



The Aging Study of Pyeongchang Rural Area (ASPRA): Findings and Perspectives for Human Aging, Frailty, and Disability

Ji Yeon Baek¹, Eunju Lee¹, Gahee Oh², Yu Rang Park³, Heayon Lee^{1,4}, Jihye Lim⁵, Hyungchul Park^{5,6}, Chan Mi Park⁷, Chang Ki Lee^{8,9}, Hee-Won Jung¹, Il-Young Jang^{1,9}, Dae Hyun Kim^{2,10}

¹Division of Geriatrics, Department of Internal Medicine, Asan Medical Center, University of Ulsan College of Medicine, Seoul, Korea

²Marcus Institute for Aging Research, Hebrew Senior Life, Boston, MA, USA

³Department of Biomedical Systems Informatics, Yonsei University College of Medicine, Seoul, Korea

⁴Division of Pulmonary, Critical Care and Sleep Medicine, Department of Internal Medicine, Eunpyeong St. Mary's Hospital, College of Medicine, The Catholic University of Korea, Seoul, Korea

⁵Department of Gastroenterology, Asan Medical Center, University of Ulsan College of Medicine, Seoul, Korea

⁶Department of Gastroenterology, Ilsan Paik Hospital, Inje University College of Medicine, Goyang, Korea

⁷Harvard T. H. Chan School of Public Health, Boston, MA, USA

⁸Goldman Urology Clinic, Seoul, Korea

⁹PyeongChang Health Center & County Hospital, PyeongChang, Korea

¹⁰Division of Gerontology, Department of Medicine, Beth Israel Deaconess Medical Center, Boston, MA, USA

Corresponding Author:

Hee-Won Jung, MD, PhD
Division of Geriatrics, Department of Internal Medicine, Asan Medical Center, University of Ulsan College of Medicine, 88 Olympic-ro 43-gil, Songpa-gu, Seoul 05505, Korea
E-mail: dr.ecsta@gmail.com
ORCID:
<https://orcid.org/0000-0002-2583-3354>

Il-Young Jang, MD
Division of Geriatrics, Department of Internal Medicine, Asan Medical Center, University of Ulsan College of Medicine, 88 Olympic-ro 43-gil, Songpa-gu, Seoul 05505, Korea
E-mail: onezero2@gmail.com
ORCID:
<https://orcid.org/0000-0003-3617-3301>

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The Aging Study of Pyeongchang Rural Area (ASPRA) is a population-based, prospective cohort study of older adults in Pyeongchang, South Korea. Since the initial enrollment of 382 participants, the ASPRA has been maintained and has conducted comprehensive geriatric assessments annually, gradually expanding its population and coverage area. As a cohort study of aging-related conditions and their functional consequences, the ASPRA leveraged Pyeongchang's relatively low annual population movement rate and its healthcare delivery system, which was largely maintained by community health posts. Since its establishment, the ASPRA has reported numerous observational and multicomponent intervention studies on functional decline, geriatric syndrome, and frailty. Here, we discuss the findings and perspectives of ASPRA studies. We hope that the ASPRA enables the further implementation of a longitudinal study design on geriatric parameters and the development of public health strategies targeting aging-related conditions, especially in resource-limited community settings.

Key Words: Cohort, Frailty, Aging phenotype, Intervention

INTRODUCTION

The accumulation of diseases and functional deficits with age has

resulted in the development of care models for the aging population to address healthcare and welfare issues that may differ among individuals.¹⁾ Population-based longitudinal studies are corner-

stones for studying the natural course and healthcare impact of aging-related conditions, such as frailty and sarcopenia.^{2,3)} Studying these age-related conditions requires distinct features, such as the availability of functional measures that cover multiple facets of human health, as both baseline parameters and outcome measures. However, these functional parameters have been considered less important than disease- or organ-related factors in traditional population-based studies or drug development studies targeting chronic diseases in younger adult populations.⁴⁾

