Associations between Seasonal Variation of Heart Rate Variability and Healthy Life Expectancy in Japan

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***Abstract*—Although both summer heat and winter cold increase the risk of health problems, the effects could be modified by living environment and clothes. We investigated the relationship between regional differences in healthy life span (HALE)and seasonal variations in Heart Rate Variability (HRV) that may reflect biological burden caused by heat and cold weather. Using the Allostatic State Mapping by Ambulatory ECG Repository (ALLSTAR) database, we analyzed the 24-h standard deviation of sinus-rhythm R-R intervals (SDNN) among 86,712 men and 108,771 women across Japan as a measure of HRV. Then, SDNN data were divided into 47 prefectures, averaged over 4 seasons, and associated with the prefectural averages of HALE reported by Japanese government. As the results, in both sexes, prefectural age-adjusted HALE negatively correlated with seasonal variation of prefectural age-adjusted SDNN, while it did not corelated significantly with prefectural age-adjusted SDNN of any seasons. Additionally, there was no significant correlation between prefectural age-adjusted average life expectancy and the seasonal variation of prefectural age-adjusted SDNN. Our observations support the hypothesis that the magnitude of the seasonal variation in biological burden might be a shortening factor for HALE.**

***Index Terms*—ALLSTAR, healthy life expectancy, heart rate variability, seasonal**

I. Introduction

Along with increasing aging societies, the gap between Average Life Expectancy(ALE) and healthy life expectancy (HALE) became a critical issue (Fig. 1) [1]. For Japanese men, the last 9.79 years of their lives cannot live on their own for health reasons. This period is 12.99 year in Japanese women. By improving preventive medicine and improving lifestyle through public health awareness, HALE has gradually increased, but the gap has hardly narrowed as ALE has also increased.

It is recognized that HALE shows a distinct regional difference in Japan [1]. Although the clear reasons for the regional difference are unknown, in an ambulatory ECG big data study, we have previously reported that regional differences in HALE but not ALE are associated with regional differences in Heart Rate Variability (HRV); prefectures with higher age-adjusted HRV have longer age-adjusted HALE in both men and women [2]. Using big data of actigraphic physical activity, we have also observed the association between regional difference in age-adjusted physical activity and age-adjusted HALE [3].

However, it is still unclear why there are differences in HRV and physical activity between prefectures. Although the influence of climate differences between prefectures can be considered, the regional distribution of HALE, HRV, and physical activity observed so far does not match the distribution of average temperature and precipitation. In this study, we hypothesized that the physiological effects of seasonal variations may be a factor of regional variation in HALE. Although both summer heat and winter cold increase the risk of health problems, the effects could be modified by living environment and clothes. We therefore investigated the seasonal variations in HRV that may reflect biological burden caused by heat and cold weather. Using an ambulatory ECG big data of Allostatic State Mapping by Ambulatory ECG Repository (ALLSTAR) [4], we analyzed the relationship between regional differences in HALE and seasonal variations in HRV.

II. Methods

A. Database

We studied Holter ECG big data that has been accumulated by ALLSTAR Research Group since 2009 [5]. The database consists of >300 thousand of 24-hr Holter ECG recorded with standardized Holter recorders (Cardy 303 pico+, Suzuken CO., LTD, Nagoya, Japan) between April 2012 and July 2014 in almost all prefectures in Japan. We used data only from subjects >20 whose electrocardiogram showed sinus rhythm >90% of the recording length with no abnormal finding on clinical ECG diagnosis. The study protocol has been approved by the Research Ethics Committee of Nagoya City University Graduate School of Medical Sciences (No. 709).

