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REVIEW ARTICLE

Multidimensional insights about healthy aging from the cohort study for community-dwelling older adults: The SONIC study

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The Septuagenarian, Octogenarian, Nonagenarian Investigation with Centenarian (SONIC) study was established considering population trends and targeting the oldest-old population. This study is unique in its narrow age range, consisting of individuals aged in their 70s, 80s and 90s, and is carried out as a longitudinal cohort study with follow ups every 3 years in urban and rural areas of eastern and western Japan. The aims of the SONIC study are primarily to clarify aging-related changes in multiple domains of human functioning, explore the dynamics of interactions among these domains and identify factors influencing healthy longevity, including psychological well-being. Investigations spanning medical, dental, nutritional, psychological and sociological fields were carried out by specialists, yielding important results. Findings from the SONIC study in Japan, a super-aged society, will provide valuable information for addressing the global aging trend. This review introduces the results from the SONIC study, and explains factors contributing to healthy longevity and happy aging. **Geriatr Gerontol Int 2025; 25: 346–355**.

Keywords: healthy longevity, longitudinal cohort, multidimensional aspects, oldest-old population, SONIC study.

Introduction

Recent epidemiological studies on aging have identified factors related to health outcomes and longevity. In Japan, life expectancy has increased to 81.1 years for men and 87.1 years for women in 2024. The number of centenarians has surpassed 95 000, and is expected to quintuple by 2060. The most rapidly growing age group over the next decade will be the oldest-old (≥85 or ≥90 years). The Septuagenarian, Octogenarian, Nonagenarian Investigation with Centenarian (SONIC) study was established with this trend in mind, targeting the oldest-old population (Fig. 1).[1]

The SONIC study has two primary objectives: first, to clarify aging-related changes across various domains of human functioning and the interactions between these domains, and second, to identify factors that influence healthy longevity, including psychological well-being. The SONIC study's framework includes several unique characteristics. The first feature is its interdisciplinary nature, involving researchers from diverse fields, including medicine, biology, dentistry, nutrition, psychology and sociology.

The second characteristic is the participant diversity. The study spans four urban and non-urban areas in Kanto (Itabashi Ward and Nishitama area: Hinohara Village, Hinode Town, Okutama Town,

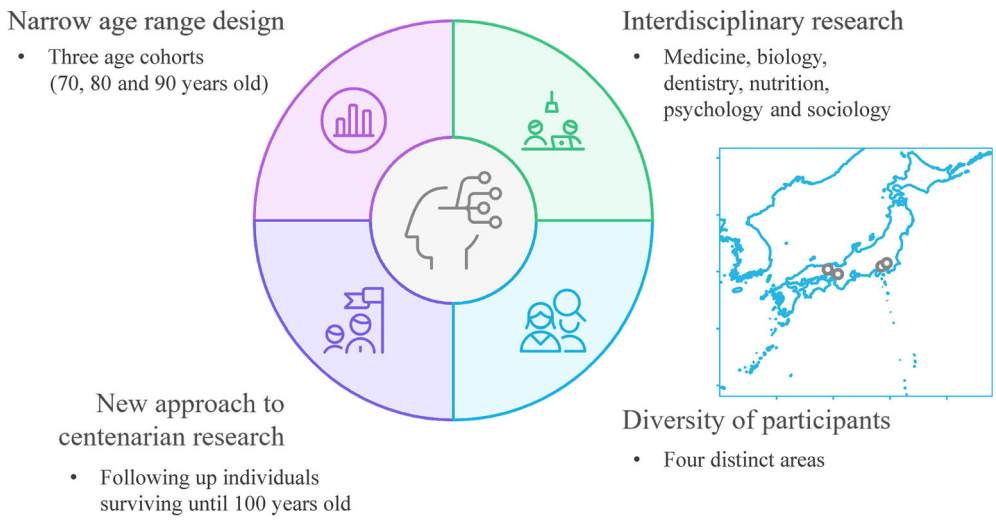

Figure 1 The features of the Septuagenarian, Octogenarian, Nonagenarian Investigation with Centenarian (SONIC) study.

and part of Ome City) and Kansai (Itami City and Asago City), each with distinct demographic and regional attributes. Participants represent varied sociodemographic backgrounds, including education, work experience, family structure and residential environment.

