Comparing the differences in three measures of healthy life expectancy, effects of mortality, and proportions of unhealthy people according to prefectures in Japan: An Ecological study

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Research note

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Abstract

Objective: An Ecological study using open data collected, compiled, and published in government statistics in Japan was conducted. The study aimed to verify the differences in these three measures of healthy life expectancy (HLE), namely disability-free life expectancy without activity limitation (DFLE-AL), life expectancy with self-perceived health (LE-SH), and disability-free life expectancy without care need (DFLE-CN), in relation to appropriate policymaking.

Results: Using data from 47 prefectures in 2010, 2013, and 2016, the three types of HLE were extended over time. There were strong correlations between DFLE-AL and LE-SH (r = 0.69–0.83) as well as LE and DFLE-CN (r = 0.75–0.98) in both sexes. However, the other correlations were either weak or not significant. Regression analysis examining the association between the aging rate, mortality, the proportion of unhealthy people, and three types of HLE showed that the "subjective unhealthy rate" was significant (the standardized partial regression coefficients = -0.56– -0.34) in models with DFLE-AL and LE-SH as dependent variables. Therefore, DFLE-CN was suggested to be a different indicator from the other two HLEs. The "subjective unhealthy rate" had a significant influence on the prefectural DFLE-AL and LE-SH.

Introduction

The healthy life expectancy (HLE) has been one of the important goals of the national health policy in Japan.[1] The HLEs that local governments have set as the target value were calculated using the Sullivan method.[2] There are several definitions of "unhealthy," and three measures of HLE that differed according to the definition of "unhealthy" have been used as target values.[3] These three measures of HLE were selected for this study and comprised the following: (i) disability-free life expectancy without activity limitation (DFLE-AL), (ii) life expectancy with self-perceived health (LE-SH), and (iii) disability-free life expectancy without care need (DFLE-CN) (Additional file.1).

Some studies[4-6] and surveys of local governments[7-8] on the factors that extend these HLE measures have been reported, but these studies referred only to a single HLE, and few reports have mentioned the differences between and characteristics of different measures of HLE. Furthermore, even in studies in which sub-concepts, such as frailty and ADL, were set as objective variables instead of HLE, it was concluded that they contributed to the HLE extension. Moreover, the three measures of HLE were not distinguished and tended to be treated as a single indicator.[9-12]

LE-SH and DFLE-AL can be calculated only every three years because the basic data for their calculations are extracted from the survey of the Japanese government, which is carried out every three years. It has also been reported that while Life Expectancy (LE) and HLE are consistently linearly extended in both sexes, the percentage of unhealthy periods in LE has also increased.[13] Therefore, the evaluation of HLE every three years may show the extension of HLE due to the extension of LE. In Japanese administrative organizations, the linkage between policy and budget system has been regarded as an issue.[14] HLE evaluation every three years is disadvantageous in that it cannot be linked to the project budget that is carried out every year. In policymaking, clarifying the relationships between HLE, mortality, and the proportion of unhealthy people, seeking the indicator that can be monitored annually by local governments, is important. By evaluating the indicator every year, it can also be expected that the influence of the extension of LE will be reduced.

This study aimed to compare LE and three measures of HLE and clarify the association between mortality, the proportion of unhealthy people, and each measure of HLE.

Methods

Study design and data resource

We conducted an ecological study using open data collected, compiled, and published as government statistics for 2010, 2013, and 2016 by prefecture. The data used for analysis were LE, three measures of HLE—population by age, number of deaths, and the number of unhealthy people. The values of the three measures of HLE and LE were obtained from the "Healthy Life Report from Japan."[3] All other variables were derived from the government statistics website, "e-Stat."[15] The population by age was derived from the 2010 population census and population estimates from 2013 and 2016. The number of deaths was derived from official vital statistics. There are three measures of "number of unhealthy people," as they vary according to the method of HLE (Additional file1). In DFLE-AL, the people who answered "Yes" to the question "Do health problems currently affect your daily life in some way? (Yes/No)" were regarded as unhealthy, and in LE-SH, the people who answered "Not very good" or "Not good" to the question "What is your current state of health?", which is rated on a 5-point scale (range, not good–very good), were regarded as unhealthy. The numbers of unhealthy persons in DFLE-AL and LE-SH were derived from a comprehensive survey of living conditions.[16] In DFLE-CN, the people requiring long-term care (level 2 or higher) were determined to be unhealthy in a survey of long-term care benefit expenses.[17]

Main outcome

LE and three measures of HLE were used as outcome variables.

