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Feature Article

Associations between socioeconomic status, aging and functionality among older women

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ABSTRACT

To assess if there is an association between socioeconomic status and quality of life, functional status and markers of aging, we studied 86 women aged 73 ± 7 years, who answered the WHO Qol Bref quality of life survey. Mini mental state examination, timed up and go test, 12 minutes' walk, hand grip and quadriceps strength, dual X-ray absorptiometry (DEXA), carotid intima-media thickness and telomere length in peripheral leukocytes were measured. Successful aging was defined as a walking speed, handgrip strength, appendicular lean body mass, timed up and go and minimental values above cutoff points for disability. Participants with successful aging had a higher quality of life score and were more likely to live in rich municipalities. There was a positive correlation between telomere length, right handgrip strength and total fat free mass. Therefore, there is an association between socioeconomic status, successful aging and quality of life.

Introduction

In 2010, people over 60 years of age constituted 13% of the total population of Chile.[1] It is pertinent to question whether longevity is accompanied by preserved functionality and quality of life. In developing countries like Chile, socially vulnerable groups experience a less successful aging process. Several components may play a role in this phenomenon such as risk behaviors, lifestyle, age or other factors such as poverty, which limits access to adequate nutrition, health services and recreational activities.[2]

In previous studies of older adults in the city of Santiago, no large differences in mortality were observed between different socioeconomic strata, but inequity was demonstrated by the higher prevalence of functional limitations among older people from poor neighborhoods.[3,4] There are profound gender and socioeconomic differences among older adults, thus healthy life years gained are not equal for society as a whole.[5] Moreover, socioeconomic status is an important determinant of educational attainment.[6]

A recent study performed in England showed that chronic psychological distress and low socioeconomic status were associated with higher mortality and that the detrimental effect of psychological distress on mortality is amplified by low socioeconomic status.[7] Many studies have suggested a relationship between chronic stress and poor health indices, including cardiovascular risk factors,[8] poor immune function[9] and eventually a faster aging rate.[10] Socioeconomic status is an important predictor of health and disease. The less affluent deal with a significant number of social and environmental conditions that contribute to chronic stress.[11] However the mechanism by which stress causes these consequences has not been unraveled. The proposed hypothesis is that stress impacts health through the modulation of cellular aging rate.[12]

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Telomere length measured in peripheral blood mononuclear cells is used as a marker of aging.[13] Shortened telomeres correlate with age and age-associated diseases such as cardiovascular disease, diabetes and osteoporosis.[14] Also, among women, there is an association between perceived stress and shorter telomeres in peripheral blood mononuclear cells.[11]

We conducted a survey in elderly non-disabled adults residing in the city of Santiago de Chile, between 2009 and 2010, showing that quality of life is closely linked with socioeconomic status and education level of the participants.[15] We hypothesized that low socioeconomic status would be associated with less successful aging. To test this hypothesis, we performed a secondary analysis of data from the above mentioned quality of life survey. Using internationally accepted cutoff points for functional measures, body composition[16] and minimental examination,[17] we constructed a model of successful aging, defined as those participants who had all their functional parameters and minimental score over the cutoff points to define disability and a body composition not indicating the presence of sarcopenia. We measured telomere length as a marker of overall aging and carotid intima-media thickness (CIMT) as a marker of vascular aging.[18]

Thus, the aim of this study was to evaluate if socioeconomic status was associated with successful aging and markers of aging such as telomere length and CIMT, among healthy elderly Chilean women.

Methods

Participants

We invited a group of elderly women living independently in metropolitan Santiago and ascribed to community centers for older people, to participate in this study. All participants were contacted at their community centers, where they meet regularly. All had answered the quality of life survey, the WHOQOL bref,[19] between October 2009 and May 2010. The survey included questions about socioeconomic status, environment, functional and health-related issues. We excluded participants with physical disabilities, which would preclude the performance of functional tests, and those with chronic, life-threatening diseases such as cancer, heart failure, kidney or liver failure or a minimental state score below 21. This study was approved by the ethics committee of Institute of Nutrition and Food Technology (INTA) and all participants signed a written informed consent.