A third unique feature is the study's narrow age range design, which sets up three age cohorts (70, 80 and 90 years), each with a 3-year age span rather than a broader range. Follow-up surveys are carried out every 3 years for each cohort. By maintaining a narrow age range, the results can reflect individual differences without needing age as an adjustment variable.

A fourth feature positions the SONIC study as a novel approach to centenarian research, as indicated by its acronym. The study includes a large cohort with the potential to reach 100 years. For example, of the oldest cohort (90th) venue survey participants recruited in 2012 for the first time ($n = 325$, 140 men, 185 women), >47 survived until 100 years-of-age, and two could participate in the invitation-type study over the age of 100 years.

Participants completed various examinations in a random order at survey venues: verifying pre-filled questionnaires, answering additional psychosocial questions in interviews, undergoing cognitive tests, physical function tests, medical tests (including blood samples, blood pressure, breathing capacities, carotid ultrasonography) and dental assessments. (including natural teeth count, occlusal force, taste sensitivity and masticatory performance).

Data collection varied by cohort due to participant volume. The first wave began in 2010 for the 70s cohort, 2011 for the 80s cohort and 2012 for the 90s cohort. The second wave started in 2013 in the same sequence. For the 90s cohort, due to lower participation, additional recruitment occurred in 2015 and 2018.

All participants were recruited through residential registries, providing their name, sex, birth date and address within specific birth date ranges. These ranges differed slightly across the four study regions due to local government database schedules, time allocations for data transcription and regional recruitment start dates.

The SONIC study uses an invitation-based survey method, inviting participants to nearby survey venues, primarily local community centers owned by local governments. Invitations explained the study's purposes and methods. Participants confirmed their participation by returning an agreement letter specifying their preferred date and time. Additionally, invitees received a questionnaire booklet covering socioeconomic status, psychosocial variables, medical and dental conditions, and food intake to complete in advance. Participants who could not fill out the booklet themselves or with help from family completed it at the survey venue.

Tables 1 and 2 show participant totals and follow-up study participation by age cohort and sex.

Medical aspects

The main aim of the SONIC study is to investigate factors associated with healthy longevity, focusing on the decline of physical and cognitive function, diseases that influence the definition of healthy longevity, and related biomarkers, which are crucial for health promotion in Japan's super-aging society.[2]

Genetic factors in longevity

In the SONIC study, we explored genetic factors, focusing on genes associated with longevity and cardiovascular diseases (CVD). The Forkhead box transcription factor 3A (*FOXO3A*) gene is a strong candidate gene for longevity.[3,4] It has been reported that the single-nucleotide polymorphism, rs2802292, in *FOXO3A* is associated with both longevity[3] and protection against CVD[5] in Japanese Americans. We investigated the association of rs2802292 in *FOXO3A* with heart diseases in participants aged 70 and 80 years in the SONIC study, finding a newly clarified sex difference in this association.[6] Additionally, rs2802292 in *FOXO3A* was associated with hypertension in older women in the SONIC study.[7] The tumor suppressor genes, *CDKN2A/CDKN2B*, and the long non-coding RNA, ANRIL, at chromosome region 9p21 are known susceptibility loci for CVD.[8] We examined the association of several single-nucleotide polymorphisms in this region with CVD and longevity among the SONIC study participants and centenarians/supercentenarians, finding a positive association with CVD, but not with longevity.[9] We also explored mechanisms involving the expression of ANRIL and *CDKN2A/CDKN2B* in SONIC participants with carotid atherosclerosis.[10]

Factors related to cognitive decline and dementia

Dementia is a major threat to healthy longevity in Japan. In the SONIC study, we examined factors related to cognitive decline and dementia, particularly lifestyle-related diseases, such as hypertension, dyslipidemia and diabetes mellitus, which are prevalent in older adults and are potential risk factors for cognitive decline.[11]