Korea has developed policies to meet the care needs of the growing aging population. These policies include long-term care insurance, which started in 2009.⁵⁾ As the number of older people increases, care demands to serve these populations threaten to overwhelm the Korean health system. Researchers have noted unmet needs for effective management strategies using concepts from geriatric medicine to prevent functional decline in community-dwelling older adults,^{6,7)} as the results of early Korean studies have suggested that frailty is a common geriatric condition associated with future adverse health outcomes.^{8,9)} However, to our knowledge, when the Aging Study of Pyeongchang Rural Area (ASPRA) was conceptualized in 2014, no longitudinal population-based studies had comprehensively recorded geriatric functional and medical parameters, including frailty and physical performance, in Korea.⁷⁾

To provide evidence on the longitudinal functional outcomes according to geriatric parameters, the cohorts have to meet following characteristics: (1) participants of the cohort should be representative of the target population;¹⁰⁾ (2) outcome measures should include functional parameters, mortality, and state of institutionalization into facilities, including nursing homes or convalescent hospitals;^{11,12)} and (3) for long-term outcomes, attrition rate should be as low as possible.¹³⁾ As a rural area surrounded by mountains, most of the population of Pyeongchang county depends on healthcare services from the community health posts (CHP) of the public sector network for medical services, which are operated by the Ministry of Health and Welfare, including annual vaccination for influenza and health examinations. As agriculture is the main industry in this area, the annual population movement rate has been innately low in Pyeongchang county, with the annual immigration or emigration rates being <5% of the total population. Therefore, by targeting the older population of this area registered in the CHP network, the cohort may easily meet the requirements to provide information regarding long-term outcomes.

Hence, the ASPRA was designed to capture these in-depth geriatric features in a longitudinal study. The researchers hypothesized that frailty is a dynamic phenotype of human aging, a modifiable

condition addressed by multicomponent interventions designed with geriatric principles targeting person-centered problems in mobility, nutrition, medication, and social needs. In the present study, we aimed to (1) evaluate the impact of baseline geriatric features on the natural course of functional changes, (2) develop and validate appropriate screening tools for geriatric conditions, including frailty, targeting massive older populations or resource-limited public health settings, and (3) establish individual-centered health promotion schemes, which are both effective and feasible even in resource-limited rural areas, to delay the incidence of disabilities due to frailty. This review summarizes the findings of observational and intervention studies from the ASPRA to obtain future perspectives in designing community-based public health strategies targeting age-related conditions.

ASPRA DESIGN AND POPULATION

The ASPRA is a population-based, prospective, rural cohort study of older adults living in Pyeongchang county (total population 43,592; aged ≥ 65 years, 24% in 2017) in Gangwon province, Korea. The study was initially designed and established without a specific funding source and planned to leverage the opportunity to interview eligible participants for routine annual influenza vaccination by volunteering health care personnel of CHP in the study area. Afterwards, this study was mainly supported by the Pyeongchang County Hospital, Asan Institute for Life Science, and the Division of Geriatrics at Asan Medical Center. Several national grants and philanthropic personal donations also partially contributed to the funding.

The eligible participants in the ASPRA were aged 65 years and older, registered in the National Healthcare Service (NHS), ambulatory with or without an assistive device, living at home, and able to provide informed consent by themselves or via their proxies. Participants who had lived in a nursing home, hospital or received nursing home-level care at home were excluded. Potentially eligible participants were screened using the NHS member registry and received an email or a phone call to visit the CHP for annual checkups or vaccination. The study was approved by the Institutional Review Board of Asan Medical Center, Seoul, Korea (No. 2015-0673) and was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

More than 90% of the eligible population in Pyeongchang participated in the ASPRA. Their sociodemographic characteristics were similar to those of the national sample of rural population, apart from the high proportions of individuals without a formal education (44% vs. 22.6%) and currently working (mostly in agri-

culture) (60.7% vs. 39%),⁷⁾ observed in the first year of the study.