Main predictors

The predictor variables were converted to the following rates or ratios: aging rate, mortality, and proportion of unhealthy people. The proportion of unhealthy people was used as the main predictor. In this paper, we define the proportion of unhealthy people for three measures of HLE as the restriction rate for DFLE-AL, the subjective unhealthy rate for LE-SH, and the care need rate for DFLE-CN. The restriction rate and the subjective unhealthy rate were calculated by dividing the number of unhealthy people in the anonymous self-administered questionnaire by the number of each survey respondents. The care need rate was calculated by dividing the number of persons requiring long-term care (level 2 or higher) by the number of persons aged ≥40 years who were eligible for long-term care insurance.

Other variables

Mortality, aging rate, and data year were used as the other predictor variables. Mortality was calculated by dividing the number of deaths by the total population. The aging rate was calculated by dividing the population aged ≥65 years by the total population. Data year was used after converting from 1 to 3 in the order of 2010, 2013, and 2016. To assist with interpretation, all variables except data year were expressed in “per 1000 persons.”

Statistical analyses

First, Spearman's rank correlation coefficients for LE and the three measures of HLE were calculated to confirm their similarity. Then, regression analysis was performed using a generalized linear mixed model (GLMM), in which three measures of HLE were used as dependent variables. Data year, aging rate, mortality, and proportion of unhealthy people were included as independent variables.

In the regression analysis according to the GLMM, data of 47 prefectures in 2010, 2013, and 2016 were combined for all variables and treated as variables of 140 samples (the data for Kumamoto Prefecture in 2016 are missing due to an earthquake). For the independent variables, the model was constructed after the evaluation of multicollinearity using a variance inflation factor (VIF). Models with both aging rate and mortality as independent variables had a high VIF value of 8.4–15.2, which could lead to multicollinearity problems. Therefore, Model 1, with data year, aging rate, restriction rate, subjective unhealthy rate, and care need rate as independent variables, and Model 2, with mortality as the independent variable in place of the aging rate, were developed. In these two models, regression analyses were performed by sex with each HLE as the dependent variable. For all regression analyses, we calculated a random slope for the data year variable and a random intercept by the prefecture variable (Figures 1 and 2).

For estimation of the parameters, simulated draws from the posterior were obtained for each parameter using the Markov chain Monte Carlo (MCMC) method.[18-19] The simulated draws were preceded with 2500 “burn-in” draws, which were discarded from the analysis. The MCMC chain was thinned by including only every second draw, yielding 5000 simulated posterior observations. Then, Rhat was calculated to confirm the convergence of the simulation. Rhat is an index of the divergence between chains, and in the case of three or more chains, if it is 1.1 or less by convention, it is considered to have converged.

Analyses were performed using the open source statistical software R (ver. 3.6.2)[20,] and the Rstan[19] package was used for the parameter estimation by MCMC.

Results

The correlations between DFLE-AL and LE-SH were high for both males and females (males, 0.74–0.83; females, 0.69–0.79) in all data years. However, the correlation between DFLE-CN and the other two measures of HLE was moderately correlated at 0.46–0.57 in males but not significantly correlated (or weakly correlated) at 0.31 in females. Furthermore, the correlation between LE and DFLE-CN showed a strong correlation with 0.97–0.98 for males and 0.75–0.85 for females. However, the correlation between LE and the other two HLEs was moderate at 0.42–0.55 for males and not significant (or weak) at 0.30 for females. (Additional file 2, Table 1)

The GLMM results for the standardized partial regression coefficients (β) in males (Figure.1) showed that, for all models with DFLE-AL and LE-SH as dependent variables, data year (β = 0.74–1.11) and subjective unhealthy rate (β = -0.43– -0.34) were significant factors. For both models with DFLE-CN as dependent variable, care need rate (β = -0.50– -0.19) were significant.

The GLMM results for the standardized partial regression coefficients in females (Figure 2) showed that, for all models with each HLE as dependent variables, data year (β = 0.18– 1.02) was a significant factor. Among the models with DFLE-AL and LE-SH as dependent variables, subjective unhealthy rate (β = -0.56– -0.54) was significant in all models. For both models with DFLE-CN as the dependent variable, care need rate (β = -0.22– -0.27) were significant.

Finally, values of Rhat equaled to 1.0 for all parameters, indicating convergence across the four chains initiated from disparate starting values. All indications pointed to the fact that the MCMC algorithm achieved convergence for all parameters.