Table 1 Invitation type participants of the Septuagenarian, Octogenarian, Nonagenarian Investigation with Centenarian (SONIC) study by data collection waves and years

		Sampled			Total			1st Wave			2nd Wave			3rd Wave			4th Wave			5th Wave		
Survey years							70	2010			2013	2014		2016	2017		2019	2020		2022	2023	
							80	2011			2014	2015		2017	2018		2020	2021		2023	2024	
							90	2012	2015	2018	2015	2018	2021	2018	21/22	23/24	2021	23/24	2027	23/24	2027	2030
		M	F	Total	M	F	Total	M	F	total	M	F	Total	M	F	Total	M	F	Total	M	F	Total
70	*n*	2247	2451	4698	576	653	1229	478	521	999	426	484	910	380	442	822	272	278	550	198	221	419
	%				25.6	26.6	26.2	83.0	79.8	81.3	74.0	74.1	74.0	66.0	67.7	66.9	47.2	42.6	44.8	34.4	33.8	34.1
80	*n*	2406	3451	5857	582	631	1213	460	513	973	487	497	984	272	268	540	85	83	168	60	59	119
	%				24.2	18.3	20.7	79.0	81.3	80.2	83.7	78.8	81.1	46.7	42.5	44.5	14.6	13.2	13.8	10.3	9.4	9.8
90	*n*	8441	15 566	24 007	422	461	883	393	414	807	151	189	340	57	51	108						
	%				5.0	3.0	3.7	93.1	89.8	91.4	35.8	41.0	38.5	13.5	11.1	12.2						

(1) Sampled indicates total number of people invited to the Septuagenarian, Octogenarian, Nonagenarian Investigation with Centenarian (SONIC) study.

(2)Total indicates the total number of participants in the SONIC study.

(3) We performed the 70s and 80s cohorts' first wave survey in 2010 and 2011. About the 90s cohort's, we recruited 90 years participants and performed first wave survey in 2012. In addition, we also recruited new 90 years participants and performed first wave survey both in 2015 and 2018.

(4) During the second wave of survey recruitment, we recruited the new 70s and 80s participants to compensate for the dropouts by sending an invitation letter.

(5) To increase participation, we recruited participants for two consecutive years from the second wave.

(6) We could not perform the invitation-type survey in 2020, because of the COVID-19 pandemic.

(7) In the 90s cohort, we will collect fifth wave data for participants recruted in 2015 future in 2027 and 2030, and we will collect fourth wave data for participants recruted in 2018 fourth wave data in 2030.

F, female; M, male.

Table 2 Number of mail survey participants during the COVID-19 pandemic

		2020				2021			
		Summer		Winter		Summer		Winter	
		M	F	M	F	M	F	M	F
70		366	456	298	353	339	410	300	358
80		269	306			178	227		
90	2012	24	42			10	23		
	2015	63	71			39	46		
	2018	106	94			70	71		

Mail surveys were performed four times for participants aged in their 70s, and twice for participants aged in their 80s and 90s.
F, female; M, male.

Blood pressure (BP) level is associated with cognitive decline, showing age-related differences.[12,13] Daily BP variability, measured at home, is also a factor associated with cognitive decline in individuals age >85 years.[14] Additionally, white coat and masked hypertension showed distinct characteristics across age groups.[15] Comorbid hypertension and diabetes mellitus[16] or dyslipidemia[17] were strong predictors of future cognitive decline. Silent strokes, commonly seen in older adults with hypertension, were also identified as a risk factor for cognitive decline.[18] Conversely, cognitive decline might lead to anemia in older adults.[19] Biomarkers for cognitive decline identified in the SONIC study include inflammation indicators, such as serum A/G ratio,[20] high-sensitivity C-reactive protein,[21] respiratory function[22] and a novel N-glycopeptide.[23] Daily alcohol intake might increase cognitive decline risk, whereas wine consumption might offer protective benefits.[24]