The cohort gradually expanded its footprint in Pyeongchang county. The study that had initiated with 382 participants from three small villages in 2014 included 1,529 individuals who had undergone at least one examination in December 2018. Among 1,529 people, 50 died and 127 were institutionalized owing to functional decline, based on the available records in December 2018. Among the remaining population, 241 were censored because of moving to another area (n = 102), decline for follow-up (n = 110), and unavailability for contact (n = 19) by December 2018.

Compared to an urban cohort in Korea (the Korean Longitudinal Study on Health and Aging [KLoSHA]), the ASPRA population showed a higher frailty status (17.4% vs. 10.3%) as measured by the CHS frailty criteria.¹⁴⁾ Among the CHS criteria components, low activity had the highest discriminative ability in the ASPRA, while weight loss had the highest discriminative power in the KLoSHA. Moreover, the rural population of the ASPRA had a greater disease burden and activities of daily living (ADL)/instrumental activities of daily living (IADL) disability than those in the KLoSHA.¹⁴⁾ These results suggest the need for customized approaches based on regional discrepancies when public health professionals plan to screen for frailty status or designate targeted components of frailty for intervention.

MEASUREMENTS AND DATA STRUCTURE

Comprehensive geriatric assessment was annually performed by trained nurses at regional CHP or Pyeongchang County Hospital; this included frailty assessment (Cardiovascular Health Study [CHS] frailty criteria, Korean version of the FRAIL criteria), multimorbidity, sarcopenia (muscle mass, hand grip strength, and gait speed), ADL/IADL disability, cognitive dysfunction, depression, fall, malnutrition, and polypharmacy. Additionally, information about prognosis (vital status, hospitalization, and institutionalization to either nursing home or convalescent hospitals due to functional decline), falls, malnutrition, body mass index (BMI), and disability were gathered every 3 months⁷⁾ (Table 1). The history of hospital visits, including emergency room and outpatient clinic visits, was collected based on memory recall.

While core geriatric parameters remained the same throughout the examination, some variables were included for logistical issues and study purposes. For example, the Short Physical Performance Battery (SPPB) was introduced in 2015 as a key measure of physical performance both at baseline and as an outcome measure, and the Physical Activity Scale for the Elderly (PASE), a proprietary tool to assess physical activity, was replaced by the International

Physical Activity Questionnaire (IPAQ) in 2015. Some parameters were included temporarily for research purposes, including questionnaires for erectile dysfunction,¹⁵⁾ constipation,¹⁶⁾ oral health,¹⁷⁾ and pulmonary function.

For longitudinal analysis, the annual follow-up of core geriatric parameters made the data structure of the study an unbalanced panel data, providing opportunities for in-depth longitudinal analyses of geriatric features, including trajectory analysis¹⁸⁾ and study of meaningful clinical differences.¹⁹⁾

FINDINGS AND IMPLICATIONS

Beginning with the initial article on the cohort profile in March 2016, the ASPRA published 23 articles in several journals, including the *Journal of Cachexia, Sarcopenia and Muscle, Age and Ageing, the Journal of Gerontology, Series A: Medical Science, Journal of the American Geriatrics Society, and Journal of Medical Internet Research* et al. to date (September 2021). Our research collaboration encompassed 32 researchers working in the Asan Medical Center, CHP in PyeongChang, PyeongChang Health Center and Country Hospital, Yonsei University College of Medicine, Eunpyeong St. Mary's Hospital, Ilsan Paik Hospital, Seoul National University Bundang Hospital, Kyung Hee Hospital, Marcus Institute for Aging Research, Beth Israel Deaconess Medical Center, Harvard T. H. Chan School of Public Health, University of Maryland School of Medicine, Dalhousie University & Nova Scotia Health, and Dyphi Research Institute. Our collaborative researchers had diverse career statuses; they included medical residents, clinical fellows, professors, and public officials and their specialties. These methodologies, which involved family medicine, pulmonology, gastroenterology, urology, psychiatry, epidemiology, biomedical informatics, and biostatistics, were not limited to geriatrics.