Procedures

Participants were assessed at the Institute of Nutrition and Food Technology of the University of Chile (INTA) during 2012 by a health professional, who performed a minimental state examination (MMSE) and a functional assessment, including timed up and go (TUG)[20] and 12 min walk.[21] Body weight and height, waist and hip circumference, blood pressure, handgrip strength using a hand grip dynamometer (Hand Dynamometer T-18, Country Technology, Inc.) and quadriceps strength using a quadriceps table,[22] were also measured. The best of three measurements of the last two parameters was recorded. A neck ultrasound was performed for the measurement of carotid intima-media thickness (CIMT) using a General Electric LogiQ e device, equipped with border recognition software. This examination was conducted by a trained professional according to previously published guidelines.[23] The mean and maximal value of at least 100 measurements per side was reported. A dual X-ray absorptiometry (DEXA) was performed to measure body composition using Lunar iDEXA equipment, since fat free mass is a strong predictor of functional capacity.[24] A fasting blood sample was obtained for routine biochemistry and isolation of peripheral blood mononuclear cells for the measurement of telomere length using the quantitative polymerase chain reaction described by Cawthon et al,[25] whose results were expressed as a ratio to a housekeeping gene.

Measures

Each question in the WHOQOL bref quality of life survey has five possible answers, representing a score fluctuating from 1 to 5 (best quality of life). The overall quality of life score of each participant was expressed as a percentage of the maximal obtainable score (100%) of the survey, summing all questions effectively answered. Socioeconomic status of participants was determined according to the classification of the municipality of residence, based on a survey conducted by the Chilean Ministry of Planning (MIDEPLAN) and by interviewers' assessment.

Using internationally accepted cutoff points, we defined participants with successful aging as those who complied with all of the following criteria: a walking speed of 1 m/s or more, a hand grip strength of 16 kg or more, an appendicular lean body mass per body mass index (ALM_{BMI}) of 0.512 or more,[16] a timed up and go of 8.1 s or less,[26,27] and a minimental state score over 24.[17] We did not include quadriceps strength in this classification due to the lack of internationally accepted cutoff points for this parameter.

Statistical analysis

All statistical analyzes were done using Stata 10.0 (StataCorp, 4905 Lakeway Drave, College Station, Texas 77845, USA). Normality of variable distribution was assessed using the Shapiro–Wilk test. Normally distributed variables were expressed as mean $\pm$ standard deviation, otherwise as median and interquartile range. Concordance was determined using kappa analysis between educational, socioeconomic levels assessed by interviewers and by municipality of residence in Santiago. Educational levels were grouped into 3 categories: illiterate/elementary education, secondary education and technical school/higher education. Women with successful aging were compared with their counterparts using ANOVA and Bonferroni tests when variables had a normal distribution or Kruskal Wallis otherwise. A logistic regression model was performed including successful aging as the dependent variable and age, quality of life score, educational level socioeconomic status, telomere length and CIMT as independent variables. Univariate associations between variables were quantified using Spearman's correlation. A p-value of <0.05 was considered statistically significant.

Results

We contacted 110 women and 86, aged 73 $\pm$ 7 years agreed to participate. The studied population consisted of 15 participants with illiterate level/primary education, 38 with high school/secondary education and 33 with technical school/higher education. Twenty four resided in poor, 24 in intermediate and 40 in rich municipalities. The educational level of the participants had a concordance of 70 and 68% with the socioeconomic level assessed by interviewers and with the municipality of residence in Santiago, respectively (Weighted kappa <0.01). Thus, the educational level of the participants was used as another indicator of socioeconomic status. Demographic characteristics, cognitive status and quality of life scores of the studied population are shown in Table 1. Quality of life scores were significantly higher among participants in technical school/higher education category ($p < 0.05$), as reported previously.[15] The illiterate/primary education group had a significantly

Table 1
Demographic and clinical variables[a] of participants.