Factors related to physical frailty/sarcopenia and long-term care

The SONIC study also explored factors contributing to physical frailty and sarcopenia. Advanced age and musculoskeletal diseases are strongly associated with physical frailty.[25] However, we identified factors associated with future physical frailty that were stratified by the presence of musculoskeletal diseases.[26] Heart disease was a significant risk factor for future frailty in community-dwelling older adults.[27] Age differences were also evident in the associations between sleep status and frailty,[28] and the relationship of frailty with heart disease and social factors.[29] Low BP control among participants with hypertension at age 80 years was found to increase frailty risk.[13] Furthermore, no association was observed between daily salt intake and systolic BP in participants with physical frailty. In contrast, robust participants showed a positive association between systolic BP and salt intake.[30] Thus, salt intake restriction might be careful in older adults with frailty. Novel biomarkers related to frailty and sarcopenia included plasma adiponectin,[31] serum vitamin D[32] and the serum creatinine/cystatin C ratio.[33] Bodyweight loss was a strong predictor of frailty/sarcopenia, and we examined age-specific factors associated with weight loss in the 70s, 80s and 90s cohorts.[34] For long-term care certifications, diseases, such as stroke, musculoskeletal diseases and cancer, were linked to social subgroups.[35] Slow walking speed was a predictor of future long-term care certifications.[36] During the COVID-19 pandemic, we observed declines in daily activities and identified related factors in the SONIC study.[37]

Characteristics of diseases and geriatric syndrome in older adults

In the SONIC study, we investigated disease characteristics in older adults. Anemia is common among older adults and is a major factor in geriatric syndromes, potentially linked to low self-rated health in community-dwelling older adults.[38] Depressive symptoms, another common geriatric syndrome, might correlate with IADL decline, with differences across age groups.[39] Strict diabetes management might negatively impact mental health in older adults.[40] For atherosclerosis risk, we found that elevated uric acid levels were associated with carotid atherosclerosis in women at age 70 years, suggesting uric acid as a risk factor limited to certain age groups.[41] Additionally, adequate protein intake might not only slow chronic kidney disease progression in older adults, but also protect against frailty.[42]

Polypharmacy in older populations

Polypharmacy is a significant health concern in older adults, leading to frailty and increased healthcare costs in Japan. The SONIC study found that higher neuroticism in men and lower extraversion in women were associated with polypharmacy.[43] Taking ≥10 medications was linked to reduced grip strength and walking speed, whereas taking one to four medications was associated with increased walking speed.[44] Polypharmacy was also linked to a higher risk of falls.[45] Effective health management for older adults should emphasize minimizing unnecessary medication to improve health outcomes.

Validation of the health assessment questionnaire in older adults

To prevent lifestyle-related diseases and frailty, the Japanese government has implemented a screening program for older adults, especially those aged ≥75 years. This program includes a 15-item health assessment questionnaire focusing on frailty (12 items), general health (2 items) and smoking habits (1 item). Confirmatory factor analysis showed that a model with a higher-order factor of "frailty" with five subfactors (physical function, nutritional status, oral function, cognitive function and social aspects) was a good fit.[46] The 12 frailty-related items showed high predictive power for frailty prevalence based on the Japanese Cardiovascular Health Study criteria, with cut-off points of 3 and 4, yielding 55.9% sensitivity and 85.8% specificity, respectively.[47] These results suggest the questionnaire is effective for screening frailty in community-dwelling older adults.

Dental and nutritional aspects

Tooth loss and oral function

Tooth loss is one of the most prevalent oral health issues associated with aging. Our studies have shown that a reduction in posterior occlusal support is linked to an increased risk of tooth loss.[48,49] Hatta *et al.* reported that dental implants placed in free-end edentulous spaces might help extend the longevity of adjacent teeth.[50] The mechanism linking reduced occlusal support to tooth loss likely involves increased occlusal load or trauma to the remaining teeth. Tooth loss has a profound impact on masticatory function. Higashi *et al.* found that reduced occlusal support was associated with decreased masticatory performance.[51] Seto *et al.* showed that the number of teeth, occlusal force and depression can influence subjective evaluations of chewing difficulty.[52] Additionally, Hatta *et al.* showed that although tongue pressure decreased significantly over time, occlusal force did not, suggesting that tongue muscles might be more susceptible to aging than masticatory muscles.[53]