Frailty Assessment and Screening Tests

Historically, two main models have prevailed in defining frailty: the phenotype and cumulative deficit models.²⁰⁾ Briefly, the CHS frailty phenotype consists of five components: exhaustion, low activity, slowness, weakness, and weight loss,³⁾ in which the presence of more than three components indicates a frailty state of an individual. Otherwise, the cumulative deficit model is the sum of the impaired items as a proportion of the total assessment items, which is represented as a frailty index.²¹⁾

To assess the frailty status using the CHS frailty phenotype, it was essential to define low physical activity. The PASE is a commonly used tool for evaluating physical activity; however, its drawbacks include the time required to perform the assessment and the inability to convert the results to a standardized quantity, the total

Table 1. Study component schedules

Procedure	YR1 ^{a)}		YR2		YR3		YR4		YR5		YR6 ^{b)}
	Dec 2014–	Q1–3	Dec 2015–	Q1–3	Dec 2016–	Q1–3	Dec 2017–	Q1–3	Dec 2018–	Q1–3	Dec 2019–
Baseline interview ^{c)}	X		X		X		X		X		X
Body weight and height	X	X	X	X	X	X	X	X	X	X	X
Frailty assessment (CHS criteria, the FRAIL scale)	X	X	X ^{d)}								
Social frailty questionnaire							X ^{e)}		X		X ^{e)}
Physical performance (SPPB, grip strength)	X ^{f)}		X		X		X		X		X
Bioimpedance analysis	X		X		X		X		X		X
Disability (ADL, IADL)	X	X	X	X	X	X	X	X	X	X	X
Depression (CES-D)	X		X		X		X		X		X
Nutrition (MNA-SF)	X	X	X	X	X	X	X	X	X	X	X
Quality of life (EQ-5D-3L)	X		X		X		X		X		X
Urologic symptom, male (IPSS, IIEF-5)			X ^{g)}		X		X ^{g)}				
Urologic symptom, female (OABSS, ICIQ)			X ^{h)}		X		X ⁱ⁾				
Bowel habits questionnaire									X		X
Oral health (GOHAI)			X ^{j)}		X		X ^{j)}				
Pulmonary function (PEFR, mMRC)									X ^{k)}		X
Fall history	X	X	X	X	X	X	X	X	X	X	X
Hospitalization/institutionalization/death	X	X	X	X	X	X	X	X	X	X	X

ADL, activities of daily living; CES-D, The Center for Epidemiological Studies Depression Scale; CHS, Cardiovascular Health Study; EQ-5D-3L, the EuroQol-5 Dimensions-3 Levels; FRAIL, Fatigue, Resistance, Ambulation, Illness, and Loss of weight; GOHAI, General Oral Health Assessment Index; IADL, instrumental activities of daily living; ICIQ, International Consultation on Incontinence Questionnaire; IIEF-5, five-item version of the International Index of Erectile Function; IPSS, International Prostate Symptom Score; K-PASE, Korean version of Physical Activity Scale for the Elderly; mMRC, modified Medical Research Council Dyspnea Scale; MNA-SF, The Mini-Nutritional Assessment Short-Form; OABSS, overactive bladder symptom score; PEFR, peak expiratory flow rate; Q1–3, first through third quarters; SPPB, short physical performance battery; YR, year.

^{a)}When new regions were added to the cohort, new enrollments were made.

^{b)}The annual follow-up in 2020 was not fully evaluated due to coronavirus disease 2019 (COVID-19).

^{c)}The baseline interview includes questions on demographic characteristics (age, sex, marital status), living status, occupation, income, education level, drinking and smoking habits, underlying diseases, current use of prescription, and history of fall in the past year.

^{d)}For low activity assessment, the K-PASE was replaced by the International Physical Activity Questionnaire.

