Life Course Determinants and Adverse Health-related Outcomes of Pre-frailty Trajectories among Older Adults: Using the Korean Longitudinal Study of Aging 2006-2020

Sumi Lee

The Graduate School

Yonsei University

Department of Nursing

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Sumi Lee

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This certifies that the dissertation of Sumi Lee is approved.

Thesis Supervisor: JuHee Lee

Committee Member: Tae Wha Lee

Committee Member: Chang Oh Kim

Committee Member: Chang Gi Park

Committee Member: Young Joo Lee

The Graduate School

Yonsei University

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TABLE OF CONTENTS

TABLE OF CONTENTS i

LIST OF FIGURES v

LIST OF TABLES vi

ABSTRACT vii

1. INTRODUCTION 1

1.1. Background 1

1.2. Aims 5

1.3. Definitions 5

2. LITERATURE REVIEW 8

2.1. Concept and Measure of Pre-frailty 8

2.2. Research on Pre-frailty 17

3. THEORETICAL FRAMWORK 27

3.1. The Conceptual Framework 27

4. METHODS 31

4.1. Study Design 31

4.2. Research Data 31

4.3. Sample 32

4.4. Variables 33

4.5. Data Collection and Ethical Consideration 46

4.6. Data Analysis 46

5. RESULTS 49

5.1. Participants Characteristics 49

5.2. Pre-frailty Trajectories 54

5.3. Differences in Life Course Determinants by Group 61

5.4. Adverse Health-related Outcomes and Pre-frailty Trajectory Groups 73

6. DISCUSSION 76

6.1. Pre-frailty Trajectories 77

6.2. Differences in Life Course Determinants by Group 79

6.3. Adverse Health-related Outcomes and Pre-frailty Trajectory Groups 81

7. CONCLUTIONS 85

7.1. Implications 85

7.2. Limitations 87

7.3. Suggestions for Future Research 88

REFERENCES …… 89

APPENDIX …… 111

Appendix 1. Comparison of pre-frailty measurement …… 111

Appendix 2. Review about frailty trajectories …… 114

Appendix 3. Review about life course determinants influencing pre-frailty …… 118

Appendix 4. Pre-frailty associated with hospitalization among adverse health-related outcomes …… 122

Appendix 5. Pre-frailty associated with mortality among adverse health-related outcomes …… 127

Appendix 6. Questionnaire in this study …… 130

Appendix 7. The GRoLTS Checklist in the study …… 138

Appendix 8-1. Mean for each item of Frailty Index in the remaining pre-frailty group by year …… 140

Appendix 8-2. Mean for each item of Frailty Index in the slowly increasing frailty group by year …… 141

Appendix 8-3. Mean for each item of Frailty Index in the rapidly worsening frailty group by year …… 142

Appendix 9. Predicted probability of life course determinants by group …… 143

Appendix 10. Differences in characteristics of excluded and included participants by year …… 144

Appendix 11. Syntax of this study …… 146

ABSTRACT IN KOREAN …… 147

LIST OF FIGURES

Figure 1. An integral conceptual model of frailty 28

Figure 2. The conceptual framework of this study 30

Figure 3. Flow of the selection process for this study sample 34

Figure 4. Mean Frailty Index by year 52

Figure 5. Trend of frailty status by year 52

Figure 6. Change rate of Bayesian information criteria of pre-frailty trajectories 56

Figure 7. Plots of observed values and predicted counts from group-based trajectory models of pre-frailty across every two years of follow-up in KLoSA 2006-2020 59

Figure 8. Marginplots about predicted probabilities of life course determinants by group 67

Figure 9. Kaplan–Meier survival curves by group 75

LIST OF TABLES

Table 1. Operationalization of the variable in this study …… 36

Table 2. Characteristics of pre-frail participants at baseline …… 50

Table 3. Mean Frailty Index by year …… 51

Table 4. Difference of level of frailty according to classification criteria by year …. 53

Table 5. Life course determinants influencing pre-frailty using panel Tobit regression analysis …… 54

Table 6. Fit index and classification rate by model according to the number of pre-frailty trajectories …… 55

Table 7. Parameter estimates for pre-frailty trajectory groups …… 58

Table 8. Mean Frailty Index according to the groups by year …… 60

Table 9. Groups characteristics at baseline …… 62

Table 10. Differences in life course determinants by group …… 66

Table 11. Adjusted effect of pre-frailty trajectory groups on hospitalization and mortality …… 73

Table 12. Mean and median for survival time by group …… 74

ABSTRACT

Life Course Determinants and Adverse Health-related Outcomes of Pre-frailty Trajectories among Older Adults: Using the Korean Longitudinal Study of Aging 2006-2020

Objectives: Identifying pre-frailty is important because it provides an opportunity to prevent frailty and adverse health-related outcomes by maintaining or increasing physiologic reserve capacity. This study aimed to identify pre-frailty trajectory groups, investigate life course determinants influencing the pre-frailty trajectory groups and evaluate their association with adverse health-related outcomes including hospitalization and mortality.

Conceptual framework: Gobbens et al.'s (2010) Integral Conceptual Model of Frailty described frailty as a dynamic condition that affects individuals in which one or more of their physical, psychological, and social functions are impaired. Life course determinants and diseases are antecedents for frailty. The model explains the process leading to disability, health care utilization, and death due to adverse outcomes of frailty (Gobbens et al., 2010). The model also suggests that nursing intervention can improve frailty. In this study, a conceptual framework was constructed to identify the effect of life course determinants on the pre-frailty trajectory groups and the relationship between the groups and adverse health-related outcomes based on the Integral Conceptual Model of Frailty.

Methods: This study was a secondary data analysis study using the Korean Longitudinal Study of Aging data (2006-2020). Pre-frailty was measured by modifying the Frailty Index constructed by Jung et al. (2022). The Frailty Index (FI) scores were categorized as follows: non-frailty (FI $\leq$0.08), pre-frailty (FI >0.08 to FI <0.25), and frailty (FI $\geq$0.25).

Results: Using group-based trajectory models, the participants on pre-frailty trajectories were divided into three groups: 1) remaining pre-frailty (n = 1,229, 62.9%), 2) slowly increasing frailty (n = 556, 28.4%), and 3) rapidly worsening frailty (n = 170, 8.7%). Participants were more likely to belong to the rapidly worsening frailty group if they were older and did not have health check-ups. Those in the rapidly worsening frailty group had a high risk of hospitalization and mortality (Hazard ratio [HR] = 1.41, 95% confidence interval [CI]: 1.03–1.93 and HR = 1.68, 95% CI: 1.23–2.29, respectively) compared with the slowly increasing frailty group. The median survival time of the rapidly worsening frailty group was nine years, one year shorter than the other groups.

Conclusions: This study identified the pre-frailty trajectories among community-dwelling older adults. Pre-frailty trajectories provided a rationale for nursing interventions including target population, priorities, timing and components of intervention. The risk of adverse health-related outcomes was higher in older adults who rapidly became frailty. Interventions to reduce frailty and adverse health-related outcomes should be prioritized for the rapidly worsening frailty group.

Key words: Frailty, Pre-frailty, Predictor, Outcomes, Hospitalization, Mortality, Older adults, Trajectory, Longitudinal data

1. INTRODUCTION

1.1. Background

Frailty can be defined as the accumulation of health deficits that occur during the aging process and describes a state in which one or more of the physical, psychological, and social domains are impaired (Gobbens et al., 2010; Rockwood & Mitnitski, 2007). Frailty is a significant health-related problem among older adults. Progressive frailty is being increasingly prioritized because of the high risk of adverse health-related outcomes from frailty, such as physical limitations, disabilities, falls, cognitive decline, fractures, and reduced life satisfaction (Romero-Ortuno et al., 2015; Vermeiren et al., 2016).

The global prevalence of frailty and pre-frailty accounts for 12–24% and 46–49%, respectively, worldwide (O'Caoimh et al., 2021). The prevalence of frailty and pre-frailty among Korean older adults has been reported to be 11.2–27.5% and 49.7–54.3%, respectively (Baek & Min, 2022; Kim et al., 2018), which is slightly higher than the global prevalence. These data suggest that pre-frailty is widespread among community-dwelling older adults. Pre-frailty is defined within the context of an operational definition of frailty. In the Cardiovascular Health Study (CHS), Fried et al. (2001) suggested five components of frailty: weight loss, exhaustion, slowness, weakness, and low physical activity. These component items were classified as non-frailty (none), pre-frailty (1–2 items), and frailty (3–5 items). Pre-frailty is described as a state in which the criteria for frailty are not fully met (Fried et al., 2001). In 2001, Mitnitski, Mogilner, and Rockwood developed a frailty

index (FI) consisting of 1) health-related items, 2) items with increased prevalence during aging, and 3) health deficiencies that occur across multiple organs rather than a single organ (Searle et al., 2008). The FI is then calculated as the ratio of current deficits to total deficits (Mitnitski et al., 2001). Pre-frailty was presented as the cumulative result of physical, psychological, and social health deficiencies and has an FI score between >0.08 and <0.25 (Rogers & Fancourt, 2020; Song et al., 2010).

Pre-frailty is an intermediate stage between non-frailty and frailty, with a high risk of exacerbation into frailty (Siriwardhana et al., 2018). Pre-frailty comprises multidimensional characteristics, such as slow walking speed, fatigue, low body mass index, depression, cognitive decline, and social isolation (Fried et al., 2001; Lee et al., 2014; Makizako et al., 2015; Petermann-Rocha et al., 2021). A systematic review reported that the progression rate of pre-frailty to frailty was 18.2% and that the improvement rate of pre-frailty to non-frailty was 23.1% (Kojima et al., 2019), which highlights the dynamic state of pre-frailty (Sezgin et al., 2020). In particular, this result shows that pre-frailty can be transitioned back to non-frailty. The reversable condition of pre-frailty is meaningful since it provides an opportunity to delay the progression to frailty by maintaining or increasing the physiological reserve capacity (Kojima et al., 2019; Walters et al., 2017). Therefore, to prevent and manage frailty, it is important to understand how older adults' pre-frail condition change dynamically.

In most studies, researchers have mainly focused on the frailty trajectories; however, information on pre-frailty trajectories is scarce and needs to be fully elucidated. Experts

have agreed on guidelines for frailty interventions, including comprehensive health care plans, physical activity programs, and protein supplements, for frail individuals diagnosed with weight loss or malnutrition (Dent et al., 2019). Additionally, frailty screening, planning, and intervention components have been recommended (Dent et al., 2019), but intervention timing has yet to be discussed. By determining the pre-frailty trajectories, it is possible to identify the appropriate intervention timing, target populations, priorities, and intervention strategies. Since pre-frailty is highly dynamic, it is important that healthcare providers and policymakers screen for pre-frailty and intervene accordingly (Gill et al., 2006; Lang et al., 2009). To the best of our knowledge, this study is the first to report on pre-frailty trajectories.

Research has focused on the predictive factors of pre-frailty and considered demographic factors such as age, sex, education level, and marital status. Recently, studies have also been conducted to identify the modifiable predictors of pre-frailty. Low-intensity physical activity was not associated with pre-frailty, but moderate to vigorous physical activity was shown to reduce the risk (Kikuchi et al., 2021). Also, a healthy diet has been shown to lower the risk of pre-frailty (Ward et al., 2021). By identifying the risk factors of pre-frailty, this study may improve our understanding of the modifiable factors and contribute to developing appropriate interventions.

The Integral Conceptual Model of Frailty (ICMF) (Gobbens, et al., 2010) describes disability, the increasing use of healthcare, and death as adverse outcomes of frailty. In addition, many studies have consistently reported that pre-frailty increases the risk of

disability, and a significant association between pre-frailty and disability has been identified (Forti et al., 2014; Fried et al., 2001; Romero-Ortuno et al., 2015; Vermeiren et al., 2016). Hospitalization is stressful for older adults which can increase the social and economic burden on older adults, their families, and caregivers (Coelho et al., 2015; Lan et al., 2021). The relationship between hospitalization and pre-frailty remains unclear, and associations between the two have been inconsistently reported (Forti et al., 2014; Gill et al., 2014; Jung et al., 2014). In addition, mortality has been reported to be significantly associated with pre-frailty (Baek & Min, 2022; Cano et al., 2012; Lee et al., 2018); however, comparing the results is difficult because of the differences in the study populations, the pre-frailty measurements, and the follow-up periods. This current study attempted to investigate the relationship between pre-frailty and mortality in Korean older adults using the FI, which has a high mortality predictive power during the 14-year follow-up period. Understanding of the relationship between pre-frailty and mortality will provide the foundation for outlining the efficient use of limited medical resources and reducing medical costs.

This study aimed to identify the pre-frailty trajectories in the longitudinal data, examine life course determinants affecting these trajectories, and investigate the hospitalization and mortality associated with these trajectories through the ICMF (Gobbens et al., 2010). This study results will provide knowledge about the pre-frailty trajectories among older adults identifying high-risk groups through the life course determinants of pre-frailty trajectories and provide data for tailored interventions. Finally, this study results will contribute to the

development of an evidence-based nursing intervention through information on appropriate intervention timing, target populations, priorities, and intervention strategies by investigating the relationship between the pre-frailty trajectories and adverse health-related outcomes.