Impact of periodontal disease

Miki *et al.* identified that the periodontal inflamed surface area, which measures the severity and extent of periodontitis, was associated with high-sensitivity C-reactive protein, a marker of systemic inflammation.[54] Kitamura *et al.* suggested that maintaining good periodontal health might be important for preventing atherosclerosis development and progression.[55] Furthermore, periodontal probing depth correlated significantly with occlusal force and self-rated food acceptability, even among individuals with complete posterior occlusal contacts and no tooth mobility.[56]

Oral health-related quality of life

Takeshita *et al.* reported that personality traits are associated with oral health-related quality of life, independently of objective oral health measures.[57] Mihara *et al.* suggested that oral health-related quality of life correlates significantly with the degree of gerotranscendence, independent of objective oral health status.[58]

Association with nutritional intake

Inomata *et al.* examined the relationship between occlusal force, number of teeth and nutritional intake using a self-administered diet quality questionnaire.[59,60] The results showed that lower occlusal force was significantly associated with lower intake of vegetables and antioxidant vitamins. In the 70s age group, the number of teeth was associated with intake of calcium and zinc, whereas no significant associations were observed in the 80s group, suggesting that nutrient intake might be more closely related to occlusal force than to the number of teeth. Inomata *et al.* also reported that removable partial denture wearers consumed more vegetables, n-3 fatty acids, calcium, vitamin A and dietary fiber than non-wearers.[61] Mameno *et al.* found that occlusal force and occlusal contact area were significantly associated with dietary hardness.[62] These findings underscore the importance of prosthetic rehabilitation for maintaining adequate nutritional intake. Additionally, Fukutake *et al.* found that oral stereognostic ability was significantly associated with green and yellow vegetable intake in older complete denture wearers.[63] Tada *et al.* suggested that reduced posterior occlusion was associated with an increased prevalence of atherosclerosis due to declines in key dietary intakes, such as fish, shellfish, vitamin B6 and n-3 fatty acids.[64]

Association with physical function

Fukutake *et al.* assessed the impact of occlusal force and the number of teeth on body mass index reduction in older adults over a 3- to 6-year follow-up period.[65] The analysis showed that although the number of teeth was not significantly associated with body mass index reduction, lower occlusal force correlated with a decline in body mass index, suggesting that reduced occlusal force might contribute to weight loss. Okada *et al.* found that slow walking speed (<0.8 m/s) was significantly linked to occlusal force, with lower protein intake mediating this association.[66] Hatta *et al.* concluded that a lack of posterior occlusal support at baseline predicted reduced walking speed over 3 years.[67] These findings suggest that dental treatments to preserve occlusal support might help prevent a decline in walking speed. Our studies also identified that occlusal force, masticatory performance and tongue pressure were significantly associated with grip strength.[68,69] Murotani *et al.* found that tongue–lip motor and swallowing functions were good indicators of walking speed.[69] These measures could serve as proxies for physical decline in older adults, and may be valuable for screening physical frailty.

Association with cognitive function

In our study, the relationship between cognitive function and oral status was examined from multiple perspectives.[70–76] Ikebe *et al.* comprehensively explored this relationship, concluding that occlusal force correlated with cognitive function.[73] Path analysis showed both direct and indirect associations through dietary intake, even after controlling for potential confounding factors. Okubo *et al.* reported that a diet rich in vegetables, soy products, fruits, fish, and foods with dietary hardness might benefit cognitive function in older adults.[71,74] These findings suggest that decreased oral function might coincide with early cognitive decline. Longitudinal studies also support the role of maintaining occlusal force in preventing cognitive decline. Hatta *et al.* found that the number of teeth and occlusal force were associated with cognitive function at follow up, even after adjusting for other risk factors.[75] Mameno *et al.* observed that the intake of green and yellow vegetables, and meat, influenced by the number of teeth, was associated with cognitive function in a 9-year study.[76] These findings imply that preserving teeth and occlusal force might protect against cognitive decline.