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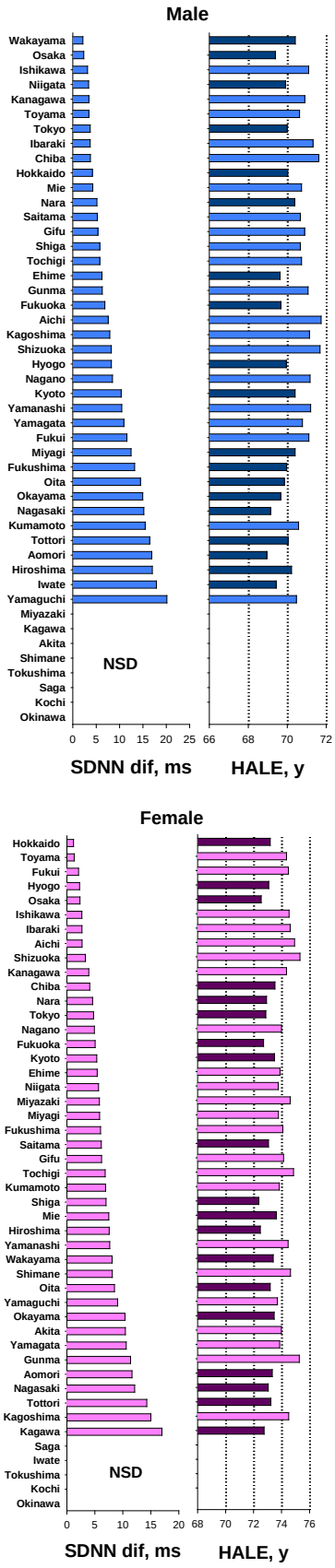

Figure 2. Seasonal difference in SDNN and healthy life expectancy (HALE) in Japanese prefectures. SDNN dif = range of seasonal difference in SDNN; NSD = no sufficient data.

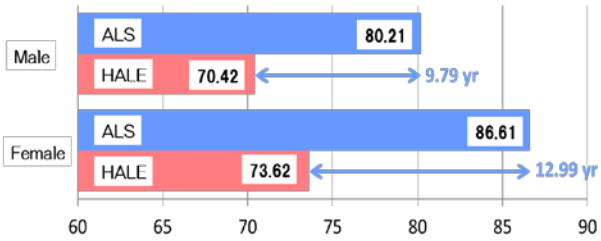

Figure. 1. Average life expectancy (ALE) and healthy life expectancy (HALE) in Japanese men and women (from Japanese Health, Labor, and Welfare Ministry).

B. Data Analysis

The Holter ECG signals were analyzed by a Holter ECG scanner (Cardy 5, Suzuken Co., LTD, Nagoya, Japan), on which all QRS waves were detected and labeled for rhythm annotations. We analyzed 24-hour SD only from normal-to-normal R-R intervals (SDNN) as an HRV measure among 86,712 men (median age [IQR], 68 [56-77] yr) and 108,771 women (70 [58-79] yr).

SDNN were divided into the matrix of 47 prefectures x four seasons, and least-square means adjusted for the effect of age were calculated for each cell. The seasonal difference in SDNN of each prefecture was defined as the range of difference among four seasons (max-min) and was associated with the prefectural averages of HALE and ALE reported by Japanese government (the inter-prefecture ranking of HALE published by the Japanese Health, Labour, Welfare Ministry [1] (Fig. 2). Only prefectures with an enough sample size >150 for each sex were used for analysis.

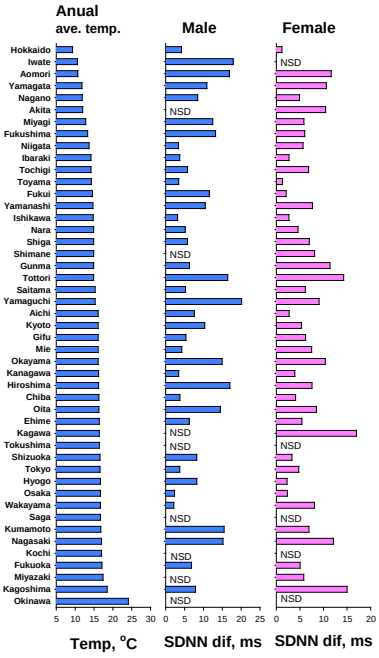

Figure 3. Annual average temperature and seasonal difference in SDNN in Japanese prefectures. SDNN dif = range of seasonal difference in SDNN; NSD = no sufficient data.