1.2. Aims

The present study was designed to investigate changes in pre-frailty over time, what life course determinants influence these changes, and how these changes are related to adverse outcomes based on the Integral Conceptual Model of Frailty (Gobbens et al., 2010).

The specific aims were (1) to identify the pre-frailty trajectories among community-dwelling older adults, (2) to examine the life course determinants of pre-frailty trajectories, and (3) to investigate the relationship between pre-frailty trajectories and hospitalization and mortality.

1.3. Definitions

1) Pre-frailty

- Theoretical definition: Pre-frailty was defined as a state in which the criteria for frailty were not met, an intermediate stage between non-frailty and frailty, a potentially reversible condition that could nevertheless progress to a frail state (Gill et al., 2006; Sezgin et al., 2020).
- Operational definition: Pre-frailty was described as a score measured using the FI,

which was conceptualized by Mitnitski, Mogilner, and Rockwood (2001). Pre-frailty was measured using the modified FI suggested by Jung et al. (2022) based on the Korean Longitudinal Study of Aging (KLoSA) data. Four items of the cognitive domain were added to this study and the scores for the items were modified into three categories (Beak & Min, 2022; Searle et al., 2008). In this study, the FI values were classified as pre-frailty (>0.08 to <0.25), which is the classification criteria presented by Song et al. (2010) and Rogers et al. (2020).

2) Life course determinants

- Theoretical definition: Life course determinants are factors in the integral model of frailty that influence the relationship between frailty and adverse outcomes. These include demographic characteristics such as age, sex, education, income, ethnicity, marital status, living environment, lifestyle, life events, and biological and genetic factors (Gobbens et al., 2010).
- Operational definition: Life course determinants were defined as age, sex, education, marital status, household income, lifestyle (physical activity, breakfast, alcohol consumption, smoking, sleep disturbance, and health check-ups), and life events (falls).

3) Adverse health-related outcomes

- Theoretical definition: Adverse health-related outcomes occur from life course determinants, physical, psychological, and social frailty, and can lead to disability, healthcare utilization (hospitalization and nursing home admissions), and death, which occur sequentially (Gobbens et al., 2010).
- Operational definition: Adverse health-related outcomes were defined as hospitalization and mortality. (1) Hospitalization was measured by asking whether the participants had been hospitalized within the past year. (2) Mortality was defined as all-cause mortality from 2008 to 2020 and was the announcement of death by a family member or an acquaintance (Korea Employment Information Service, 2020).

2. LITERATURE REVIEW

2.1. Concept and Measure of Pre-frailty

1) Concept of pre-frailty

In gerontology, frailty was first used as a synonym of the institutionalization (van Kan et al., 2008). Pre-frailty can be understood through three representative theories, namely the cycle of frailty model, the cumulative deficit model, and the Integral Conceptual Model of Frailty (ICMF) (Gobbens, et al., 2010). The cycle of frailty suggests that a vicious cycle of inadequate nutrition and sarcopenia leads to a decline in muscle strength, gait speed, and physical activity, ultimately leading to disability and death (Fried et al., 2001). Fried et al suggests that the cycle of frailty consists of shrinking (unintentional weight loss), weakness (low handgrip strength), exhaustion (severe fatigue), slowness (slow gait speed), and decreased physical activity (Fried et al., 2001). Frailty was defined as a physiological syndrome in which internal and external stressors (e.g., infection, injury, surgery, medication) and impairment of physiological reserves make individuals more vulnerable (Fried et al., 2001). Pre-frailty was defined as a state in which the criteria for frailty were not met. The cycle of frailty focused on a single physical domain. Although it is insufficient to screen frailty because the CHS does not include psychological and social domains, we focused on physical domain of frailty, which greatly contributed to our understanding of the pathophysiology of frailty (Kim & Kim, 2011). There is also a movement to view frailty

as a broader social construct, focusing on frailty not only in the physical domain but also in multidimensional domains such as the cognitive, psychological, social, and environmental domains.

Frailty can lead to vulnerability, which can be caused by a loss of reserves in several domains including the energy, physical ability, and cognition (Rockwood et al., 2000). The cumulative deficit model explains why people who correspond to the same chronological age does not have the same risk of adverse outcomes. Health problems accumulate with age, and more deficits lead to a greater risk of frailty (Rockwood & Mitnitski, 2007; Rockwood, 2016). Frailty synergistically affects multiple systems, by which a critical point is reached resulting in adverse outcomes such as the decreased ability to perform daily activities independently and needs help from others (Rockwood et al., 2000). Rockwood et al. (2007) described frailty as a dynamic syndrome that is expressed as the result of accumulative health deficits linked to aging, such as signs, symptoms, diseases, and laboratory data. Frailty is that not everyone has the same number of deficiencies at the same chronological age. The more the deficit accumulates, the greater the risk an individual may experience.

The Frailty Index (FI) is expressed as a ratio of the total scores of the items divided by the total number of answered items (Mitnitski et al., 2010; Searle et al., 2008). The score of FI ranges from 0 (no health deficiency) to 1 (health deficiency) for each item, with higher scores meaning a higher level of frailty (Searle et al., 2008). Since the original FI was aimed at identifying frailty, only the classification criteria for frailty (FI >0.25) were presented.

However, in previous studies, the classification criteria for pre-frailty were reviewed. Mitnitski, Mogilner, and Rockwood (2001), who developed the FI, investigated the classification criteria of tools following Searle's "2008 FI Composition Standard Procedure". We found classification criteria that verified the reliability and validity of the FI in a community setting. Mitnitski et al. (2001) developed the FI for community-dwelling older adults in Canada. Therefore, the purpose of this study is to identify the pre-frailty trajectories in community-dwelling older adults. As a result, Song et al.'s FI in 2010 and Rogers's FI in 2020 were consulted. Song et al. (2010) constructed the FI consisting of 36 items for Canadians aged 65 and over. These items identified the effect of frailty on the prediction of mortality. Rogers and Fancourt (2020) also examined the effect of cultural engagement in British adults aged 50 and over on the frailty trajectory. The FI consisted of 56 items including mobility, chronic conditions, depression, and cognitive function (Rogers & Fancourt, 2020). Although there are differences in the number of items, component items, and scoring criteria of the FIs proposed by Song et al. (2010) and Rogers et al. (2020), the FI Composition Standard Procedure was followed, and the reliability and validity of the tool were verified in a community setting. Based on this evidence, the classification criteria were as follows: pre-frailty (FI >0.08 to <0.25) and frailty (FI ≥0.25). Pre-frailty was defined as the cumulative result of physical, psychological, and social health deficiencies with an FI score of >0.08 and <0.25.

The ICMF explains the frailty pathway from an integrated perspective rather than the existing physiological and medical perspectives that primarily focused on the physical

domain (Gobbens et al., 2010). The ICMF shows that frailty-related adverse outcomes could be reduced via nursing interventions. Frailty was defined as a dynamic state in which an individual experiences one or more domains of functional impairments (physical, psychological, and social domains) (Gobbens et al., 2010). Gobbens and colleagues were mainly interested in investigating the multidimensional characteristics of frailty using the Tilburg Frailty Indicator (TFI) and did not discuss pre-frailty. Applying the ICMF to nursing interventions to improve frailty requires a comprehensive understanding of the dynamic state of pre-frailty, the influence of life course determinants on pre-frailty, and the relationship between pre-frailty and adverse health-related outcomes.

Pre-frailty is an intermediate stage between frailty and non-frailty (Fried et al., 2001), in which an individual's condition can deteriorate and become frail (Siriwardhana et al., 2018). However, no consensual definition of pre-frailty has been agreed upon among researchers (Rodríguez-Mañas et al., 2013; Sezgin et al., 2020). Pre-frailty is represented within the context of frailty (Sezgin et al., 2020). Pre-frailty consists of multidimensional domains in which physical, psychological, or social functions can be impaired, which may reduce the quality of life (Rockwood et al., 2007; Sezgin et al., 2020). Pre-frailty is also recognized as a concept that has multifactorial characteristics, such as physical fitness, nutritional status, oral function, depressive symptom, and social isolation (Sezgin et al., 2020). Pre-frailty is a dynamic state that exists on a continuum between non-frailty and frailty. However, it is also a potentially reversible condition that can either progress to the

frail state or, through nursing interventions (Gill et al., 2006; Gobbens et al., 2010), can return to the non-frail state (O'Caoimh et al., 2018; Walters et al., 2017).

To summarize, pre-frailty can be defined as an intermediate stage between non-frailty and frailty, a potentially reversible risk condition that can progress to frailty. Pre-frailty is multidimensional and consists of multifactorial characteristics related to aging. Interventions are necessary for individuals with pre-frailty because this is the first step that can lead to eventual frailty and adverse health-related outcomes.

2) Pre-frailty measurements

At present, there is insufficient information and knowledge regarding pre-frailty measurement. Therefore, a literature review was conducted to obtain knowledge and information on the pre-frailty measurements by comprehensively examining the types, components, methods, and classification criteria comprising pre-frailty. The purpose of the review is to provide a comprehensive understanding of pre-frailty measurements.

A total of eight pre-frailty measurements were identified (Appendix 1), author, name of measurement, number of items, components, classification of domains, and criteria for classifying pre-frailty were also examined. The number of items varied from three to 52 for each measurement. The components of the pre-frailty measurements were classified into physical, functional, medical, psychological, cognitive, and social domains.

The physical domain was included in all the pre-frailty instruments, while the functional domain was included in five instruments. However, there were only three pre-frailty tools

that included the psychological domain and the social domain (Jones et al., 2004; Mitnitski et al., 2001; Pillotto et al., 2008). The Cardiovascular Health Study (CHS) index, the Study of Osteoporotic Fractures (SOF), and the Fatigue, Resistance, Ambulation, Illness, and Loss of weight (FRAIL) index classify pre-frailty and frailty by using a corresponding number for each item. The FI, the Frailty Index derived from the Comprehensive Geriatric Assessment (FI-CGA), and the Clinical Frailty Scale (CFS) total the scores of each item and divide them by the total number of responses. Pre-frailty and frailty are then classified according to the cut-off.

The CHS index, which is often referred to as Fried's Frailty Phenotype, has five components: weakness, exhaustion, unintentional weight loss, low physical activity, and slowness. Weakness is described as handgrip strength of 20th percentile or lower by sex and body mass index. Exhaustion is self-reported and measured using two items on the Center for Epidemiological Studies Depression scale (CES-D). Unintentional weight loss can be self-reported or measured, with weight loss of ≥5% during the previous year indicating frailty. Low physical activity is associated with low energy expenditure, as measured by the Minnesota Leisure Time Activity Questionnaire. And slowness is measured as walking time of about 15 feet and classified lowest quintile by sex and height. The CHS index has three classifications: non-frailty (none), pre-frailty (1–2 items), and frailty (3–5 items). Pre-frailty refers to a state in which the criteria for frailty are not met (Fried et al., 2001). The CHS index is used to objectively evaluate the physical domain based on the biological model of frailty proposed by Fried et al. (2001). This indicator has

a relatively high predictive value often used for the purpose of screening frailty and adverse outcomes, including mortality (Dent et al., 2016). However, the CHS index is not widely used in the clinical setting. This is because it not only measures handgrip strength that is not frequently used in daily life, but also does not include the psychological and social domains of pre-frailty. Therefore, it does have limitations when evaluating pre-frailty.

The FI was initially proposed by Mitnitski et al. (2001) as a way of measuring multidimensional frailty. Mitnitski (2002) proposed and listed 70 cumulative health deficiencies that could explain to frailty, such as signs, symptoms, diseases, health examinations, and laboratory data. The list of health deficiencies may relate to health rather than age and could reflect various physiological systems (Searle et al., 2008). Additionally, by integrating health information across systems to quantify health problems, the FI could reflect the extent to which deficiencies contribute to systemic dysregulation (Kim et al., 2015). The FI is expressed as a ratio of the total scores of the items divided by the total number of answered items. The score of FI ranges from 0 (no health deficiency) to 1 (health deficiency) for each item, with higher scores meaning a higher level of frailty (Searle et al., 2008). Pre-frailty was defined as the cumulative result of physical, psychological, and social health deficiencies with an FI score of >0.08 and <0.25 (Song et al., 2010; Rogers & Fancourt, 2020).

Studied using the FI reported in the United States, United Kingdom, and Europe (Hoogendijk et al., 2017; Rogers & Fancourt, 2020; Theou et al., 2013), and recently, studies have been reported in Asia, including South Korea and China (Beak & Min, 2022;

Fan et al., 2020). When comparing the predictive power of adverse health-related outcomes such as frailty screening, admission to nursing homes, long-term hospital stays, and mortality among older adults, the FI was useful in predicting adverse health-related outcomes (Dent et al., 2014; Dent & Perez-Zepeda, 2015; Theou et al., 2013). Although predictive power is high, FI is not frequently used in clinical settings since it is time-consuming to calculate (Hubbard et al., 2009).