^{e)}The social frailty questionnaire was conducted from July 2018 to January 2020.

^{f)}SPPB was not conducted in 2014.

^{g)}The urologic symptom questionnaires for men (IPSS, IIEF-5) was used from February 2016 to December 2017.

^{h)}The urologic symptom questionnaires for women (OABSS, ICIQ) was used in February 2016.

ⁱ⁾The termination periods differed: OABSS in December 2017 and ICIQ in February 2018.

^{j)}The frailty-related section of the GOHAI was used from February 2016 to December 2017.

^{k)}PEFR and mMRC were measured from October 2019.

metabolic equivalent task minutes per week (MET-min/wk); these might limit the application of this method in large population-based community studies. Therefore, in the ASPRA, we compared agreements in calculating the physical activity of the CHS frailty criteria between the PASE and IPAQ short form, which is simpler and can be transformed to MET-min/wk. We found that a simpler IPAQ short form could replace PASE in assessing frailty based on the CHS frailty criteria in Korean older adults.²²⁾

Assessing frailty status of individuals using these two models might be less feasible in a large-scale population setting, as there is always an issue of limited resources. Hence, there is a need for a simple and rapid screening tool to identify at-risk older adults, especially those in community and hospital settings. The ASPRA applied the Korean version of the Fatigue, Resistance, Ambulation, Illness, and Loss of weight (FRAIL scale) to screen for frailty. The simple FRAIL questionnaire was not inferior to the Kihon + 3 in-

dex²³⁾ and was associated with geriatric syndromes and 3-year health-related outcomes, such as disability, institutionalization, and mortality.²⁴⁾ The results of our analysis showed that the FRAIL scale, a phenotype-based questionnaire, behaved similarly in general to a deficit accumulation model-based Kihon + 3 index. Based on these findings, subsequent studies to identify a core aging phenotype underlying the broad definitions of frailty were conceptualized.

Frailty and Geriatric Parameters

Frailty is an overall health condition of individuals with increased vulnerability to stressors, which leads to adverse health outcomes, including falls, disability, loss of independence, institutionalization, and death.²⁾ Hence, frailty is a comprehensive concept that encompasses geriatric syndromes, sarcopenia, and physical performance. In the ASPRA, urologic symptoms and erectile dysfunction were common in older adults (prevalence rates of 41.4% and 52.4%, respectively) and were associated with frailty, multimorbidity, sarcopenia, polypharmacy, SPPB score, and ADL/IADL disability.^{15,25)} Likewise, chronic constipation (prevalence 10.7%) also showed a good correlation with frailty.¹⁶⁾

In the ASPRA, the social frailty rates, as evaluated by the questionnaire,²⁶⁾ were 20.5% and 9.1% and overlapped with physical frailty.²⁷⁾ Social frailty was associated with an increased risk of ADL disability and depression. Moreover, future disability was better predicted by using both physical frailty and social frailty (C-statistic, the probability of predicting the outcome was better than chance by logistic regression models, 0.73) compared to a single frailty index (C-statistic 0.68 for physical frailty and 0.71 for social frailty), which underlined the importance of screening for social frailty.²⁷⁾ The results of these studies suggested that the frailty spectrum might be a single, global indicator reflecting the burden of age-related conditions in individuals (biological age spectrum), which may serve as a guiding criterion for delivering individualized interventions.

Frailty was a dynamic predictor of risk. The results of the longitudinal analysis showed that baseline frailty, defined by either phenotype model or deficit accumulation models, was associated with adverse health outcomes, including functional decline and a composite outcome of death or institutionalization due to disability (C-statistic 0.79; CHS phenotype 0.78 for the 26-item frailty index and 0.79 for the 34-item frailty index).²⁸⁾ Longitudinally, the frailty spectrum dynamically changed, and we identified the frailty index as a sensitive indicator to capture the smallest changes among individuals over time. In addition to its importance in predicting health outcomes, we recognized that the frailty spectrum per se may serve as an indicator of clinical outcome in intervention studies, which

target aging related conditions.

