted to monitor the changes in TL in relation to the progression of physical aging over the period leading up to death, rather than simply in terms of the number of years since birth. The present study makes it possible to verify the correlation between TL and life expectancy in the very elderly.

Although the number of days until death is generally expected to decrease with age, this trend was not confirmed in women. Furthermore, eTL showed a significant positive correlation with the number of days until death in both men and women, with a particularly strong correlation observed in women. Thus, eTL can more accurately estimate life expectancy than age, suggesting its potential as an indicator of the aging progression. Furthermore, the present analysis predicted that TL shortening accelerates as death approaches, suggesting a decline in the ability to maintain TL with advancing age.

To examine the relationship between TL and life expectancy in more detail, we categorized the participants into those with long and short eTLs relative to their age and examined the correlation between eTL and life expectancy in each group. No correlation was found in those with long eTLs, in either men or women. This discrepancy between eTL and life expectancy may be more pronounced in very elderly individuals not residing in nursing homes, who may have longer TLs at the same age. This may mirror previous studies of TL in very elderly individuals where no correlation between TL and life expectancy was found.

Furthermore, in very old individuals for whom no correlation between eTL and life expectancy is observed, examining the correlation between measured TL and laboratory

test parameters other than age may identify the factors more closely associated with life expectancy than age itself.
In the present study, TL shortening changed concomitantly with the progression of several laboratory test parameters. It is unclear whether correcting these laboratory test parameters can directly prevent TL shortening, and whether maintaining adequate nutrition, appropriate serum albumin and appropriate serum cholesterol directly prevent TL shortening. Further research is warranted to determine whether improving the laboratory test parameters abnormalities identified in this study can actually slow TL shortening and extends the lifespan of long-lived individuals.

Conclusions and limitations

The results presented in this particle are limited and not generalizable at this time for the following reasons:
(1) The population used to formulate the new eTL mainly consists of patients treated in hospitals.
(2) The new eTL is derived from TL measurements of a limited number of people, not a large number.
(3) The new eTL is constructed from a single test item, which is convenient, but ignores other factors that influence telomere shortening.
(4) The life expectancy analysis using the new eTL is based on a biased population of elderly people residing in a geriatric health services facility.
(5) The eTL of elderly people in a geriatric health services facilitys has not been compared with measured TL.
Therefore, to verify the conclusions of this paper, multivariate analysis is needed to examine the correlation between measured TL in a large, unbiased population and values of a wider variety of clinical test items.

Declarations

Author contributions: Maeda T contributes to data curation, formal analysis, funding acquisition, methodology, project administration, resources, software, validation, visualization, and writing of this manuscript.

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Conflict of interest: Not applicable.

Ethical approval and informed consent: The study on telomere length measurement using genomic DNA extracted from peripheral leukocytes, as described in this paper, was conducted with the approval of the Conjoint Health Research Ethics Board of Kyushu University (Approval number 203). The latter part of this study is an observational study using clinical data recorded during routine medical care after hospitalization. The clinical research at geriatric health services facility Tabaru was conducted with comprehensive consent regarding the use of personal data. In accordance with the Declaration of Helsinki, this facility conducts clinical research, and under the name of the facility director, it is clearly stated on the bulletin board for broad consent that personal information obtained at this facility may be used for research purposes. Furthermore, consent regarding the use of clinical data was also obtained from the residents' families at the time of hospitalization.

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