The FI-CGA was developed by Jones et al. in 2004. The Comprehensive Geriatric Assessment (CGA) is a comprehensive geriatric clinical assessment, which includes a multidisciplinary team assessment of physical, disease, psychological, functional, and nutritional status. The FI-CGA is a frailty index derived from CGA, which is a tool that simply uses data to help doctors who care for older adults to measure frailty (Jones et al., 2004; Jones et al., 2005). The FI-CGA includes the physical as well as the psychological and social domains. Psychological items measure depression using the Geriatric Depression Scale, and social items are social resources (e.g., patients who are institutionalized, use formal home support, or live alone). Based on the cumulative deficit model, the FI-CGA counts the number of deficient items and divides it by the number of items that responded, expressed as a range from 0 to 1 (Jones et al., 2005). However, the FI-CGA is difficult to use because it requires professional manpower, a large budget, and ample time to measure. To further simplify the assessment of frailty in older adults, Rockwood et al. (2010) expanded it to include 52 CGA components.

Morley et al.'s (2012) FRAIL is a measurement that includes physical and medical domains consisting of five items: fatigue, resistance, ambulation, illness, and weight loss. These measurement scores were classified as non-frailty (none), pre-frailty (1–2 items), and frailty (3–5 items). It is a simple test that can improve the screening of pre-frailty without the need for a face-to-face interview (Dent et al., 2016). A self-diagnosis, telephone or online survey are available, which has the advantage of more efficient evaluation of frailty (Dent et al., 2016).

The SOF, developed by Bilotta et al. (2011), is based on the theory of biological causes that uses three items to evaluate weight loss, exhaustion, and low mobility. The SOF is classified into non-frailty (none), pre-frailty (1 item), and frailty (2–3 items). The SOF, like the CHS index, only includes the physical domain, therefore, it limits to multidimensional evaluation.

The Multidimensional Prognostic Index (MPI) was developed as a death prognostic measurement for hospitalized older patients (Pilotto et al., 2008). The components of MPI include comorbidity, polypharmacy, nutrition, cognition, pressure sore risk, living status, Activities of Daily Living (ADL), and Instrumental Activities of Daily Living (IADL). Total scores ranged from 0 to 1. Scores were classified according to cut-off values into pre-frailty (MPI >0.34) and frailty (MPI >0.66). Although it is a simpler measurement than the FI (Pilotto et al., 2012). However, several studies are required to validate the validity and predictability of MPI (Dent et al., 2016).

To summarize, the literature review examined the types, domains, components, number of items, and classification criteria for diagnosing pre-frailty. Consequently, this review will collate knowledge that will broaden our understanding of pre-frailty measures and enable researchers to select pre-frailty measurements. Currently, there is no gold standard for pre-frailty measurement that has been agreed upon by researchers. However, the FI is a comprehensive pre-frailty measurement with a comprehensive, multidimensional feature that can show cumulative health changes during the aging process.

2.2. Research on Pre-frailty

1) Trajectories of frailty

The health trajectory relies on longitudinal data of individuals, families, or groups to identify the process underlying the dynamic changes in acute or chronic health status over time (Whyman & Henly, 2011). The health trajectory is essential for developing interventions for managing patient-centric nursing and policymaking (Whyman & Henly, 2011). Although recent studies on the definition of pre-frailty, its predictors, and adverse health-related outcomes were described, studies on the pre-frailty trajectories have not been reported yet. This study intends to obtain information regarding the changes in pre-frailty from frailty trajectories. Thus, a literature review was performed in order to identify information regarding the pre-frailty and frailty trajectories (Appendix 2).

As a result of the literature review, ten trajectory articles were identified. These articles were classified according to the study characteristics (country, year, inclusion criteria for participants, sample size, mean age, ratio of women, and ethnicity), research method (frailty measurement and follow-up period), and main results (the number of classifications about frailty trajectories, classification rate, and other results).

The study characteristics are described below. Studies were conducted in the United States, the United Kingdom, and Spain, Canada. Publication years ranged from 2012 to 2021, with three studies published in 2018. The inclusion criteria for participants, including country, age, ethnicity, mobility, cognitive impairment, and health status (terminal illness) were reported. Only three studies were presented as specific inclusion criteria: response rate, omission rate for a variable, and minimum number of follow-up participants (Howrey et al., 2020; Roger & Fancourt, 2020).

The sample sizes ranged from 690 to 13,495 participants, with an age range of 64.0 to 85.1 years. Five studies included only older adults aged 65 and over (Álvarez-Bustos et al., 2021; Howrey et al., 2020; Liu et al., 2018; Peek et al., 2012; Stow et al., 2018), while other studies included middle-aged adults. The ratio of women among the participants varied from 53% to 73%.

Several studies used the FI for frailty trajectories (Gajic-Veljanoski et al., 2018; Lohman et al., 2017; Rogers et al., 2017; Rogers & Fancourt, 2020; Stow et al., 2018), while four studies used the CHS index (Buchman et al., 2014; Howrey et al., 2020; Liu et al., 2018; Peek et al., 2012). The follow-up period ranged from one to 18 years.

The number of frailty trajectories was usually derived from three to four (Howrey et al., 2020; Liu et al., 2018; Peek et al., 2012; Stow et al., 2018). The frailty trajectories showed three major patterns: remaining frailty, worsening to frailty, and improving to non-frailty. Stow et al. (2018) divided frailty trajectories into three groups: rapidly rising frailty, moderately increasing frailty, and stable frailty. These trajectories can be classified as remaining frailty (stable frailty) and worsening to frailty (rapidly rising frailty and moderately increasing frailty). Also, Álvarez-Bustos et al. (2021) reported five frailty trajectories in Spain: remaining frailty, worsening from non-frailty, increasing frailty, developing frailty, and improving to non-frailty. These trajectories can be classified as remaining frailty, worsening to frailty (worsening from non-frailty, increasing frailty, and developing frailty), and improving to non-frailty. Although there were differences depending on the study population and follow-up period, the classification rate for worsening frailty was mostly high (Álvarez-Bustos et al., 2021; Peek et al., 2012; Stow et al., 2018).

Among the modifiable factors, fracture and obesity predicted frailty progression (Gajic-Veljanoski et al., 2018). Moderate physical activity, a high frequency of cultural participation, and social support were reported as protective factors for frailty (Peek et al., 2012, Rogers et al., 2017; Rogers & Fancourt, 2020). The frailty trajectories were statistically significant with disability, admission to nursing home, and mortality (but hospital admission) (Liu et al., 2018).

In summary, the literature review identified information for the study characteristics, the frailty measurements, the follow-up period, and the trajectory pattern. It was also possible to acquire knowledge about health trajectories that can predict changes in pre-frailty trajectories over time.

2) Effect of life course determinants on pre-frailty

The purpose of this study is to identify the life course determinants of pre-frailty through literature review. In particular, we aimed to investigate the modifiable factors of pre-frailty. As a result of reviewing the literature, life course determinants affecting pre-frailty were classified into demographic factors, lifestyle, life event, and biologic factors (Appendix 3).

First, the effect of demographic factors, including age, sex, education level, marital status, and income, on pre-frailty is as follows. The risk of pre-frailty is positively correlated with age (Fan et al., 2021; Norazman et al., 2020; Romero-Ortuno et al., 2021). Romero-Ortuno et al. (2021) surveyed 8,174 people who aged 50 and over, and conducted an Ireland study to identify the factors that affected pre-frailty. Older age was associated with the transition from pre-frailty to frailty (Romero-Ortuno et al., 2021). Studies reported that women had a higher risk of pre-frailty than men (Fan et al., 2021; Romero-Ortuno et al., 2021). Findings about relationships between pre-frailty and high education level were inconsistent across studies (Fan et al., 2021; Romero-Ortuno et al., 2021). Studies reported that marital status and income did not affect pre-frailty (Pollack et al., 2017; Norazman et al., 2020).

Studies of lifestyle factors influencing pre-frailty have been conducted on physical activity, leisure-time activity, sedentary behaviors, malnutrition, healthy diet, alcohol consumption, smoking, sleep disturbance, and weight management. Kikuchi et al. (2021) studied the associations between intensity physical activity and pre-frailty in 511 Japanese community-dwelling older adults. According to the metabolic equivalent of task (METs), light physical activity and pre-frailty were not related, whereas moderate to vigorous physical activity decreased the risk of pre-frailty. In addition, prolonged sedentary behaviors increased the risk of pre-frailty (Kikuchi et al., 2021). Leisure-time activity was measured as watching television, gardening, cycling, walking, running, jogging, swimming, and competitive/vigorous exercise (Savela et al., 2013). Moderate and high leisure-time activity did not have a significant effect on the pre-frailty (Savela et al., 2013). Nutritional status was measured by the Mini-Nutrition Assessment-Short Form in which higher scores indicate better nutritional status. Study reported that pre-frailty was not associated with malnutrition risk (Norazman et al., 2020). A healthy diet, as measured using the Alternative Healthy Eating Index, Dietary Approaches to Stop Hypertension, and Mediterranean Diet, was associated with a lower risk of pre-frailty (Ward et al., 2021). Findings have shown that the transition from pre-frailty to frailty were not associated with alcohol consumption and smoking (Fan et al., 2019). Sleep measured objectively for nighttime total sleep time, wake after sleep onset, sleep fragmentation, and percent sleep (percentage of sleep intervals spent sleeping) using ActiGraph for 72 hours was not associated with pre-frailty (Guida et al., 2021). A longitudinal study showed that underweight and overweight were not

associated with the transition from pre-frailty to frailty while obese was associated (Fan et al., 2021). The correlations between body fat, mid-upper arm circumference and waist circumference and pre-frailty were not clear (Crow et al., 2019; Norazman et al., 2020).

The history of falls among life events has been reported to be associated with pre-frailty (Gratza et al., 2019). For pre-frailty measurement, Short Performance Physical Battery (SPPB) was used, and 7 to 9 points out of a total of 12 points of SPPB was classified as pre-frailty. The history of falls about fall environment, activity before fall, and time of day when the fall occurred (morning, afternoon, evening and night) was collected monthly by phone. Study have found that a history of falls was not associated with pre-frailty (Gratza et al., 2019).

Biologic factors for pre-frailty included level of cortisol, testosterone, and vitamin D. Low level of testosterone and vitamin D increased the risk of pre-frailty (Carcaillon, et al. 2012; Sergi et al., 2015; Sousa-Santos et al., 2018), but cortisol was not associated with pre-frailty (de Almeida Holanda et al., 2012).

To summarize, the life course determinants that affected pre-frailty were age, sex, physical activity, sedentary behaviors, healthy diet, nighttime total sleep time, body mass index (BMI) (>28.0), testosterone, and vitamin D level. A literature review of the influence of life course determinants on pre-frailty provides knowledge about modifiable factors and insights that can guide prevention and intervention strategies for pre-frailty.

3) Adverse health-related outcomes associated with pre-frailty

(1) Hospitalization associated with pre-frailty

Frailty is linked to important adverse health-related outcomes. In a systematic review, frailty was shown to increase adverse health-related outcomes such as the risk of falls, fractures, nursing home admission, hospitalization, and premature mortality (Vermeiren et al., 2016). Among them, hospitalization for frailty can increase the social and economic burden for older adults as well as their families and caregivers (Chang et al., 2018; Kojima, 2016). However, information regarding the association between pre-frailty and hospitalization is limited. The literature review in this study aimed to identify the relationship between pre-frailty and hospitalization among community-dwelling older adults (Appendix 4).

A total of nine studies on pre-frailty and hospitalization were found, and the number of study participants varied from 754 to 8,844. The studies were mostly conducted in communities, only one study included supportive housing facilities (Hogan et al., 2012). Four studies were conducted in the United States, while the United Kingdom, Italy, Canada, Mexico, and South Korea had one study each. Participants in most studies were over 65 years old, but only Bouillon et al. (2013) included those over 55 years old. In seven studies, the CHS was used as frailty measurement (Avial-Funes et al., 2009; Bandeen-Roche et al., 2006; Bouillon et al., 2013; Gill et al., 2011; Hogan et al., 2012; Jung et al., 2014; Kiely et al., 2009). In the other studies, the FI, Korean Longitudinal Study on Health and Aging (KLoSHA), Paulson-Lichtenberg Frailty Index (PLFI), and SOF were use. Most hospitalization measures were self-reported, but one study (Paluson & Lichtenberg, 2015) used objective hospital record data. The follow-up period ranged from one to eight years.

The literature review showed that, when compared with non-frail individuals, three studies showed a significant risk of hospitalization in pre-frail individuals (Bouillon et al., 2013; Kiely et al., 2009; Paulson & Lichtenberg, 2015) and a non-significant risk in five studies (Avial-Funes et al., 2009; Bandeen-Roche et al., 2006; Forti et al., 2014; Gill et al., 2011; Jung et al., 2014).