	Illiterate or primary education (n = 15)	Secondary education (n = 38)	Technical school/higher education (n = 33)	p-Value
Age (years)	75.7 ± 5.4	72.1 ± 7.6	72.1 ± 6.1	NS
Body mass index (kg/m^2)	27.7 ± 4.2	26.9 ± 5.3	27.2 ± 4.2	NS
Waist circumference (cm)	93.5 ± 9.7	92.1 ± 10.5	92.8 ± 9.9	NS
Hip circumference (cm)	101.3 ± 8.6	102.6 ± 10.3	102.8 ± 9.7	NS
Systolic blood pressure (mm Hg)	132 (119–145)	122 (115–146)	132 (122–138)	NS
Diastolic blood pressure (mm Hg)	73 (59–76)	73 (66–83)	73 (68–79)	NS
Minimental score	27 (25–29)	29 (29–30)	29 (29–30)	[b]
Quality of life score (% of max score)	67.0 ± 10.1	66.9 ± 9.6	74.3 ± 9.0	[c]

[a] Results expressed as mean ± standard deviation for normally distributed variables or median (interquartile range).
[b] Illiterate or primary education participants significantly different from other two groups.
[c] Participants with technical/higher education significantly different from other two groups.

lower score on the minimental than those of the other two educational groups ($p < 0.01$).

Body composition, functional measures, carotid intima-media thickness and the main laboratory results are shown in Table 2. Participants of the illiterate/primary education group had a significantly higher TUG compared with the other two groups and lower right quadriceps strength than participants in the technical school/higher education group. No other differences were observed.

Table 3 shows the characteristics of women with successful aging, compared with their counterparts. The former had a higher quality of life score and a higher proportion lived in municipalities classified as rich. In the logistic regression model, age (odds ratio (OR) 0.9, 95% confidence intervals (CI) 0.83–0.98) and living in a rich municipality (OR 4.4, 95% CI 1.5–12.9) were significant predictors of successful aging. The two biological markers of aging (telomere length and CIMT) did not enter in the logistic regression model. However, there was a positive correlation between telomere length, left handgrip strength and total fat free mass (Spearman's rho 0.32, $p \leq 0.01$ and 0.24, $p = 0.05$, respectively).

Discussion

In this study, we observed that elderly women with a normal functional capacity, defined here as successful aging, had a higher quality of life score and lived in richer neighborhoods.

The association between quality of life, socioeconomic level and functional capacity, indicates a two-way link. On one side, it is reasonable that people with lower functionality will have a worse perception of their quality of life and this association has been reported previously.[27] However the possibility that a low socioeconomic level worsens functional capacity *per se,* is a worrisome alternative since it begins a vicious circle where an unfavorable social environment may limit activity and functionality, thus enhancing a negative perception of life. Actually, poorer individuals of a society report experiencing more stress[28–30] and a less rewarding life, due to environmental, cultural and urban issues.[31,32] Moreover, a low socioeconomic condition could play a causative role in the loss of functional capacity of older people. One of the reasons for this association are the less healthy lifestyles and poorer

Table 2
Functional variables, body composition, carotid intima-media thickness and laboratory results of participants.[a]

	Illiterate or primary education (n = 15)	Secondary education (n = 38)	Technical school/higher education (n = 33)	p-Value
Functional variables				
Left quadriceps strength (Newton)	201.7 ± 45.1	215.3 ± 64.7	234.8 ± 67.2	NS
Right quadriceps strength (Newton)	206.7 ± 49.01	226.5 ± 58.3	253.8 ± 63.0	[b]
Right hand grip strength (kg)	21.1 ± 5.7	20.8 ± 3.8	21.4 ± 4.8	NS
Left hand grip strength (kg)	18.9 ± 4.7	19.3 ± 4.0	19.9 ± 4.4	NS
Timed up and go (sec)	7.8 (6.2–94)	6.4 (5.8–7.7)	6.1 (5.6–6.8)	[c]
Twelve minute walk (m)	855.7 (739.2–1004.7)	968 (849.2–1045)	878.3 (805.9–977.4)	NS
Body composition				
Total body fat (kg)	25.20 ± 7.40	26.40 ± 8.90	27.70 ± 8.90	NS
Total fat free mass (kg)	33.2 (32.1–36.8)	35.6 (33.1–38.8)	36.0 (34.2–36.5)	NS
Total bone mass (kg)	1.90 ± 0.34	2.00 ± 0.28	21.00 ± 0.28	NS
Carotid intima-media thickness				
Mean value (mm)	0.78 (0.64–0.96)	0.7 (0.63–0.86)	0.77 (0.68–0.85)	NS
Maximal value (mm)	0.86 (0.75–1.08)	0.76 (0.7–1.01)	0.82 (0.76–0.90)	NS
Laboratory values				
Telomere length (TS ratio)	1.5 ± 1.3	1.4 ± 0.9	1.3 ± 0.8	NS
Serum glucose (mmol/L)	5.5 ± 1.3	5.2 ± 0.8	5.2 ± 0.8	NS
Total cholesterol (mmol/L)	4.9 ± 1.1	5.1 ± 0.7	5.4 ± 1.2	NS
HDL cholesterol (mmol/L)	1.4 ± 0.5	1.6 ± 0.4	1.6 ± 0.4	NS
Triacylglycerol (mmol/L)	1.6 ± 0.8	1.5 ± 1.0	1.5 ± 0.5	NS
Glomerular filtration rate (ml/min/1.73 m^2)[d]	64.6 ± 16.9	72.3 ± 14.4	73.3 ± 16.6	NS