Discussion

The GLMM results showed that data year had the greatest influence on all three measures of HLE for both sexes, suggesting the LE extension over time might be significant. In addition, from the results of Spearman's correlation coefficient, DFLE-AL and LE-SH had strong correlations with r = 0.69–0.83 for all “Data years,” indicating that these indices are similar. Nevertheless, DFLE-CN showed a strong correlation (r = 0.75–0.98) with LE rather than the other two HLEs; therefore, DFLE-CN appeared to be an indicator more closely aligned to LE than the other two measures of HLE.

In DFLE-AL, a third-party judges the state of health based on the physical condition, which depends on the nursing care insurance system, so that the physical aspects are strongly reflected. The other two HLEs are questionnaire-based unhealthy judgments, but women are considered to have no correlation because they judge health in other aspects, such as psychological and social aspects. It was reported that women tend to report worse subjective health than men, and gender gaps in subjective are health not systematically related to socioeconomic gender inequalities.[21-22] Hence, it is not clear why there is a gender gap in subjective health (i.e., the “subjective unhealthy rate”).

Furthermore, the GLMM result shows that the “subjective unhealthy rate” influenced the DFLE-AL and LE-SH, that used subjective health scales involving an anonymous self-administered questionnaire to calculate the proportion of unhealthy people. This finding supports previous studies, which reported that subjective health was related to reducing mortality and the incidence of cardiovascular diseases.[23-26] Other studies that examined factors that extend HLE also reported that eliminating malignant neoplasms, cerebrovascular diseases neoplasms, and cerebrovascular diseases extends DFLE-CN,[4] and that lifestyle habits, such as smoking cessation and vegetable intake, are associated with the extension of DFLE-CN.[7-8] Therefore, the "subjective unhealthy rate" may be an indicator for predicting the extension of DFLE-AL and LE-SH as a representative measure of these factors showed in previous studies.

From these results, it is necessary to evaluate the extension of DFLE-CN in consideration of the large influence of extension of LE, and annual monitoring of the “subjective unhealthy rate” can be useful in evaluating the extension of LE-SH and DFLE-AL. If the subjective unhealthy rate is evaluated every year, projects related to the extension of HLE can also be evaluated every year, the cooperation with the budget can be made, and the effect of the extension of the LE on the extension of HLE by will be reduced.

Conclusion

All three HLEs was most associated with increased life expectancy over time. DFLE-AL, and LE-SH were strongly correlated, and the evaluation excluding the effect of LE is necessary for DFLE-AL. The subjective unhealthy rate had a significant influence on prefectural DFLE-AL and LE-SH.

Limitations

This ecological study was conducted on a prefectural basis and could not assess HLE at an individual level. Further, the care need rate was calculated by dividing the population aged ≥40 years; however, the rate might have been underestimated due to the large denominator, as people aged between 40 and 65 years and eligible for long-term care insurance are limited to those with certain diseases.

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and material

The data used in this study are those that have been researched by the Japanese government and made publicly available on the website.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

KT planned the study, performed all analyses, and wrote the paper. SO and KK supervised the data analysis and contributed to revising the paper.

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Abbreviations

LE: Life expectancy

HLE: Healthy life expectancy

DFLE-AL: Disability-free life expectancy without activity limitation

LE-SH: Life Expectancy with self-perceived health

DFLE-CN: Disability-free life expectancy without care need

ADL: Activities of daily living

IADL: Instrumental activities of daily living

GLMM: Generalized linear mixed model

MCMC: Markov chain Monte Carlo method

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Table

Table 1. Correlation coefficients for life expectancy and three measures of healthy life expectancy according to year

		Male				Female			
		LE	DFLE-AL	LE-SH	DFLE-CN	LE	DFLE-AL	LE-SH	DFLE-CN
2010 (n = 47)	LE	1.00				1.00			
	DFLE-AL	0.43**	1.00			0.06	1.00		
	LE-SH	0.44**	0.83**	1.00		0.18	0.72**	1.00	
	DFLE-CN	0.97**	0.48**	0.50**	1.00	0.85**	0.13	0.27	1.00
2013 (n = 47)	LE	1.00				1.00			
	DFLE-AL	0.43**	1.00			0.02	1.00		
	LE-SH	0.51**	0.74**	1.00		0.16	0.79**	1.00	
	DFLE-CN	0.98**	0.48**	0.57**	1.00	0.84**	0.16	0.19	1.00
2016 (n = 46†)	LE	1.00				1.00			
	DFLE-AL	0.42**	1.00			-0.08	1.00		
	LE-SH	0.55**	0.81**	1.00		0.30*	0.69**	1.00	
	DFLE-CN	0.98**	0.46**	0.56**	1.00	0.75**	0.02	0.31*	1.00