Study also reported no significant relationship between hospitalization for pre-frailty, as measured by CHS and FI consisting of 43 items, although the association between hospitalization and pre-frailty, as measured by the full FI (83 items), was statistically significant (Hogan et al., 2012).

Paulson and Lichtenberg (2015) analyzed pre-frailty by using the PLFI to measure weakness, exhaustion, wasting, slowness, and falls. The classification scores for frailty were 0 (non-frailty), 1–2 (pre-frailty), and 3–5 (frailty). Significant associations between hospitalization and pre-frailty were reported after four and eight years of follow-up.

In summary, frailty is becoming increasingly important when caring for older adults. The literature review shows that the relationship between pre-frailty and hospitalization has been inconsistently reported. In order to reduce the burden of hospitalization, further studies are needed to understand the relationship between the two. Nurses must use validated frailty measurements to evaluate early changes in pre-frailty among older adults and to develop interventions and intervention strategies for reducing the risk of hospitalization.

(2) Mortality associated with pre-frailty

Disability, health care utilization and death can occur as a result of adverse outcomes of frailty (Gobbens et al., 2010). According to a systematic review, frailty as measured by FI was reported to be significantly associated with premature mortality (Kojima, Iliffe, & Walters, 2018). However, the conclusion about the relationship between the intermediate stage pre-frailty and mortality still ambiguous. A literature review was performed to identify the relationship between pre-frailty and mortality (Appendix 5).

As a result, a total of eight studies were identified. In this review, first author, publication year, sample, age range of sample, pre-frailty measurement, follow-up period, adjustment factors, and the results about mortality, were examined. The publication years of the articles ranged from 2009 to 2022. The number of samples ranged from as low as 840 to as high as 725,759. The age criteria of the study sample were mostly the older adults 65 years or older. In two studies, adults 45 years and older were included (Beak & Min, 2022; Malmstrom et al., 2014).

To measure pre-frailty, four studies used the CHS (Ávila-Funes et al., 2009; Cano et al., 2012; Lee et al., 2018; Jacobs et al., 2011), two studies used the FI (Beak & Min, 2022; Malmstrom et al., 2014). And the MPI and The Lifetime Transition Period Health Examination version of the Korean Frailty Index (THE frailty index) were used. For the follow-up period, five studies had follow-up periods of less than 10 years, and three studies had follow-up periods of more than 10 years (Beak & Min, 2022; Cano et al., 2012; Nari et al., 2021). Four studies reported corresponding hazard ratio (HR) for the risk of death, with potential adjustment factors including age and sex (Ávila-Funes et al., 2009; Cano et

al., 2012; Lee et al., 2018; Jacobs et al., 2011). In addition, one study provided the odds ratio (OR) (Malmstrom et al., 2014).

A significant association between pre-frailty and mortality was reported in almost all studies except for that by Avila-Funes et al. (2009). Ávila-Funes et al. (2009) measured pre-frailty using the CHS in older adults over 65 years old in Mexican study and followed up for 4 years. As a result, it was reported that there was no relationship between the pre-frailty and mortality. On the other hand, a study that measured pre-frailty using the CHS and 3-year follow-up Korean older adults showed a significant relationship between pre-frailty and mortality (Lee et al., 2018). In study using the FI, the mortality among those in pre-frailty groups was higher than that of those in non-frailty groups (Baek & Min, 2022). And the ratio of mortality risk was higher among frailty men group than among frailty women group, and the predictive ability of the FI concerning sex differences was reported (Baek & Min, 2022).

To summarize, the results of literature review on the associations between pre-frailty and mortality were consistent. However, comparison of study results is difficult. This is because of differences in the study population, pre-frailty measurement, and follow-up period. Further research is necessary that consider variety of study populations, pre-frailty measurement with proven reliability and validity, and follow-up period of 10 years or more. Understanding of the relationship between pre-frailty and adverse health-related outcomes will provide a foundation for efficient use of limited medical resources and medical cost reduction.

3. THEORETICAL FRAMEWORK

3.1. The Conceptual Framework

The theoretical framework of this study is the Integral Conceptual Model of frailty (ICMF) developed by Gobbens et al. (2010). Other model of frailty cycle, which describes the physiological, biological and molecular pathways of frailty, focuses on physical domains (Fried et al., 2001); thus, other model has limitations when it comes to understanding the multidimensional characteristics of pre-frailty. The ICMF explains the multidimensional characteristics and dynamics of pre-frailty, including physical, psychological, and social domains, based on a holistic perspective (Gobbens et al., 2010). Therefore, the ICMF was selected as a conceptual framework for this study. This model presents the pathways to frailty during the aging process and emphasizes the provision of nursing interventions to prevent and delay frailty and its adverse outcomes (Gobbens et al., 2010).

In Figure 1, the ICMF model characterized a life cycle approach to describe the pathways leading to frailty and its outcomes. Frailty was defined specifically to the functional impairment of one or more physical, psychological, and social domains that increase the risk of adverse outcomes in an individual's life (Gobbens et al., 2010). By examining the path of frailty, the life course determinants and diseases are highly likely to result in adverse outcomes by affecting frailty (Gobbens et al., 2010). Life course determinants

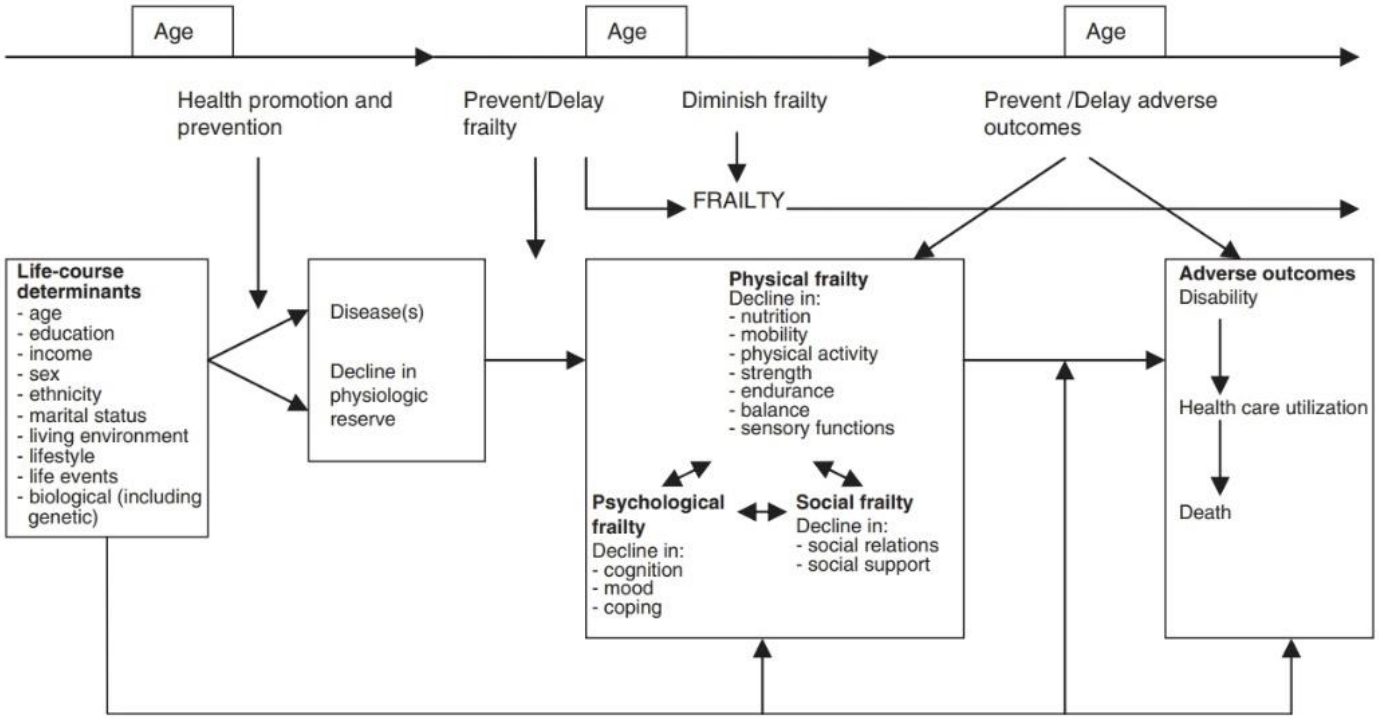


Figure 1. An integral conceptual model of frailty

Reference: Gobbens, R. J., Luijkx, K. G., Wijnen-Sponselee, M. T., & Schols, J. M. (2010). Towards an integral conceptual model of frailty. *The Journal of Nutrition, Health & Aging*, *14*(3), 175-181.

include demographic characteristics such as age, sex, education, ethnicity, income, marital status, and living environment. Disease factors refer to a decrease in physiological reserves, which is an age-related physiological vulnerability resulting from a decrease in an individual's ability to maintain homeostasis and cope with stress. Physical frailty includes the deterioration of mobility, physical activity, strength, nutrition, fatigue, balance, and sensory functions. Psychologic frailty reduces cognitive, emotional and coping abilities. Social frailty occurs when social relationships and social support decrease. These factors may induce physical, psychological and social frailty, resulting in adverse outcomes such as disability, health care utilization (hospitalization and nursing home admission), and death (Gobbens et al., 2010).

In this study, based on the ICMF, a conceptual framework for pre-frailty trajectory among older adults was constructed as shown in Figure 2. The older adults experience pre-frailty due to impairment of physical or psychological functions in the aging process. This study was conducted to identify the pre-frailty trajectories, to examine the life course determinants of pre-frailty trajectories, and to investigate adverse health-related outcomes associated with pre-frailty trajectories. The effects of pre-frailty on disability have been consistently reported (Fried et al., 2001; Forti et al., 2014; Romero-Ortuno et al., 2015). This study examined adverse health-related outcomes, including hospitalization and mortality.

In the ICMF, the pathway leading to frailty is modulated by antecedent life course determinants and diseases (Gobbens et al., 2010). However, this study had limitations in

including components in life course determinants and did not include ethnicity, living environment, and biological factors. Adverse health-related outcomes, such as disability, health care utilization, and death, occur sequentially due to life course determinants and frailty. This study examined only hospitalization and mortality, excluding disability, and had a limitation in that it did not reflect the sequence.

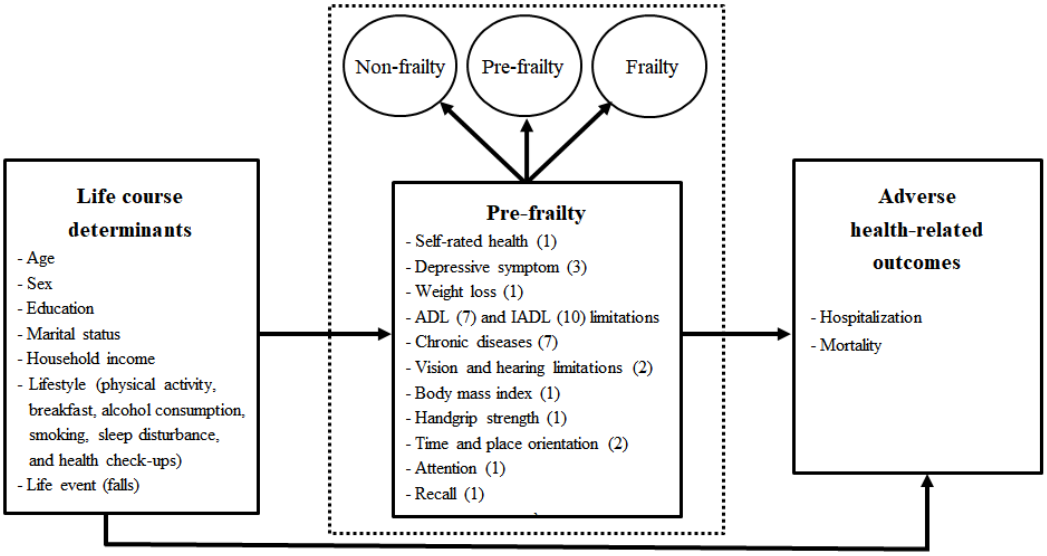


Figure 2. The conceptual framework of this study

ADL: activities of daily living, IADL: instrumental activities of daily living.

4. METHODS

4.1. Study Design

This study was a secondary data analysis to identify the pre-frailty trajectories, influential life course determinants on pre-frailty trajectories, and relationship between adverse health-related outcomes and pre-frailty trajectories using the Korean Longitudinal Study of Aging (KLoSA) data from 2006 to 2020.

4.2. Research Data

This study used KLoSA data collected between 2006 and 2020. The KLoSA is data collected to measure and understand the conditions including the demographic, socioeconomic, physical, psychological and health-related status of older adults as South Korea becomes a super-aged society so that effective national policy can be implemented (Korea Employment Information Service, 2020).

Standard KLoSA questionnaire were administered in even-numbered years while surveys about specific topics were administered in odd-numbered years. The target population of KLoSA was 10,254 adults who were at least 45 years old except on Jeju Island in 2006. The KLoSA investigated the physical function, health, psychological and social status of the older adults. The KLoSA was a longitudinal study data with final year of 2020.