[a] Results expressed as mean ± standard deviation for normally distributed variables or as median (percentile 25–percentile 75) otherwise.
[b] Illiterate or primary education significantly different from technical school/higher education participants.
[c] Illiterate or primary education participants significantly different from other two groups.
[d] Calculated using the four variable Modification of Diet in Renal Disease (MDRD) study equation.

Table 3
Comparison of women by successful aging group.[a,b]

	Successful aging	Unsuccessful aging	p-Value[d]
	(n = 36)	(n = 50)	
Age (years)	71.2 ± 5.9	73.9 ± 7.2	NS
Quality of life score (%)	72.8 ± 9.8	67.6 ± 9.8	0.02
Telomere length (TS ratio)	1.19 (0.77–2.06)	1.27 (0.61–1.59)	NS
Carotid intima-media thickness (mm)[c]	0.72 (0.62–0.83)	0.77 (0.66–0.87)	NS
	Number (%)		
Municipality of residence			
Poor	6 (17)	18 (36)	
Intermediate	7 (19)	15 (30)	0.02
Rich	23 (64)	17 (34)	
Level of education			
Illiterate/elementary	4 (12)	11 (22)	
Secondary	16 (44)	22 (44)	NS
Technical/University	16 (44)	17 (34)	

[a] Defined as having values above (successful) versus below (unsuccessful) usual cutoffs for walking speed, hand grip strength, appendicular lean body mass, timed up and go and minimental score.
[b] Values are either mean ± standard deviation, median (interquartile range), or number (%).
[c] Average of both sides.
[d] t-test for normally distributed variables, Kruskal–Wallis for non-normal variables, or and chi-square for categorical variables.

nutrition of less educated people, who have higher levels of sedentariness, more cardiovascular risk factors, are less receptive to or have a lower comprehension of health promotion educational campaigns.[32] Recent studies done in different countries also show that older people of lower socioeconomic status have lower handgrip strength[33] or timed up and go speed.[34]

The positive correlation between the length of telomeres, total fat free mass and handgrip may indicate that people who have more lean body mass and greater muscle strength in upper extremities are those that exhibit a lower aging rate, and thus a lower physiological age. Hand grip strength is extensively used as a functional marker among older people and is used to define cutoff points for sarcopenia.[35] This functional measure is not a target during exercise training; therefore it is less amenable of being modified by external or behavioral issues. A recent report showed that exposure to physical work had an almost negligible effect on this parameter.[36]

No other association between leukocyte telomere length and other studied variables was found. There are many explanations for this lack of association. The most obvious, is that the study may be underpowered to demonstrate a difference in telomere length and functional or socioeconomic parameters, considering the great variability of T/S ratio.[37] The other explanation is that leukocyte telomere length has no biological association with functionality or socioeconomic level of older people. This is also a reasonable explanation, considering that T/S ratio is measured in a particular type of cells that may have no relationship with muscle or vascular cells. In a previous study we measured T/S ratio in muscle biopsies and observed significant differences between sarcopenic older people and their younger counterparts.[38] However a meta-analysis showed that there is an association, although weak, between telomere length and socioeconomic status.[39]

This study has several weaknesses. Namely it is a cross sectional study in which we evaluated only women, therefore results cannot be extrapolated to men. Another limitation is that measurements of quality of life and biological parameters were not simultaneous; therefore quality of life scores could have been different at the time of the second assessment. The thorough assessment of functional parameters performed in this study, which have been previously validated in similar populations and that have a prognostic value both in terms of mortality and functional decline, is a strength.