Physical Performance as a Core Measure of Human Aging Phenotypes

Although the two main models of frailty (phenotype and cumulative deficit models) are well validated in various contexts, there remains an unmet need for more objective and clinically feasible markers in frailty assessment. Both models can be influenced by cultural differences in the population, as these include subjective questionnaires about respondents' physical, functional, and mood statuses. Moreover, comorbidities and laboratory abnormalities may significantly affect the cumulative deficit model score. For instance, by overweighting some features pointing in a similar direction (e.g., blood pressure parameters and laboratory abnormalities related to hypertensive heart diseases), a frailty index may have biased characteristics tracing certain clinical features (e.g., vascular aging spectrum), rather than alterations of human global fitness associated with aging.

In the ASPRA data, gait speed was associated with age, sex, and frailty and was a good predictor of composite outcomes, including mortality and institutionalization.²⁹⁾ Subsequently, we reported that calculating functional age using three SPPB parameters (standing balance, walking speed, and chair rise test) was correlated with the frailty index and had more discriminative power in assessing frailty status compared to chronological age.³⁰⁾ From these observations, we hypothesized that the physical performance spectrum might be a core feature reflecting the global burden of human aging, serving as a measure of biological age and a potential linker between varying definitions of frailty. In a recent report, we showed that the SPPB can be a crosswalk between two main frailty models, as the SPPB showed not only a good correlation with the two frailty models but also comparability in predicting composite outcomes, thus supporting our hypothesis.²⁸⁾

Moreover, a meaningful difference in the SPPB score was observed according to the trajectory group of disability measured by the total number of disabled domains of ADL and IADL.¹⁸⁾ The mean SPPB score of the relatively stable group in disability was 10.2, while that of the rapidly deteriorated group was 3.1, which also implied the important role of SPPB in assessing future severity of disability and burden of aging phenotype.¹⁸⁾

Sarcopenia as another Phenotype of Frailty

The clinical construct and definition of sarcopenia, defined as an aging-related condition with decreased muscle mass, muscle strength, and/or physical performance, remains controversial. Increasingly regarded as a disease, most clinical guidelines on sarcopenia have supported operational classification to identify this

condition. However, we hypothesized that sarcopenia is an age-related mobility phenotype and that potential caveats exist in defining sarcopenia using decision trees. As frailty reflects a state of cumulative physiological dysfunction, we searched for this quantitative characteristic in sarcopenia. We propose a new sarcopenia index, the sarcopenic phenotype score (SPS). The SPS counts the total number of impaired domains of sarcopenic parameters (muscle mass, muscle strength, and physical function), which ranges from 0 to 3. We found that the sarcopenic spectrum defined by the original and revised European Working Group on Sarcopenia in Older People (EWGSOP1 and EWGSOP2) criteria showed inconsistent relationships with the composite outcome of mortality and institutionalization, while the SPS showed dose-response associations with composite outcome.³¹⁾ Moreover, among various existing sarcopenic definitions, including the original and revised EWGSOP and the Asian Working Group for Sarcopenia (AWGS), only the SPS predicted future cognitive decline as assessed by the Mini-Mental State Examination (MMSE).³²⁾ These results suggest that sarcopenia can be better captured by methods combining incremental sarcopenic burden in a manner similar to that used in the frailty index, rather than by an operational, dichotomous manner of determining sarcopenia.

Multicomponent Interventions

While several types of intervention studies targeting frailty in older adults have been conducted, the results have been inconsistent. Moderate improvements in physical function were observed in some multicomponent interventions,³³⁻³⁵⁾ but not in single-exercise interventions.^{36,37)} However, limited improvement was observed even after providing multicomponent interventions.³⁸⁾ This inconsistency might be due to differences in adherence rates, target populations, and intervention program composition, enabling the satisfaction of both vulnerable older adults and resource-limited public health centers.