In 2014, 920 people born in 1962 and 1963 were added. The original sample were classified as existing panel, and the additional sample were classified as new panel. Until the 2020, the sample retention rate of the existing panel was 77.1% (n = 5,717), and the sample retention rate of the new panel was 87.2% (n = 771). Therefore, the combined sample (existing and new panel) participating in 2020 was 6,488 and the number of deaths was 512. The death questionnaire surveys family members and acquaintances about the participants' health status and death-related information before death.

The KLoSA sample was stratified by region and residential type. Regions were stratified by province, municipality, dong, and then eup or myeon. Residential types were classified as either a general house or apartment. Sampling areas were allocated by population. The KLoSA surveys were conducted face-to-face using a computer.

The KLoSA data was chosen for analysis to include a large number of community-dwelling population. In addition, the KLoSA data was longitudinal and could show changes in health status in older adults over time. This data is likely to reflect the current state of Korean older adults in 2020.

4.3. Sample

The inclusion criteria were as follows:

1) Participants who were 65 years old or over in 2006

2) Participants who responded on the FI measurements 80% or more in 2006 and 2020 (Hoogendijk et al., 2017; Stephan et al., 2020)

3) Participants who were classified as pre-frailty in 2006

4) Participants who answered all items of the life course determinants in 2006

5) Participants who participated in follow-up surveys for the KLoSA between 2008 and 2020 (At least once out of a total of seven times follow-up (Howrey et al., 2020))

A total of 10,254 individuals participated in the KLoSA (2006–2020). Of these, 4,164 were aged 65 or over. At baseline, 1,626 participants who had either non-frailty or frailty FI scores or who had missing value more than 20% on the FI measurements were excluded. A further 290 participants who did not answer the life course determinants were excluded at baselines. This study also excluded 293 participants who did not participate in the follow-up surveys from 2008 to 2020. Therefore, a total of 1,955 participants were included in the final analysis (Figure 3).

4.4. Variables

In this study, the life course determinants, pre-frailty, and adverse health-related outcomes are shown below, and in Table 1, and the instruments or questionnaires can be found in Appendix 6.

1) Life course determinants

Life course determinants including age, sex, education, marital status, household income, lifestyle, and life event were collected in 2006.

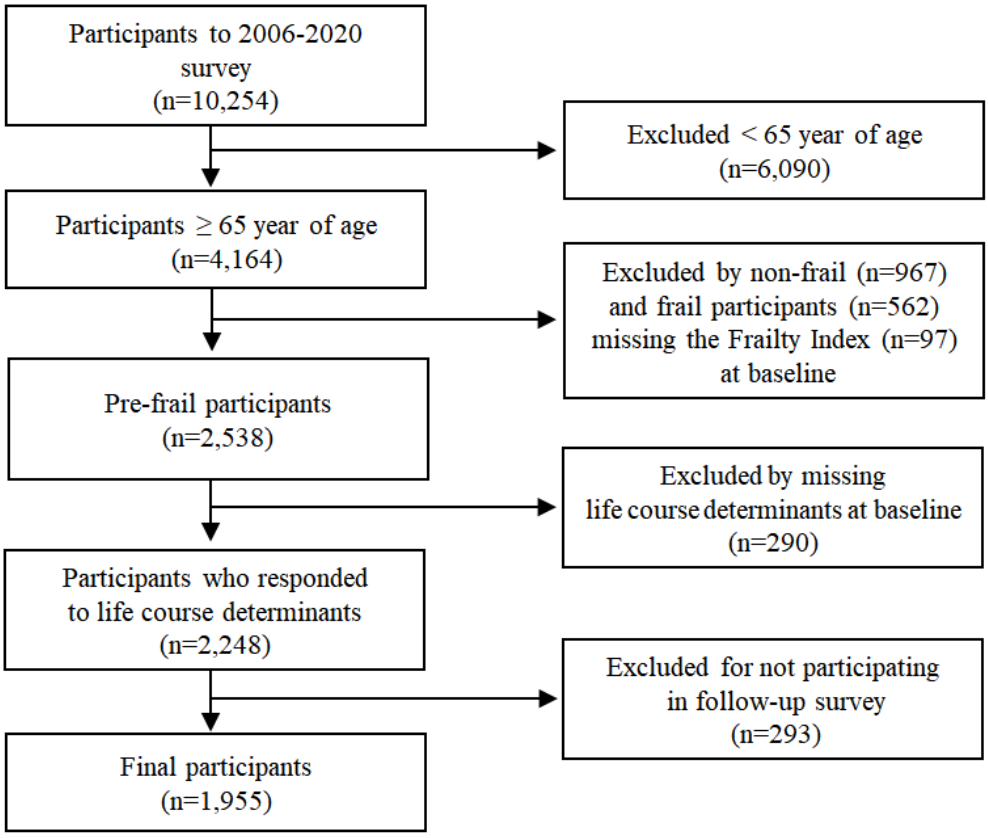


Figure 3. Flow of the selection process for this study sample

(1) Age

Participant ages were measured and coded as 0 if they were 65 to 74 years old, 1 if they were 75 to 84 years old, and 2 if they were 85 years old and over.

(2) Sex

Participants' sex was coded as 0 for men and 1 for women.

(3) Education

Education was coded as 0 for the completion of less than primary school and 1 for the completion of greater than middle school.

(4) Marital status

Marital status was measured and coded as 0 if the participant was married and 1 for unmarried (separated, divorced, widowed, or single).

(5) Household income

Previous studies (Kim, G. et al., 2019; Lee et al., 2018), categorized the previous year's total household income (measured in 10,000 KRW) into four groups based on quarters (Q1: ≤1,000,000 KRW; Q2: 1,010,000–5,000,000 KRW; Q3: 5,001,000–15,000,000 KRW; and Q4: ≥15,010,000 KRW; Q1 was coded as 0, Q2 as 1, Q3 as 2, and Q4 as 3).

(6) Lifestyle

Lifestyle was measured and was included physical activity, breakfast, alcohol consumption, smoking, sleep disturbance, and health check-ups (Gobbens & van Assen, 2016; Wister, 2022; World Health Organization, 2019). (a) Physical activity was coded as 0 if the participant had physical activity more than once during the preceding week and 1 if not. (b) Breakfast was coded as 0 if the participant ate breakfast twice over the past two days, and 1 if the participant did not eat breakfast, or ate it once. (c) Alcohol consumption was coded as 1 if the participant drank alcohol and 0 if they had never drunk alcohol or used to drink in the past. (d) Smoking was coded as 1 if the participant was a smoker, and 0 if not. (e) Sleep disturbance was measured using one item from the Korean version of the

Table 1. Operationalization of the variable in this study

Variable	Instruments or Questionnaire	Classification
1) Life course determinants		
Age	'What year was your birth?'	65-74 years=0,75-84 years=1, ≥ 85 years=2
Sex	'What is your gender?'	Men=0, Women=1
Education	'Where did you go to school? Did you graduate from your school?'	≤ Primary school=0, ≥ Middle school=1
Marital status	'What is your current marital status?'	Married=0, Separation/divorce/ bereavement/single=1
Household income	'What was your total household income in the previous year?'	Categorized on quartiles; Q1=0, Q2=1, Q3=2, Q4=3
Lifestyle	**(1) Physical activity:** 'Whether you exercise at least once a week?'	Yes=0, No=1
	(2) Breakfast: 'Have you eaten breakfast in the past two days?'	Yes(twice)=0, No(≤once)=1
	(3) Alcohol consumption: current drinking status	Yes (current drinker)=1, No (non-drinker, ex-drinker)=0
	(4) Smoking: current smoking status	Yes (current smoker)=1, No (non-smoker, ex-smoker)=0
	(5) Sleep disturbance: 'Whether you had been experienced in the preceding week?' (1 item from CES-D20)	Yes (3-4 days, 5-7 days)=1, No (<1day, 1-2 days)=0
	(6) Health check-ups: 'Have you received free health check-ups in the past 2 years?'	Yes=0, No=1

Table 1. Operationalization of the variable in this study

Variable		Instruments or Questionnaire	Classification
Life event		**Falls:** 'Have you had a fall in the past 2 years?'	Yes=1, No=0
2) Pre-frailty			
Pre-frailty		Frailty Index (37 items)	Non-frailty: FI ≤0.08, Pre-frailty: FI >0.08 to FI <0.25, Frailty: FI ≥0.25
Pre-frailty	**Psychological domain (4 items)**	**(1) Self-rated health** 'How do you feel about your health?' (1 item)	Excellent=0, very good=0.25, good=0.5, fair=0.75, poor=1
		(2) Depressive symptoms (a) Feel everything is an effort, (b) Feel depressed, (c) Feel lonely (3 items from CES-D20)	<1 day=0, 1-2 days=0.5, 3–4 days=0.5, 5–7 days=1
	Physical domain (29 items)	**(3) Weight loss** 'Have you lost 5 kilograms or more in the last year?' (1 item)	Yes=1, No=0
		(4) ADL limitation Washing, eating, dressing, bathing, transferring, toileting, incontinence using K-ADL (7 items)	Able=0, With help=0.5, Unable=1
		(5) IADL limitation Grooming, housework, meal preparations, laundry, outgoing, shopping, using transportation, finances, telephone, taking medication using K-IADL (10 items)	Able=0, With help=0.5, Unable=1

Table 1. Operationalization of the variable in this study

Variable		Instruments or Questionnaire	Classification
Pre-frailty	Physical domain (29 items)	**(6) Chronic disease** Cancer, diabetes, arthritis, hypertension, lung disease, heart disease, stroke (7 items)	None=0, Diagnosed=1(Transient ischemic attack or suspected stroke=0.5)
		(7) Vision and hearing limitation 'Are you having trouble with your daily life because of your eyesight/hearing problems?' (2 items)	No=0, Having difficulty in daily activities=1
		(8) Body mass index (BMI) Weight (kg) and height (m) measurement (1 item)	18.5–24.9kg/m^2=0, 25–29.9kg/m^2=0.5, <18.5 or ≥30kg/m^2=1
		(9) Handgrip strength (HS) The average value in kg of two handgrip strength trials for the left and right hands each using a dynamometer (1 item)	**Men** BMI≤24 and HS≤29kg=1, BMI 24.1–28 and HS≤30kg=1, BMI>28 and HS≤32kg=1 **Women** BMI≤23 and HS≤17kg=1, BMI 23.1–26 and HS≤17.3kg=1, BMI 26.1–29 and HS≤18kg=1, BMI>29 and HS≤21kg=1
	Cognitive domain (4 items)	**(10) Time orientation** 'What is the year? month? date? day of the week? season?' using K-MMSE (1 item)	Five correct=0, four correct=0.5, three or less correct=1

Table 1. Operationalization of the variable in this study

Variable		Instruments or Questionnaire	Classification
Pre-frailty	Cognitive domain (4 items)	**(11) Place orientation** 'Where are we now?', 'What is your address: City? Gu? Dong? detailed address?' using K-MMSE (1 item)	Five correct=0, four correct=0.5, three or less correct=1
		(12) Attention Ask to start at 100 and count backward by sevens. Stop after five answers using K-MMSE (1 item)	Five correct=0, three or four correct=0.5, two or less correct=1
		(13) Recall 'I told you the names of three things before. Can you tell me?' using K-MMSE (1 item)	Three correct=0, two correct=0.5, one or less correct=1
3) Adverse health-related outcomes			
Hospitalization		Hospitalization experience with one year	Yes=1, No=0
Mortality		All-cause mortality	Yes=1, No=0

ADL: Activities of Daily Living, BMI: Body mass index, CES-D: Center for Epidemiological Studies Depression scale, FI: Frailty Index, HS: handgrip strength, IADL: Instrumental Activities of Daily Living, K-ADL: Korean version of Activities of Daily Living, K-IADL: Korean version of Instrumental Activities of Daily Living, K-MMSE: Korean version of the Mini-Mental State Examination.

Center for Epidemiological Studies Depression scale (Radloff, 1977). The question was whether they had experienced sleep disturbance during the past week. Answers could be given on a 4-point Likert scale, ranging from 1 point for “rarely (less one day)” to 4 points for “frequently (more than 5 days).” Sleep disturbance were coded as 1 if the participant experienced sleep disturbance (3–4 points) and 0 if not (1–2 points). (f) Health check-ups were coded as 0 if the participant received national health check-ups by the National Health Insurance and Medical Benefit in the past two years and 1 if not.

(7) Life events

Life events measured a history of falls and were coded as 0 if the participant had not experienced falls within the past two years and 1 if otherwise.

2) Pre-frailty

Pre-frailty was measured by the modified the FI suggested by Jung et al. (2022) based on the KLoSA data. The FI consisted of 33 items on self-reported health, depressive symptoms, weight loss, ADL and IADL limitations, chronic diseases, vision and hearing limitations, BMI, and handgrip strength (Jung et al., 2022). The original FI by Mitnitski et al. (2001) includes the cognitive domain, but the Jung et al. (2022) FI does not. Based on the literature review, four items corresponding to the cognitive domain were added: time and place orientation, attention, and memory (Baek & Min et al., 2022; Hoogendijk et al., 2017; Rogers & Fancourt, 2020). In this study, the FI was measured using 37 items.