Conversely, the impact of cognitive function on taste and dietary habits has also been studied. Uota *et al.*[77] and Ogawa *et al.*[78] evaluated taste sensitivity for sweetness, bitterness, saltiness and sourness. They found that individuals with lower cognitive function had reduced sensitivity to saltiness.[77,78] Additionally, sex was identified as a major factor affecting taste sensitivity, with sensitivity to sweetness being less affected by aging.[77–79] Fukutake *et al.* reported that cognitive decline was associated with reduced oral perception, which is crucial for effective mastication, appetite and food enjoyment.[80]

Association with psychological status

Akema *et al.* assessed the relationship between occlusal force and psychological frailty, defined as a World Health Organization-5 Well-Being Index score of <13 and a Montreal Cognitive Assessment in Japanese score of <23.[81] After controlling for potential confounding factors, occlusal force was associated with a reduced

prevalence of psychological frailty. Mameno *et al*. found a significant association between oral function and mental health status, mediated by fruit and vegetable intake, and social interactions.[82]

Summary

Tooth loss and reduced occlusal force are linked to dietary changes, weight loss and declines in walking speed, suggesting that maintaining oral function is crucial for physical health in community-dwelling older adults. The findings also underscore the relationship between oral function and cognitive and psychological health. Maintaining oral health is essential for promoting the overall well-being of older adults.

Psychosocial aspects

The psychosocial study in the SONIC study has two main aims. The first is to develop appropriate scales and confirm the applicability of pre-existing tools for evaluating long-term aging-related changes. The second aim is to clarify the influence of psychosocial factors on physical and cognitive function, and psychological well-being, covering a wide age range in the older population. Both qualitative and quantitative approaches were applied.

Regarding psychological well-being, we reported on elements that constitute the well-being of centenarians and the process of achieving this state, based on interviews with centenarians.[83,84] These unique findings helped develop a core framework to uncover the structure and longitudinal change of well-being, especially in the oldest-old population. One example is the development of the Japanese version of the Valuation of Life scale.[85] The Valuation of Life scale includes a positive evaluation of the future, and positive emotions that compensate for the loss of physical and social resources. We found that the Valuation of Life scale is related to mental health and individual differences in the desired remaining years of life. We also developed and confirmed the applicability of the Gerotranscendence Scale. The Gerotranscendence Scale describes a shift in behavior from active engagement in life to innate disengagement, with a change in thinking from a realistic view to a more abstract and cosmic view. We found that the construct of gerotranscendence differs for Japanese older people compared with Western populations, leading us to develop a Japanese-specific scale.[86,87] In relation to psychological well-being, a higher Gerotranscendence Scale score is associated with better subsequent mental health[6] and with greater well-being in individuals who experience a decline in physical functioning.[88] Longitudinal data over 9 years from four collection points showed that the Gerotranscendence Scale score increases in the 70s, and remains stable in the 80s and 90s, showing positive psychological development through the oldest years.[88]

Using the SONIC study's wide age coverage, we reported age-related physical and psychosocial characteristics among participants aged in their 70s, 80s and 90s. In physical functioning, using the Short Physical Performance Battery tool, we found only slight differences between the 70s and 80s, whereas differences were larger between the 80s and 90s.[89] Regarding social activities, we reported fewer leisure activities in the older age groups.[90] These studies highlight the importance of personal and internal resources for the daily activities of older adults. We also confirmed that the Montreal Cognitive Assessment is a highly reliable tool for evaluating cognitive function across a wide age range in a normal population, showing both construct validity and reliability.[91] An analysis of factors influencing well-being in participants aged in their 90s showed that living with family, economic conditions and a sense of being useful to others are important for men and women, respectively.[92]