This prospective non-randomized study enrolled 383 older adults, 187 of whom received a multicomponent intervention for 24 weeks. The intervention program consisted of group exercise, nutritional support, depression management, deprescribing, and home hazard reduction³⁹⁻⁴⁴⁾ (Table 2). In particular, exercise intensity was individualized, starting from low intensity and increasing up to 60%–70% of the maximal exercise capacity based on the perceived exertion scale. After 6 months of the multicomponent intervention, physical function, as measured by SPPB, frailty, sarcopenia, depression, and nutritional status, improved and were sustained for 12 months.⁴⁵⁾ As the observation period extended to 30

Table 2. Contents of the multicomponent intervention program⁴⁶⁾

Focus	Intervention description
Exercise ³⁹⁾	Intervention: 60-minute group exercise session led by licensed exercise trainers. The intensity of the exercises were low at the beginning and increased every month; the exercises focused on the following: - Resistance (20 minutes): squat, plank, side plank, straight-leg raises - Balance (20 minutes): one-leg standing, shifting from side to side, heel-to-toe walk - Aerobic/endurance (20 minutes): step up and down, quick pace, dancing - The exercise trainer was given instructions not to exceed 60%–70% of the maximal exercise capacity based on the perceived exertion scale Target: all participants Frequency: twice weekly
Nutrition ^{40,41)}	Intervention: a 125-mL commercial liquid formula containing 200 kcal of energy, 24.5 g carbohydrates, 13 g protein, 5.63 g essential amino acids, and 7 g fat Target: all participants Frequency: twice daily
Depression ⁴²⁾	Intervention: evaluation by a geriatrician or psychiatrist, and supportive psychotherapy or anti-depressant medication as clinically indicated Target: participants with CES-D scores > 20 points at baseline Frequency: monthly
Polypharmacy ⁴³⁾	Intervention: medication review by a geriatrician, with dose reduction or discontinuation of potentially inappropriate medications according to the 2012 Beer's criteria Target: participants taking ≥ 5 prescription medications at baseline Frequency: monthly
Home hazards ⁴⁴⁾	Intervention: evaluation of the home environment by a visiting nurse and a social worker using the Centers for Disease Control and Prevention Home Fall Prevention Checklist, and modification of the environment to remove the identified hazards Target: all participants with any identified home hazards at baseline Frequency: 3 months

CES-D, Center for Epidemiologic Studies Depression Scale.

months, the difference between the control and intervention groups was attenuated in frailty from 18 months and disability from 24 months.^{46,47)} However, the benefits of the intervention in SPPB and institutionalization-free survival were maintained for 30 months.⁴⁶⁾

The positive results of the multicomponent interventions observed in the present study may be attributed to the high adherence rate resulting from regional characteristics and group approaches and targeting socioeconomically vulnerable older adults who will benefit from such treatment. In addition, addressing common geriatric syndromes of the community such as polypharmacy and depression after conducting comprehensive geriatric assessments, and providing tailored exercise programs might have contributed to our remarkable results. In conclusion, the findings of these studies may help public health providers to concretize their intervention plans in resource-limited communities by providing not only estimated effect sizes and intervention periods but also the timing for re-evaluation.

Application of Wearable Device and Home IoT

Population aging is now a global phenomenon and is inevitably associated with an increased number of frail older adults. Although these adults need more assistance, most prefer to age in place and live in their own homes with autonomy.⁴⁸⁾ Hence, while the demand for home care is ever increasing, limited resources and the current coronavirus disease 2019 (COVID-19) situation make it difficult to fulfill these needs. In these circumstances, technology-incorporated healthcare may be a solution. However, the wide adoption of technology-based devices and services is delayed, at least in part, due to the usability issues of vulnerable older populations.⁴⁹⁾