*p < .05, **p < .01

†The data for Kumamoto Prefecture in 2016 is missing due to an earthquake

Abbreviations: DFLE-AL, disability-free life expectancy without activity limitation; DFLE-CN, disability-free life expectancy without care need; LE, life expectancy; LE-SH, life expectancy with self-perceived health

Supporting Information

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Figures

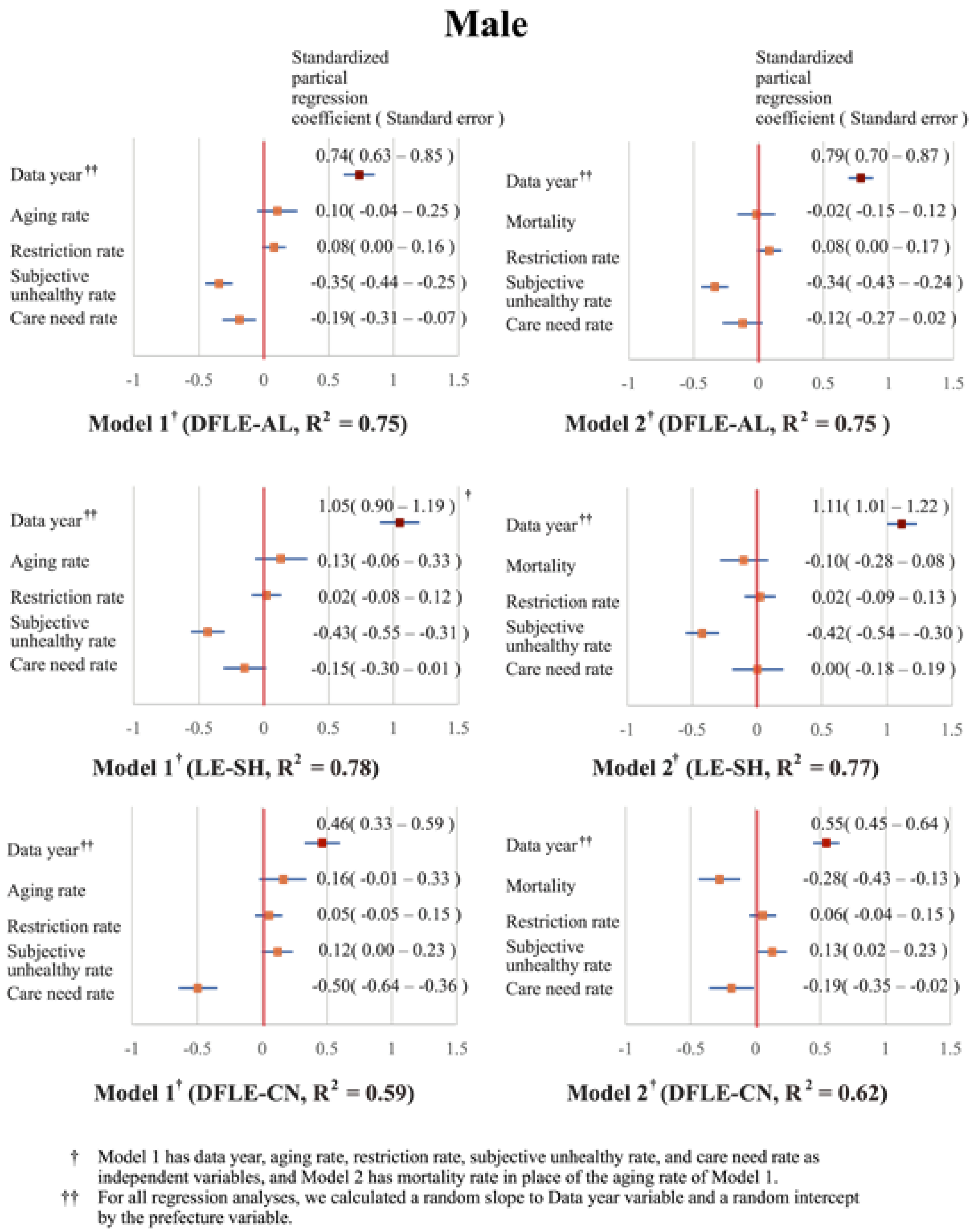

Figure 1

Regression analysis of the generalized linear mixed model of males with the three measures of HLE Abbreviations: DFLE-AL, disability-free life expectancy without activity limitation; DFLE-CN, disability-free life expectancy without care need; LE, life expectancy; LE-SH, life expectancy with self-perceived health