We showed the importance of lifestyle and environmental factors on health outcomes. Variables, such as educational background, work style in middle age and leisure activities in older age, were examined. Regarding current lifestyle, we reported a simple relationship between leisure activity involvement and cognitive function.[93] Further complex analysis showed a direct influence of leisure activities on physical and cognitive function, and mental health, which are components of successful aging.[94] Additionally, a reciprocal relationship between cognitive and physical function was confirmed. In interviews about lifelong job experience, the complexity of the longest-held job was related to higher memory, reasoning test scores[95] and global cognition.[96] Combined analysis of job complexity and current leisure activities showed that both variables are important for global cognition.[96] Regarding social participation and subjective well-being, associations varied depending on the type of social participation.[97] A detailed analysis showed that participation in regional organizations had the highest association with well-being compared with participation in nonprofit organizations, volunteer groups, sports clubs or hobby groups.[97] However, these findings are limited by the use of retrospective and single-cohort data; we are planning to confirm these results using longitudinal data.

In addition to the aforementioned studies, we introduced new methods in the SONIC study data collection. We confirmed that body analogy assists in carrying out cognitive tasks (mental rotation), even in participants aged in their late 90s,[98] suggesting that pre-existing cognitive frameworks can help compensate for cognitive decline throughout life. To better assess emotional states in older people, we applied short-interval sampling methods in a small sample of SONIC study participants.[99] Using a daily diary method, we found that emotional stability was higher in older adults compared with younger counterparts. This method was also used to analyze the relationship between pre-night sleep and daytime fatigue.[100] To expand this approach, a smartphone app for microscopic data sampling is in development. We also found associations between salivary testosterone levels and cognitive function in 70-year-olds.[101] Testing new methodologies in the SONIC study is essential for developing a gerontology-based biopsychosocial model of successful aging.

Study under the COVID-19 pandemic

As aforementioned, the COVID-19 pandemic affected longitudinal data collection in the SONIC study. During the restricted period, we carried out a mail survey for all participants, regardless of the pre-planned invitation schedule. The mail survey enabled us to analyze longitudinal changes in participants' behavior and adaptation processes. In the early phase, participants restricted their activities, influenced by COVID-19 anxiety.[37] Women with lower COVID-19 anxiety had more direct interactions, whereas those with higher anxiety tended toward indirect interactions.[102] Additionally, younger individuals and those living in cities restricted their activities more than others.[37] Pre-COVID walking speed was also associated with a decrease in activity.[37] In contrast, we observed that 80-year-old participants increased the frequency of exercise and

social interactions in the later phase of the pandemic, with exercise frequency especially increasing among those living alone.[103] Details of preventive behaviors were reported based on face-to-face interviews with participants.[104] These studies provide new insights into older adults, highlighting a shift from viewing them as "weak and frail" to recognizing their adaptability and resilience.

Conclusion

The SONIC study was established considering population trends and specifically targeting the oldest-old population. This study is characterized by its unique narrow-age range of participants in their 70s, 80s and 90s, and by a longitudinal cohort design with 3-year intervals, conducted in both urban and rural areas of eastern and western Japan. The main aims of the SONIC study are to clarify aging-related changes across multiple domains of human functioning, to explore the dynamics of interaction among these domains and to identify factors influencing healthy longevity, including psychological well-being. Investigations in the SONIC study are carried out through a multidimensional approach encompassing medical, dental, nutritional, psychological and sociological perspectives contributed by professionals from each field. The greatest advantage of the SONIC study is its integration of various multidimensional studies to examine factors contributing to healthy longevity. Nowadays, not everyone wants to live a long life, so it is hoped that the factors that lead to happy aging and well-being will be clarified.

As detailed above, many important findings have been obtained so far, and these results are already being referenced in medical and dental care for older adults, as well as in guidelines for elderly care in Japan.

Overall, based on the study's characteristics, it can be said that old age spans a long period from age 65 years to >100 years, and physical and mental changes occur throughout this period, indicating correlations between various factors depending on age. Furthermore, it is important to consider differences between men and women, as well as regional differences. Figure 2 provides a summary of the achievements from the SONIC study. We are confident that the results obtained from the SONIC study in Japan's super-aged society will provide significant and valuable information for addressing the global aging trend.