Jung et al. (2022) also tried to distinguish between non-frailty and frailty. However,

since the purpose of this study was to investigate pre-frailty trajectories, the response categories of the ADL limitation, IADL limitation, and stroke items among the FI were modified into three categories based on previous studies (Beak & Min, 2022; Searle et al., 2008).

The FI was classified by adding the scores of the measured items and dividing them by the number of measured items. For example, if the participant had 7 points out of 37, the FI score was 0.19 (7/37).

$$\text{FI} = \frac{\text{Sum of scores for each item}}{\text{Number of measured items}}$$

The FI score was a continuous variable that ranged from 0 (no health deficiency) to 1 (health deficiency) to determine frailty status. A higher FI score means a higher level of frailty (Searle et al., 2008).

Only the classification criteria for frailty (FI >0.25) were presented in the original FI (Mitnitski et al., 2001). Jung et al. (2022) also did not describe the classification criteria for pre-frailty. Therefore, a literature review was conducted on the classification criteria of pre-frailty as follows: (a) the classification criteria of tools following Searle's "2008 FI Composition Standard Procedure" (Searle et al., 2008), and (b) the classification criteria that investigated the reliability and validity of FI in a community setting. Since there are differences in the number of items, component items, and scoring criteria of the FIs proposed by Song et al. (2010) and Rogers et al. (2020), these studies were followed the FI Composition Standard Procedure, and were verified the reliability and validity of the tool

in a community setting. Therefore, the classification criteria were as follows: non-frailty (FI $\leq$0.08), pre-frailty (FI >0.08 to FI <0.25), and frailty (FI $\geq$0.25). In this study, Cronbach's alpha value of the FI was 0.857.

(1) Self-rated health

The participants were asked to rate their subjective health status (one item) using a 5-point Likert scale, where "excellent" was rated as 0, "very good" as 0.25, "good" as 0.5, "fair" as 0.75, and "poor" as 1.

(2) Depressive symptoms

Depressive symptoms were measured using three items from the Korean version of the Center for Epidemiological Studies Depression scale (Radloff, 1977). The questions were regarding depressive symptoms that had been experienced in the past week. The questions were "Did you feel that everything you did required effort?", "Are you depressed?", and "Are you lonely?". Answers were given on a 4-point Likert scale and ranged from 1 point for "sometimes (1<day)" to 4 points for "frequently (5–7 days)." Depressive symptoms were coded as 0 for less than once a day, 0.5 for 1–2 days and 3-4 days, and 1 for 5–7 days.

(3) Weight loss

Weight loss was defined as unintentional weight loss of 5 kg or more over the past year. For the self-report, the question was coded as dichotomous with "yes" or "no" using one item.

(4) ADL limitation

The ADL was measured using seven items from the Korean version of the Activities of

Daily Living (K-ADL) index developed by Won et al. (2002a). The ADL limitation was evaluated using the items about washing the face, eating, dressing, bathing, transferring, toileting, and incontinence. Each question was rated on a 3-point scale ranging from "completely independent" (1 point) to "completely dependent" (3 points). In this study, ADL was coded as 0 for participants who were completely independent, 0.5 for participants who were partially dependent (Beak & Min, 2022), and 1 for participants who were fully dependent.

(5) IADL limitation

The IADL was developed by Lawton and Brody (1969) and Won et al. (2002b) translated the Korean Instrumental Activities of Daily Living (K-IADL), it was measured using K-IADL. The IADL limitation was assessed using ten items from the K-IADL: grooming, housework, meal preparations, laundry, outgoing, shopping, using transportation, finances, telephone, and taking medication. The K-IADL answers were given on a 3-point scale, from "completely independent" (1 point) to "completely dependent" (3 points). In this study, IADL was coded as 0 for participants who were completely independent, 0.5 for participants who were partially dependent (Beak & Min, 2022), and 1 for participants who were fully dependent.

(6) Chronic diseases

Chronic diseases were measured using seven items and required a doctor's diagnosis for cancer, diabetes, arthritis, hypertension, chronic lung disease, heart disease, and stroke (Hao et al., 2018; Valderas et al., 2009). Each chronic disease was coded as 1 if the

participant had comorbidities and 0 if not. Stroke were classified as 0.5 for an additional value (Searle et al., 2008) because stroke included an intermediate response (transient ischemic attack or suspected stroke).

(7) Vision and hearing limitations

Vision and hearing limitations were measured based on responses to each of the two items such as “Are you having trouble with your daily life because of your eyesight?” and “Are you having trouble living with hearing problems?” Participants with vision and hearing problems, respectively, were classified as 1, and 0 if they had no difficulty.

(8) Body mass index

The BMI was calculated as the participant’s weight in kg divided by their height in m^2 and was used one item. The participants were classified as underweight with a BMI of <18.5 kg/m^2 and obese with a BMI of ≥ 30 kg/m^2, which was coded as 1. Participants were classified as overweight with a BMI of ≥ 25 kg/m^2 and ≤ 29.9 kg/m^2 and were coded as 0.5, and those of normal weight had a BMI of 18.5–24.9 kg/m^2 and were coded as 0.

(9) Handgrip strength

Handgrip strength was measured as the average value in kg of two handgrip strength trials for the left and right hands each using a dynamometer (NO6103; Tanita, Tokyo, Japan). The classification criteria for handgrip strength were different according to sex and BMI.

(10) Time orientation

Time orientation was measured based on responses to the questions, including “What is

the year/month/date/day of the week/season?" from the Korean version of the Mini-Mental State Examination (K-MMSE). Time orientation was one item and coded as 0 for five correct, 0.5 for four correct, and 1 for fewer than four correct (Hoogendijk et al., 2017).

(11) Place orientation

Place orientation was measured using items included in the K-MMSE. The questions are such as "Where are we now?" and "What is your address: City/Gu/Dong/detailed address?" Place orientation was one item and coded as 0 for five correct, 0.5 for four correct, and 1 for fewer than four correct (Hoogendijk et al., 2017).

(12) Attention

Attention was measured by the question from the K-MMSE, which was "Ask the participant to subtract 7 from 100. Stop after five times." Attention was one item and coded as 0 for five correct, 0.5 for three or four correct, and 1 for fewer than three correct (Hoogendijk et al., 2017).

(13) Recall

Recall was measured using one item from the K-MMSE, "I told you the names of three things before. Can you repeat them?" Recall was coded as 0 for three correct, 0.5 for two correct, and 1 for fewer than two correct (Hoogendijk et al., 2017).

3) Adverse health-related outcomes

The adverse health-related outcomes were defined as hospitalization and mortality investigated between 2008 and 2020.

(1) Hospitalization

Hospitalization was measured using self-reported outcomes and coded as 0 if the participant had not been hospitalized in the preceding year and 1 if otherwise.

(2) Mortality

Mortality was defined as all-cause mortality during the time interval from 2008 to the end of the follow-up period. The mortality questionnaire, subjective data obtained from family members or acquaintances were used for the health status and death-related information of the participants before death. Mortality was ascertained using objective data, such as death certificates, during the follow-up period.

4.5. Data Collection and Ethical Consideration

This study was reviewed and approved by the Institutional Review Board of Yonsei University (No. 4-2021-0437). The data for this study used the KLoSA targeting adults aged 45 years or older residing in Korean communities from 2006 to 2020. The researcher accessed the homepage of the Employment Survey Analysis System (https://survey.keis.or.kr/), registered as a member, and then logged in. The researcher downloaded and used raw data, questionnaires, codebooks, and the user's guide. This study was reported in compliance with the Guidelines for Reporting on Latent Trajectory Studies (GRoLTS) Checklist recommendations (van De Schoot et al., 2017) (Appendix 7).

4.6. Data Analysis

Data was analyzed using SPSS 27.0 (Windows, Armonk, NY, USA) and STATA 17.0 (Stata Corp., College Station, TX, USA).

1. The general characteristics and frailty status of participants were reported using descriptive statistics, including means, standard deviations (SDs), frequency, and percentage.

2. Pre-frailty was modeled as a censored normal variable using panel Tobit regression because the FI score was observed only within a certain range.

3. This study used the group-based trajectory model (GBTM) to estimate the pre-frailty trajectory groups (Nagin, 2005; Nagin et al., 2018). The GBTM was developed to identify different homogeneous subgroups with similar trajectories from heterogeneous groups (Nagin, 1999; Nagin, 2010). Changes in pre-frailty were modeled as a function of time (years) rather than age. The Bayesian information criteria (BIC), sample-size adjusted BIC (Sa BIC), and Akaike information criteria (AIC), entropy, and the probability that participants would belong to each trajectory subgroup were assessed (Andruff et al., 2009; Nagin, 2005; Petras & Masyn, 2010). This study also tested linear, quadratic, and cubic functions and trajectories to determine the number of trajectories, respectively. The model was selected based on theory, practical knowledge, the information criteria, the probability of belonging to each subgroup, and the significance of interpretation as determined by statistical analysis (Nagin, 2010; Yoon et al., 2020). The model was finally selected after consulting with a clinical expert group (Nagin et al., 2018).

4. This study identified the effects of life course determinants on pre-frailty trajectories

using multinomial logistic regression analysis reporting relative risk ratios (RRRs) and 95% confidence intervals (CIs). A margin analysis was also conducted to examine the probability that life course determinants belong to each pre-frailty trajectory group.

5. Cox proportional hazards regression models were used to examine the risk of hospitalization and mortality by the groups. The model was adjusted for variables (age, sex, education, marital status, household income, physical activity, breakfast, alcohol consumption, smoking, sleep disturbance, and health check-ups and falls).

6. Survival time was derived by calculating the difference between 2008 and 2020 of death. Kaplan–Meier curve, log-rank test, and median survival time were used to compare survival rates in relation to the groups.

7. The number and proportion of participants who dropouts were calculated during the follow-up period. The dropout model was analyzed to compare the characteristics of those who included participants until the final follow-up period and those who excluded participants by follow-up period.

5. RESULTS

5.1. Participant Characteristics

1) Participant characteristics at baseline

The characteristics of 1,955 pre-frail participants are described at baseline in Table 2. The average age of the participants was 72.7 years (SD = 5.7), which corresponds to the age of young older adults (McCrae et al., 2008). The proportion of women was 60.9% (n = 1,190). Participants were much more likely to have graduated from primary school or lower than had graduated from middle school or higher (n = 1,482, 75.8% versus n = 473, 24.2%). Most of the participants were married (n = 1,228, 62.8%). The proportion of older adults who regularly engaged in physical activity was 30.4% (n = 594). Almost all participants had eaten breakfast over the past two days. Non-drinkers was 72.0% (n = 1,408), and non-smokers was 86.0% (n = 1,681). During the previous week, 16.5% (n = 323) of the respondents answered that they had trouble sleeping for 3–4 days or 5–7 days. Also, 48.0% (n = 938) had received national health check-ups at baseline, while 6.1% (n = 120) of participants had experienced a fall within the previous two years.

Table 2. Characteristics of pre-frail participants at baseline (N=1,955)

Variables	n (%)		Variables	n (%)	
Age			Physical activity		
65-74 years	1,298	(66.4)	yes	594	(30.4)
75-84 years	590	(30.2)	no	1,361	(69.6)
≥ 85 years	67	(3.4)	Breakfast		
Sex			yes	1,884	(96.4)
men	765	(39.1)	no	71	(3.6)
women	1,190	(60.9)	Alcohol consumption		
Education			yes	547	(28.0)
≤ primary school	1,482	(75.8)	no	1,408	(72.0)
≥ middle school	473	(24.2)	Smoking		
Marital status			yes	274	(14.0)
			no	1,681	(86.0)
married	1,228	(62.8)	Sleep disturbance		
unmarried	727	(37.2)	yes	323	(16.5)
Household income			no	1,632	(83.5)
(Unit: 10,000 KRW)			Health check-ups		
Q1 (≤100)	490	(25.1)	yes	938	(48.0)
Q2 (101-500)	560	(28.6)	no	1,017	(52.0)
Q3 (501-1,500)	447	(22.9)	Falls		
Q4 (≥1,501)	458	(23.4)	yes	120	(6.1)
			no	1,835	(93.9)

2) Frailty status of participants

Table 3 and Figure 4 show the mean FI by year. When comparing the mean FI by year, the lowest FI was in 2006 (mean = 0.15, SD = 0.04), and the highest FI was in 2020 (mean = 0.22, SD = 0.14). This is consistent with previous studies that found that changes in the FI mean increased over time (Hoogendijk et al., 2018; Li et al., 2016).

Differences in the levels of frailty according to classification criteria by year are shown in Table 4 and Figure 5. In 2008, 10.3% of participants were classified as non-frailty, 79.2% as pre-frailty, and 10.5% as frailty. In 2020, 5.6% of participants were classified as non-frailty, 67.0% as pre-frailty, and 27.4% as frailty. The proportion of non-frailty increased between 2008 and 2010 but decreased from 2012 onwards. The proportion of pre-frailty trended to decrease, whereas the proportion of frailty continued to increase.