To identify the possible obstacles to the application of health care technology, we first observed the effect of a wearable pedometer on physical health in 2017. After participating in a wearable device-based walking program for 6 months, the prefrail group and not the robust group showed improved physical fitness and quality of life. In addition, adherence to wearing the device was higher in the presence of coaching management.⁵⁰⁾ In the home Internet of Things (IoT) study, we identified a discrepancy in the demand for home IoT services according to the position of care receiver, caregiver, and health care provider. In addition, the requirements of home IoT differed according to the degree of disability among vulnerable older adults.⁵¹⁾ Subsequently, we investigated the practical usability of integrated home IoT services in vulnerable older adults. During the 12-month study period, the usability was consistently higher in the prefrail group than that in the frail group. In addition, the usability patterns differed according to the type of service and

frailty status. We observed a discrepancy in selecting the most satisfying service before and after experiencing home IoT services, which revealed an unawareness of home IoT, in other words, digital literacy. Collectively, these results suggest that evaluating frailty status and disability in older adults, providing appropriate human interaction, and reducing unawareness and the perception gap toward technologies might be key to facilitating the adoption of technology-based healthcare services.

STRENGTH AND LIMITATIONS

Taking advantage of its strength as a well-designed cohort from the initial stage of establishment, the ASPRA has shown the feasibility of conducting observational and multicomponent interventional studies in resource-limited contexts, such as community settings. In the ASPRA, the short-term follow-up period (1 year) allowed the observation of the micro-dynamics of frailty and accompanying geriatric syndrome. In addition, the relatively isolated study region with less population migration showed reduced follow-up loss, which allowed the evaluation of long-term effects. In addition, the ASPRA has bridged the academic research field and community as it focused on a simple and feasible measurement of frailty and on identifying obstacles in adapting healthcare-related technologies. Strong support from local governments and participation by healthcare personnel in CHPs allowed data acquisition on living status, including the institutionalization, and helped to minimize follow-up losses.

However, the ASPRA has some limitations. First, the measurement methods changed during the course of the study; for example, the SPPB was introduced and PASE was replaced with IPAQ in 2015 for physical activity assessment. However, gait speed, one of the SPPB parameters, had already been measured in the initial cohort, and full-scale physical performance was analyzed after adoption of the SPPB. In addition, we verified that the IPAQ could replace PASE for assessment of frailty phenotypes before replacing PASE with the IPAQ.²²⁾ Second, due to the lack of financial support during the initial study period, no blood samples were collected for various geriatric measurements. Third, the assessment of the “disease” domain was relatively insufficient compared to the domain of frailty and functional decline. Lastly, the annual follow-up in 2020 was not properly evaluated because of COVID-19.

CONCLUSION

The ASPRA has produced numerous meaningful study results over a prolonged period thanks to the active support from local governments, public health institutions, and public health doctors.

Moreover, the ASPRA has been credited with practically improving the real health status and quality of life of local residents beyond simply bearing study results. The future directions of the ASPRA include in-depth cross-sectional and longitudinal investigations of functional decline, the occurrence of geriatric syndrome, and time-series changes in frailty. These efforts will embody various study designs that are uncommon in established domestic cohorts and verify unresolved hypotheses.

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CONFLICT OF INTEREST

The researchers claim no conflicts of interest.

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AUTHOR CONTRIBUTION

Conceptualization, JYB, HWJ, IYJ, DHK; Data curation, JYB, HWJ, IYJ; Funding acquisition, EJL, IYJ; Investigation, JYB, EJL, GHO, YRP, HYL, JHL, HCP, CMP, CKL, HWJ, IYJ, DHK; Methodology, JYB, EJL, GHO, YRP, HYL, JHL, HCP, CMP, CKL, HWJ, IYJ, DHK; Project administration, JYB, EJL, GHO, YRP, HYL, JHL, HCP, CMP, CKL, HWJ, IYJ, DHK; Supervision, EJL, HWJ, IYJ, DHK; Writing-original draft, JYB, HWJ; Writing-review & editing, JYB, HWJ, IYJ, DHK.

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