Conclusions

Successful aging among a population of elderly Chilean women was associated with socioeconomic status and quality of life perception.

References

1. National Statistics Institute of Chile (INE). Statistical Compendium 2010. Last consultation January 20th, 2013. Available at: http://www.ine.cl/canales/menu/publicaciones/compendio_estadistico/compendio_estadistico2010.php.
2. Fuentes-García A, Sánchez H, Lera L, Cea X, Albala C. Socioeconomic inequalities in the onset and progression of disability in a cohort of older people in Santiago (Chile). *Gac Sanit*. 2013;27:226–232.
3. Arroyo P, Lera L, Sánchez H, Bunout D, Santos J, Albala C. Anthropometry, body composition and functional limitations in the elderly. *Rev Med Chil*. 2007;135:846–854.
4. Mardones F. Inequality of health care for the elderly in Chile. *Rev Med Chil*. 2004;132:865–872.
5. Albala C, Sánchez H, Lera L, Angel B, Cea X. Socioeconomic inequalities in active life expectancy and disability related to obesity among older people. *Rev Med Chil*. 2011;139(10):1276–1285.
6. Winkleby MA, Jatulis DE, Frank E, Fortmann SP. Socioeconomic status and health: how education, income, and occupation contribute to risk factors for cardiovascular disease. *Am J Public Health*. 1992;82:816–820.
7. Lazzarino A, Hamer M, Stamatakis E, Steptoe A. The combined association of psychological distress and socioeconomic status with all-cause mortality. *JAMA Intern Med*. 2013;173(1):22–27.
8. Inoue N. Stress and atherosclerotic cardiovascular disease. *J Atheroscler Thromb*. 2014;21(5):391–401.
9. Dhabhar FS. Effects of stress on immune function: the good, the bad, and the beautiful. *Immunol Res*. 2014;58(2–3):193–210.
10. Seib C, Whiteside E, Humphreys J, et al. A longitudinal study of the impact of chronic psychological stress on health-related quality of life and clinical biomarkers: protocol for the Australian Healthy Aging of Women Study. *BMC Public Health*. 2014 Jan 8;14:9. http://dx.doi.org/10.1186/1471-2458-14-9.
11. Parks C, Miller D, McCanlies E, et al. Telomere length, current perceived stress, and urinary stress hormones in women. *Cancer Epidemiol Biomarkers Prev*. 2009;18(2):551–560.
12. Epel E, Blackburn E, Lin J, et al. Accelerated telomere shortening in response to life stress. *Proc Natl Acad Sci U S A*. 2004;101(49):17312–17315.
13. Aubert G, Lansdorp PM. Telomeres and aging. *Physiol Rev*. 2008;88:557–579.
14. Ehrlenbach S, Willeit P, Kiechl S, et al. Influences on the reduction of relative telomere length over 10 years in the population-based Bruneck study: introduction of a well-controlled high-throughput assay. *Int J Epidemiol*. 2009;38(6):1725–1734.
15. Bunout D, Osorio P, Barrera G, et al. Quality of life of older Chilean people living in metropolitan Santiago, Chile: influence of socioeconomic status. *Ageing Res*. 2012;4. e3:15–18.
16. Dam TT, Peters KW, Fragala M, et al. An evidence-based comparison of operational criteria for the presence of sarcopenia. *J Gerontol A Biol Sci Med Sci*. 2014;69:584–590.
17. Folstein MF, Folstein SE, Mchugh PR. Mini-Mental state: a practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res*. 1975;12:189–198.
18. Barrera G, Bunout D, de la Maza MP, Leiva L, Hirsch S. Carotid ultrasound examination as an aging and disability marker. *Geriatr Gerontol Int*. 2014;14(3):710–715.
19. Espinoza I, Osorio P, Torrejón MJ, Lucas-Carrasco R, Bunout D. Validation of the WHOQOL-BREF quality of life questionnaire among Chilean older people. *Rev Med Chil*. 2011;139:579–586.
20. Rockwood K, Awalt E, Carver D, MacKnight C. Feasibility and measurement properties of the functional reach and the timed up and go tests in the Canadian study of health and aging. *J Gerontol A Biol Sci Med Sci*. 2000;55:M70–M73.
21. McGavin CR, Gupta SP, McHardy GJ. Twelve-minute walking test for assessing disability in chronic bronchitis. *Br Med J*. 1976 Apr 3;1(6013):822–823.
22. Bunout D, Barrera G, Leiva L, et al. Effects of vitamin D supplementation and exercise training on physical performance in Chilean vitamin D deficient elderly subjects. *Exp Gerontol*. 2006;41:746–752.
23. Stein JH, Korcarz CE, Post WS. Use of carotid ultrasound to identify subclinical vascular disease and evaluate cardiovascular disease risk: summary and discussion of the American Society of Echocardiography consensus statement. *Prev Cardiol*. 2009;12(1):34–38.
24. Bunout D, Barrera G, De La Maza T, et al. Lean and fat mass as determinants of muscle strength and insulin sensitivity in Chilean elderly subjects. *J Nutr Health Aging*. 2004;8:374–378.
25. Cawthon R. Telomere measurement by quantitative PCR. *Nucleic Acids Res*. 2002;30(10):e47.