Table 3. Mean Frailty Index by year

Variables	Years	N	Mean	SD	Min	Max
Frailty Index (score)	2006	1,955	0.15	0.04	0.08	0.24
	2008	1,857	0.16	0.08	0.00	0.77
	2010	1,657	0.17	0.10	0.01	0.90
	2012	1,506	0.17	0.11	0.01	0.91
	2014	1,322	0.19	0.12	0.01	0.93
	2016	1,147	0.20	0.12	0.01	0.79
	2018	974	0.21	0.13	0.01	0.82
	2020	824	0.22	0.14	0.01	0.80

SD: Standard deviation.

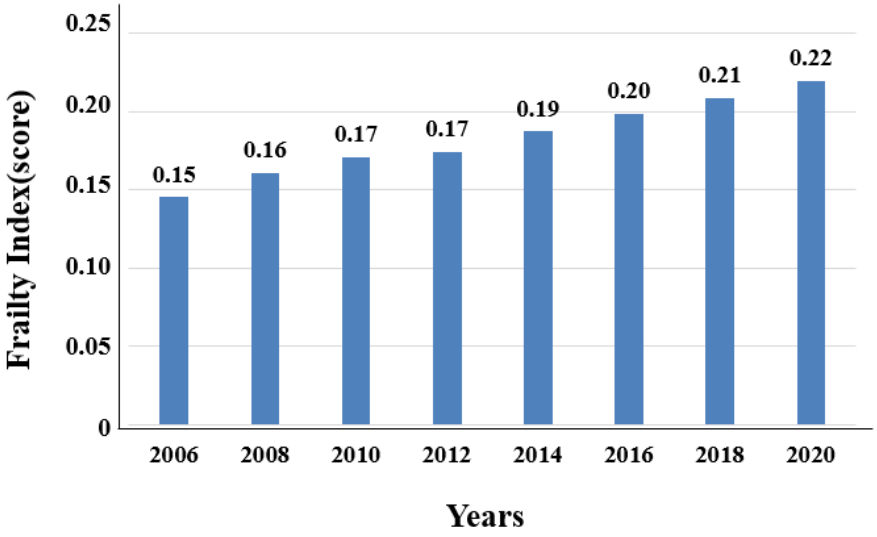


Figure 4. Mean Frailty Index by year

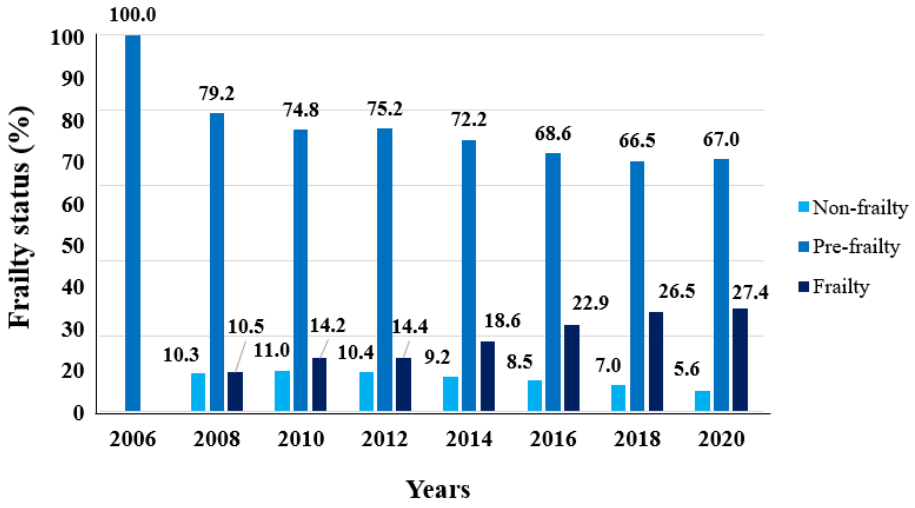


Figure 5. Trend of frailty status by year

Table 4. Difference of level of frailty according to classification criteria by year

Classification	2006	2008	2010	2012	2014	2016	2018	2020
Non-frailty (%)	0 (0.0)	192 (10.3)	182 (11.0)	157 (10.4)	121 (9.2)	97 (8.5)	68 (7.0)	46 (5.6)
Pre-frailty (%)	1,955 (100.0)	1,471 (79.2)	1,240 (74.8)	1,132 (75.2)	955 (72.2)	787 (68.6)	648 (66.5)	522 (67.0)
Frailty (%)	0 (0.0)	194 (10.5)	235 (14.2)	217 (14.4)	246 (18.6)	263 (22.9)	258 (26.5)	226 (27.4)

5.2. Pre-frailty Trajectories

1) Panel Tobit regression analysis

The results of the panel Tobit regression analysis on how life course determinants affect pre-frailty are shown in Table 5. Age, education level, sleep disturbance, and health check-ups were significantly associated with pre-frailty. Participants aged 85 years or older had a 3.7% higher risk of pre-frailty than those aged 65–74 years ($p < .001$). However, higher education levels lowered the risk of pre-frailty by 1.3% ($p = 0.002$). Participants who experienced sleep disturbance were associated with pre-frailty and had a 1.8% increased

Table 5. Life course determinants influencing pre-frailty using panel Tobit regression analysis

Variable	Coefficient	SE	*p*	95% CI	
Age	0.037	0.004	<.001	0.030	0.044
Sex	0.001	0.004	0.902	-0.008	0.009
Education	-0.013	0.004	0.002	-0.021	-0.005
Marital status	0.006	0.004	0.089	-0.001	0.013
Household income	0.000	0.001	0.951	-0.003	0.003
Physical activity	0.005	0.003	0.127	-0.001	0.012
Breakfast	-0.003	0.008	0.739	-0.018	0.013
Alcohol consumption	-0.002	0.002	0.443	-0.006	0.002
Smoking	0.000	0.003	0.994	-0.005	0.005
Sleep disturbance	0.018	0.004	<.001	0.009	0.026
Health check-ups	0.012	0.003	<.001	0.006	0.018
Falls	-0.004	0.006	0.570	-0.016	0.009

CI: confidence interval, SE: standard error.

risk of pre-frailty ($p < .001$). Participants who did not have national health check-ups had a 1.2% higher risk of pre-frailty than those who received health check-ups ($p < .001$).

2) The number of pre-frailty trajectories

The number of pre-frailty trajectories was determined by incrementally increasing the number of trajectories and examining the changes in the quality of fit index and classification rate (Table 6). The Bayesian information criteria (BIC), sample-size adjusted BIC (Sa BIC), and Akaike information criteria (AIC) all showed a decreasing trend from

Table 6. Fit Index and Classification Rate by Model according to the Number of Pre-frailty Trajectories

Criteria		Number of trajectories			
		2	**3**	**4**	**5**
Fit index	**BIC**	11082.91	11814.23	12232.50	12493.62
	SaBIC	11091.66	11825.60	12249.99	12515.49
	AIC	11119.55	11861.86	12305.77	12585.21
	Entropy	0.826	0.739	0.665	0.637
Classification rate (%)	**1**	80.2	60.2	51.4	29.0
	2	19.8	30.8	32.5	49.8
	3		9.0	10.9	9.4
	4			5.2	7.7
	5				4.1

AIC: Akaike information criterion, BIC: Bayesian information criteria, Sa BIC: Sample-size adjusted Bayesian information criteria.

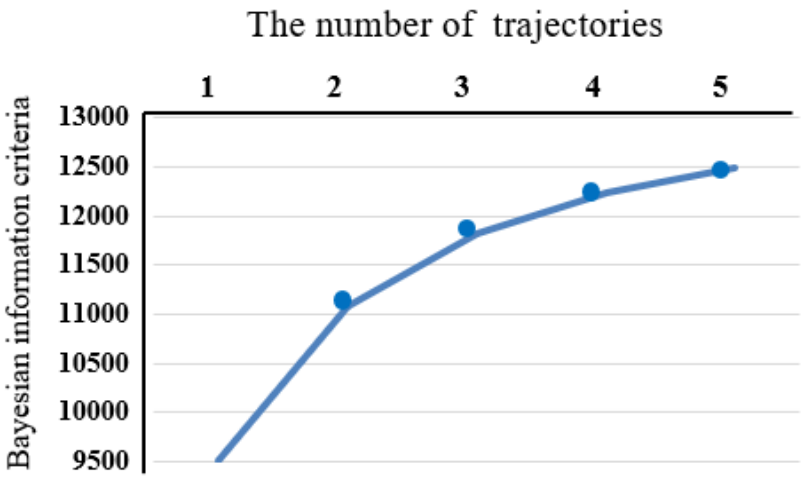


Figure 6. Change rate of Bayesian information criteria of pre-frailty trajectories

two to five models. In Figure 6, when the number of trajectories increased from two to three, the increasing trend of BIC slowed down. When the number of trajectories was three, the fit index of the model was the best value. Entropy was the highest at 0.826 when there were two trajectories, but it was 0.739 when there were three trajectories. This value was close to 1, so the group classification error is relatively small. This small error indicates that the model with three trajectories was the most suitable pre-frailty model. In the pre-frailty trajectory models, the probability that an individual would belong to Group 1 was 60.2%. The probability for belonging to Group 2 was 30.8% and Group 3 was 9.0%.

A model with three trajectories was selected as the final model since it fit the index of the model and was easy to interpret the significance of each trajectory, practical applicability, and previous studies. Therefore, it was judged whether each trajectory was

appropriate for understanding the change in pre-frailty among older adults. As criteria for judgment, an appropriate number of individuals constituting the trajectory, a well-distinguished change in pre-frailty in the graph, and a significant difference in the pre-frailty trajectories were considered (Muthén & Muthén, 2000; Nagin et al. al., 2018).

3) Final pre-frailty trajectories

Three groups with distinctive pre-frailty trajectories were identified and the parameter estimates for these models are displayed in Table 7. For pre-frailty trajectories, Group 1 was defined by the cubic parameter suggesting a maintained pre-frailty (p = 0.681); Group 2 was defined by the linear parameter showing a trend toward slowly increasing frailty over time that approached significance (p < .001); and Group 3 was defined as a cubic parameter indicating a tendency toward rapidly increasing frailty (p = 0.873).

Figure 7 shows both predicted and observed pre-frailty. Participants in Group 1 (the "remaining pre-frailty group") were considered pre-frailty but were not progressing to frailty. Group 2 (the "slowly increasing frailty group") comprised participants who were gradually becoming more frail. While participants in Group 3 (the "rapidly worsening frailty group") were labeled as pre-frailty at the baseline, but showed a consistent and rapid increase in frailty from 2008 onwards.

Table 7. Parameter estimates for pre-frailty trajectory groups

Groups	Parameter	Estimates	Standard error	*p*
1	**Intercept**	0.141	0.006	<.001
	Linear	-0.008	0.006	0.145
	Quadratic	0.002	0.001	0.242
	Cubic	0.001	0.001	0.681
2	**Intercept**	0.125	0.003	<.001
	Linear	0.027	0.001	<.001
3	**Intercept**	0.061	0.019	0.001
	Linear	0.119	0.020	<.001
	Quadratic	-0.005	0.006	0.347
	Cubic	0.001	0.001	0.873

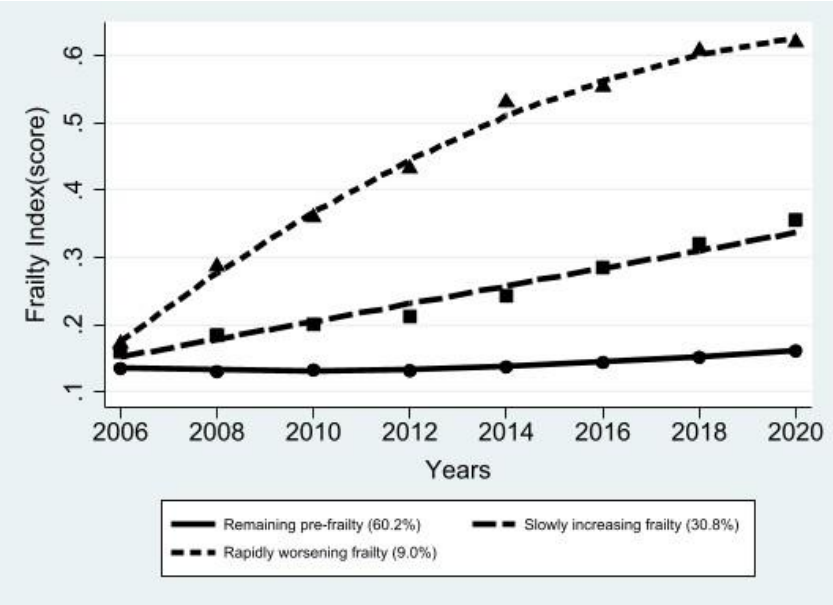


Figure 7. Plots of observed values and predicted counts from group-based trajectory models of pre-frailty across every two years of follow-up in KLoSA 2006-2020

Pre-frailty was measured using the Frailty Index (FI). A higher score indicates greater frailty. These scale scores were classified as non-frailty (FI $\leq$0.08), pre-frailty (FI >0.08 to FI <0.25), and frailty (FI $\geq$0.25). The icons represent the observed data values and the lines represent the predicted lines. Three pre-frailty trajectory groups: remaining pre-frailty (solid line, circles, n = 1,229), slowly increasing frailty (dashed line, squares, n = 556) and rapidly worsening frailty (dotted line, triangles, n = 170).