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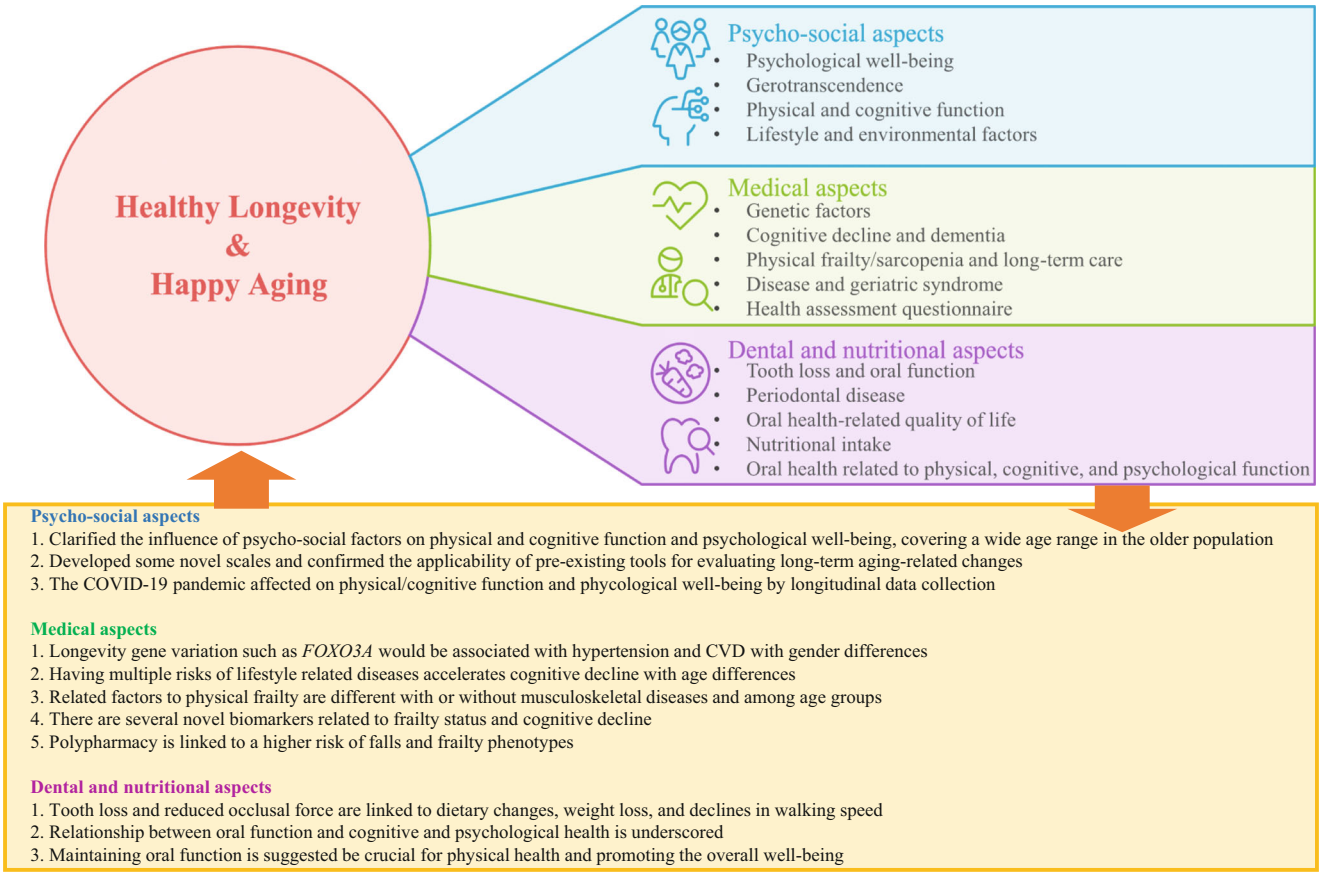

Figure 2 The overview of findings from the Septuagenarian, Octogenarian, Nonagenarian Investigation with Centenarian (SONIC) study. CVD, cardiovascular disease.

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Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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