26. Schoene D, Wu SM, Mikolaizak AS, et al. Discriminative ability and predictive validity of the timed up and go test in identifying older people who fall: systematic review and meta-analysis. *J Am Geriatr Soc*. 2013;61:202–208.
27. Alfonso-Rosa RM, Del Pozo-Cruz B, Del Pozo-Cruz J, Del Pozo-Cruz JT, Sañudo B. The relationship between nutritional status, functional capacity, and health-related quality of life in older adults with type 2 diabetes: a pilot explanatory study. *J Nutr Health Aging*. 2013;17:315–321.
28. Lazzarino AI, Hamer M, Stamatakis E, Steptoe A. Low socioeconomic status and psychological distress as synergistic predictors of mortality from stroke and coronary heart disease. *Psychosom Med*. 2013;75:311–316.
29. Marmot M. Social determinants of health inequalities. *Lancet*. 2005;365:1099–1104.
30. Perez DF, Ritvo PG, Brown PE, Holowaty E, Ardern C. Perceived walkability, social support, age, native language, and vehicle access as correlates of physical activity: a cross-sectional study of low-socioeconomic status, ethnic, minority women. *J Phys Act Health*. 2011;8:1098–1107.
31. Quinn K, Kaufman JS, Siddiqi A, Yeatts KB. Stress and the city: housing stressors are associated with respiratory health among low socioeconomic status Chicago children. *J Urban Health*. 2010;87:688–702.
32. Nordahl H, Rod NH, Frederiksen BL, et al. Education and risk of coronary heart disease: assessment of mediation by behavioral risk factors using the additive hazards model. *Eur J Epidemiol*. 2013;28:149–157.
33. Quan S, Jeong JY, Kim DH. The relationship between smoking, socioeconomic status and grip strength among community-dwelling elderly men in Korea: Hallym aging study. *Epidemiol Health*. 2013;35:e2013001. http://dx.doi.org/10.4178/epih/e2013001 [Epub 2013 Feb 18].
34. Hurst L, Stafford M, Cooper R, Hardy R, Richards M, Kuh D. Lifetime socioeconomic inequalities in physical and cognitive aging. *Am J Public Health*. 2013;103:1641–1648.
35. Sallinen J, Stenholm S, Rantanen T, Heliövaara M, Sainio P, Koskinen S. Hand-grip strength cut points to screen older persons at risk for mobility limitation. *J Am Geriatr Soc*. 2010;58:1721–1726.
36. Møller A, Reventlow S, Hansen AM, et al. Does a history of physical exposures at work affect hand-grip strength in midlife? A retrospective cohort study in Denmark. *Scand J Work Environ Health*. 2013;35(1):98–111.
37. O'Donnell CJ, Demissie S, Kimura M, et al. Leukocyte telomere length and carotid artery intimal medial thickness: the Framingham Heart Study. *Arterioscler Thromb Vasc Biol*. 2008;28:1165–1171.
38. Bunout D, Backhouse C, Leiva L, et al. Relationship between protein and mitochondrial DNA oxidative injury and telomere length and muscle loss in healthy elderly subjects. *Arch Gerontol Geriatr*. 2009;48:335–339.
39. Robertson T, Batty GD, Der G, Fenton C, Shiels PG, Benzeval M. Is socioeconomic status associated with biological aging as measured by telomere length? *Epidemiol Rev*. 2013;35(1):98–111.