III. Results

Although there were no significant correlations between HALE and SDNN of any seasons, significant negative correlation between seasonal difference in SDNN and HALE was observed in men, but not in women (Table I). In men, there was a tendency that seasonal difference in SDNN was larger in prefectures where HALE was shorter than the median (seasonal SDNN difference, 10.1 ± 5.7 vs. 7.3 ± 3.8 ms, P = 0.08; Fig. 2). In neither sex, any seasonal SDNN nor seasonal change in SDNN correlated with ALE (Fig. 3).

IV. Discussions

In this study, we analyzed the relationship between seasonal variation in SDNN and HALE among Japanese prefectures. We observed the negative association between seasonal difference in SDNN and HALE only in men but not in women.

Although the presence of seasonal differences in HRV has been reported [6], the interaction between the effects of seasons and occupation has also been recognized [7], i.e., the contrast of HRV between summer and winter may be greater in outdoor workers than indoor workers. This suggests that the health burden of seasonal environmental changes may be related not only to seasonal variations in the outdoor climate environment but also to seasonal variations in the indoor living environment. On the other hand, buildings and clothes in cold regions have high cold protection functions, but those functions are low in warm regions. Conversely, cold regions have a weaker function against heat than warm regions. Consequently, health burden in winter season could be greater in warm regions and that in summer season could be greater in cold regions. These suggest that seasonal health effects may depend on many factors including regional climate, occupation, home and office architecture, and clothes customs.

In the present study, we observed significant association between seasonal difference in SDNN and HALE only in men but not in women (Fig. 2). This may not be attributed to physiological gender difference, because we previously observed significant association between the prefectural average of age-adjusted SDNN and prefectural average of HALE in both men and women [2]. In general, men still have more opportunities to spend outside than women in Japan. Thus, current observations suggest the potential impact of differences in the causes of seasonal variations in SDNN, i.e., whether due to seasonal variations in the outdoor climate or seasonal variations in the indoor environment. We also observed no significant association between annual average temperature and seasonal variation in SDNN in either sex (Fig. 3). This observation supports that seasonal health effects are not explained only by outdoor climate. Fig. 3 also shows that there are considerable differences in the seasonal variation of SDNN even within cold, medium and warm regions, suggesting the impact of unmeasured factors such as economy and industry. These points need further analyses in future studies.

This study has limitations. First, the seasonal variation in HRV was estimated by comparing the data obtained in different seasons recorded in different subjects. Although many subjects in each season can be expected to average out the effects of individual differences, it is ideal to compare data obtained in different seasons in the same subject. Second, the ALLSTAR database consisted of Holter ECG recoded for clinical reasons. Although we used only data with no abnormal finding on clinical ECG diagnosis, the influence cannot be excluded for diseases that do not show abnormalities in ECG, particularly, those with seasonal variations in incidence. Third, we compared prefectural average of HALE and prefectural average of HRV. While HALE reflects the value expected of people aged 0, HRV was measured in adult >20 years and most of them were in their 50s to 70s. Although we adjusted the effect of age on HRV, the actual healthy life span of the subjects could differ from the HALE used in this study.

V. Conclusions

Using ALLSTAR big data, we analyzed the relationship between seasonal variation in SDNN and HALE among Japanese prefectures. We observed that HALE in men was shorter in prefectures with greater seasonal variation in HRV, although no significant association was observed for women. The magnitude of the seasonal variation in HRV may be a shortening factor for HALE in men but not women.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

EY managed the database, conceived the study, and critically reviewed the manuscript; MK maintained the database and analyzed data; YY analyzed the data; NU managed the database and critically reviewed the manuscript; JH analyzed the data and wrote the manuscript; all authors had approved the final version.

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