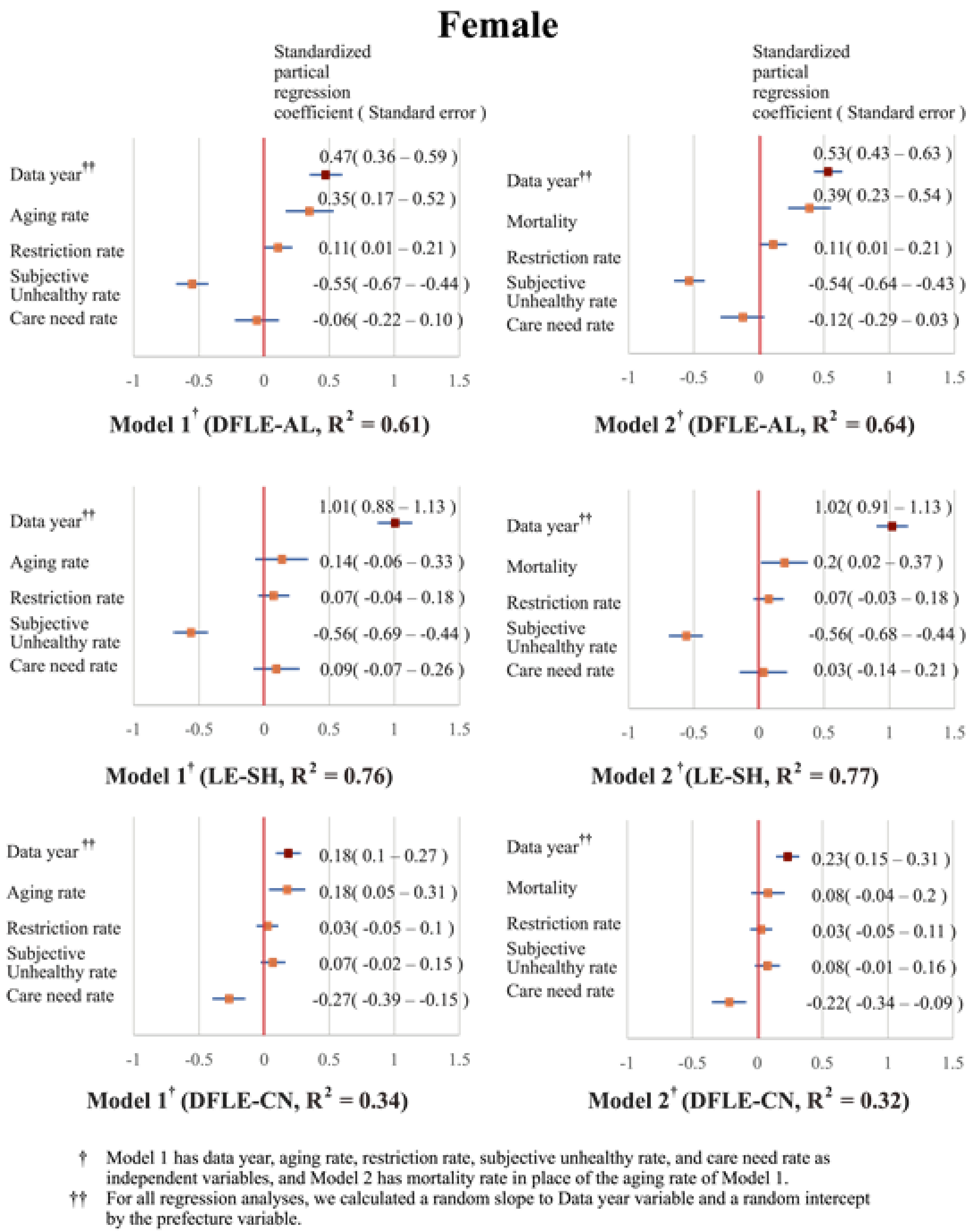

Figure 2

Regression analysis of the generalized linear mixed model of females with the three measures of HLE Abbreviations: DFLE-AL, disability-free life expectancy without activity limitation; DFLE-CN, disability-free life expectancy without care need; HLE, healthy life expectancy; LE, life expectancy; LE-SH, life expectancy with self-perceived health

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