4) Mean Frailty Index according to the groups by year

Table 8 shows the differences in the mean FI between the groups by year. The remaining pre-frailty group had the lowest FI of 0.13 from 2006 to 2012 and the highest FI of 0.16 in 2020. The slowly increasing frailty group had the lowest FI of 0.16 in 2006 and the highest FI of 0.36 in 2020. The mean FI of the slowly increasing frailty group was 0.25 in 2014, which is classified as frailty. The rapidly worsening frailty group had a mean FI of 0.29 in 2008, which was classified as frailty, and also had the highest mean of 0.62 in 2020. The mean FI for all pre-frailty trajectory groups increased consistently. The mean values for each item in FI according to the groups by year are shown in Appendix 8.

Table 8. Mean Frailty Index according to the groups by year

Variables	Years	Remaining pre-frailty (n = 1,229)	Slowly increasing frailty (n = 556)	Rapidly worsening frailty (n = 170)
Frailty Index	2006	0.13	0.16	0.17
	2008	0.13	0.19	0.29
	2010	0.13	0.21	0.37
	2012	0.13	0.22	0.44
	2014	0.14	0.25	0.53
	2016	0.14	0.29	0.56
	2018	0.15	0.32	0.61
	2020	0.16	0.36	0.62

5.3. Differences in Life Course Determinants by Group

1) Groups characteristics at baseline

There were significant differences in age, sex, education level, marital status, alcohol consumption, sleep disturbance, and health check-ups in the pre-frailty trajectory groups, but there were no significant differences in household income, physical activity, breakfast, smoking, and falls at baseline (Table 9). Compared with the other groups, the rapidly worsening frailty group had the highest mean age of 77.0 years (SD = 6.8). The proportion of women was higher in the slowly increasing frailty group (n = 373, 67.1%). The proportion of higher education level (above middle school graduation) and the proportion of married individuals were higher in the remaining pre-frailty group (n = 886, 72.1% and n = 801, 65.2%, respectively). The rate of regular physical activity in the rapidly worsening frailty group was the lowest at 25.9% (n = 44), but there were no significant differences between the groups. More than 95% of the participants in the three groups ate breakfast. In the remaining pre-frailty group, the proportion of current drinkers (n = 380, 30.9%) and the proportion of current smokers (n = 186, 15.1%) was higher than in the other groups. The rate of sleep disturbance was 20.7% (n = 115) in the slowly increasing frailty group, which was statistically significant. Participants who had regular national health check-ups were significantly more numerous in the remaining pre-frailty group (n = 634, 51.6%, $p < .001$). Participants in the rapidly worsening frailty group experienced the most falls in the previous two years (n = 12, 7.1%).

Table 9. Groups characteristics at baseline

Variables	Remaining pre-frailty (n=1,229)	Slowly increasing frailty (n=556)	Rapidly worsening frailty (n=170)	*F* or x^2 *(p)*
Age	71.6±5.2	73.7±5.5	77.0±6.8	2620.200 (< .001)***
65-74 years	913 (74.3)	326 (58.6)	59 (34.7)	154.518 (< .001) ***
75-84 years	293 (23.8)	209 (37.6)	88 (51.8)	
≥ 85 years	23 (1.9)	21 (3.8)	23 (13.5)	
Sex				14.283 (0.001) **
men	519 (42.2)	183 (32.9)	63 (37.1)	
women	710 (57.8)	373 (67.1)	107 (62.9)	
Education				24.905 (< .001) ***
≤ primary school	886 (72.1)	456 (82.0)	140 (82.4)	
≥ middle school	343 (27.9)	100 (18.0)	30 (17.6)	
Marital status				18.540 (< .001) ***
married	801 (65.2)	345 (62.1)	82 (48.2)	
unmarried	428 (34.8)	211 (37.9)	88 (51.8)	
Household income (Unit: 10,000 KRW)				9.978 (.126)
Q1 (≤100)	306 (24.9)	143 (25.7)	41 (24.1)	
Q2 (101-500)	339 (27.6)	173 (31.1)	48 (28.2)	
Q3 (501-1,500)	304 (24.7)	112 (20.1)	31 (18.2)	
Q4 (≥1,501)	280 (22.8)	128 (23.1)	50 (29.5)	

Table 9. Groups characteristics at baseline (continuous)

Variables	Remaining pre-frailty (n=1,229)		Slowly increasing frailty (n=556)		Rapidly worsening frailty (n=170)		*F* or x^2 *(p)*
Physical activity							2.276 (.320)
yes	385	(31.3)	165	(29.7)	44	(25.9)	
no	844	(68.7)	391	(70.3)	126	(74.1)	
Breakfast							.048 (.976)
yes	1185	(96.4)	535	(96.2)	164	(96.5)	
no	44	(3.6)	21	(3.8)	6	(3.5)	
Alcohol consumption							14.225 (0.001)**
yes	380	(30.9)	127	(22.8)	40	(23.5)	
no	849	(69.1)	429	(77.2)	130	(76.5)	
Smoking							5.441 (.066)
yes	186	(15.1)	73	(13.1)	15	(8.8)	
no	1043	(84.9)	483	(86.9)	155	(91.2)	
Sleep disturbance							11.348 (.003) **
yes	177	(14.4)	115	(20.7)	31	(18.2)	
no	1052	(85.6)	441	(79.3)	139	(81.8)	
Health check-ups							27.429 (< .001) ***
yes	634	(51.6)	251	(45.1)	53	(31.2)	
no	595	(48.4)	305	(54.9)	117	(68.8)	
Falls							.358 (.836)
yes	73	(5.9)	35	(6.3)	12	(7.1)	
no	1156	(94.1)	521	(93.7)	158	(92.9)	

*p<.05, **p<.01, ***p<.00.

2) Differences in life course determinants by group using multinomial logistic regression

The results of the life course determinants in the pre-frailty trajectory groups are shown in Table 10. The remaining pre-frailty group was selected as the reference group because there was no frailty from the baseline to the final follow-up period, and it was judged to be appropriate to compare to other groups. Among the life course determinants, being older, educated, married, and having sleep disturbance had an effect on the slowly increasing frailty group compared with the remaining pre-frailty group. Participants who were 75-84 years old and 85 years old and over were 2.05 times and 2.61 times more likely to be in the slowly increasing frailty group, respectively, than those who were 65–74 years old (95% CI: 1.63–2.58 and 95% CI: 1.40–4.87, respectively). Those who had completed middle school were less likely to be in the slowly increasing frailty group than those who had not (RRR = 0.66, 95% CI: 0.49–0.87). In addition, unmarried participants were less likely to be in the slowly increasing frailty group than those who were married (RRR = 0.76, 95% CI: 0.59–0.97). Those who experienced sleep disturbance were more likely to be in the slowly increasing pre-frailty group than those who did not (RRR = 1.57, 95% CI: 1.20–2.06). Being older, having low education, being married, and experiencing sleep disturbance were important predictors for participants being classified in the slowly increasing frailty group.

The life course determinants that affected the rapidly worsening frailty group were being older and receiving health check-ups compared to the remaining pre-frailty groups. Participants who were 75-84 years old and 85 years old and over were 4.14 times and 11.03

times more likely to be in the rapidly worsening frailty group, respectively, than those who were 65–74 years old (95% CI: 2.86–5.98 and 95% CI: 5.63–21.61, respectively). Age was associated with the rapidly worsening frailty group. Those who did not have health check-ups were 2.03 times more likely to be in the rapidly worsening frailty group than those who did (95% CI: 1.42–2.91). The significant predictors for being in the rapidly worsening frailty group were being older and not having health check-ups.

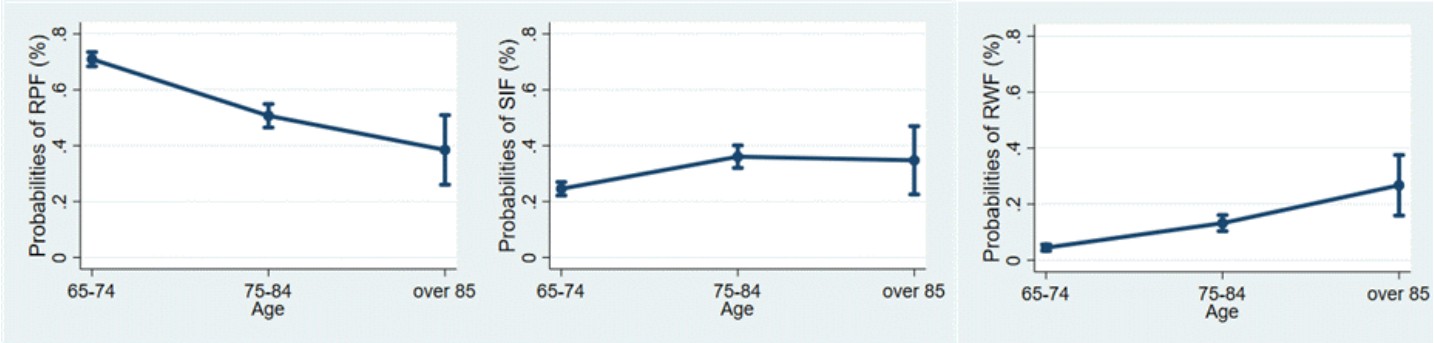
3) Predicted probability of life course determinants by group using margins

Appendix 9 and Figure 8 shows the margin analysis showing the predicted probabilities that life course determinants belong to each pre-frailty trajectory group. The probabilities of belonging to the remaining pre-frailty group, the slowly increasing frailty group, and the rapidly worsening frailty group were 70.9%, 24.6%, and 4.5% for those aged 65–74; however, for those aged 85 and older were 38.5%, 34.8%, and 26.7%, respectively. Among the life course determinants, the probability that the lifestyle belongs to the rapidly worsening frailty group is as follows: Participants who did physical activity had a lower probability than those who did not (6.6% versus 6.8%). The probability is higher for participants who did ate breakfast than participants who did not ate breakfast (6.7% versus 6.8%). Participants who currently drink and those who currently smoke are less likely to be participants who did not (6.3% versus 6.9% and 4.2% versus 7.3%, respectively). Participants who experienced sleep disturbance were more likely than those who did not (8.3% versus 6.5%). Finally, participants who received health check-ups had a lower predicted probability than participants who did not (4.9% versus 9.0%).

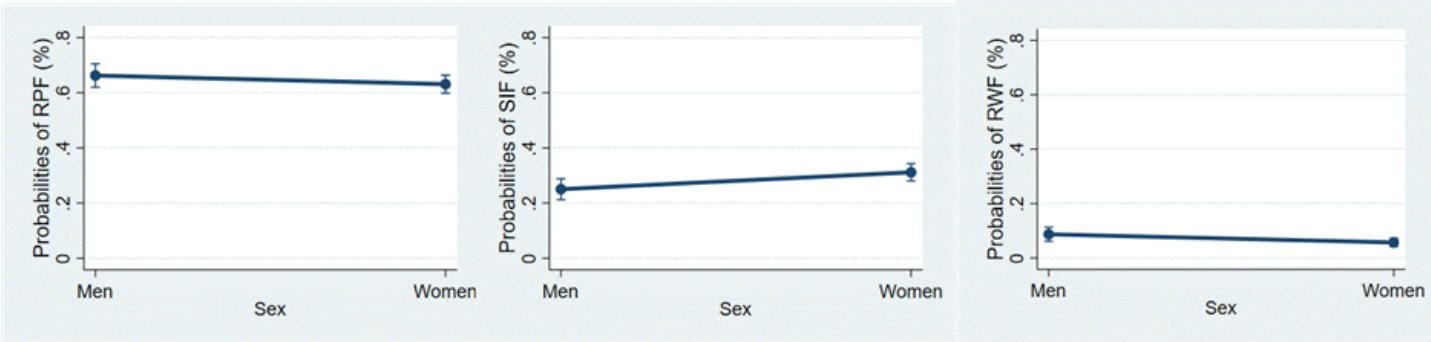
Table 10. Differences in life course determinants by group

Variables	Slowly increasing frailty vs. Remaining pre-frailty				Rapidly worsening frailty vs. Remaining pre-frailty			
	RRR	*p*	95% CI		RRR	*p*	95% CI	
Age (ref: 65-74 years)	1.00				1.00			
75-84 years	2.05	<.001	1.63	2.58	4.14	<.001	2.86	5.98
≥ 85 years	2.61	.003	1.40	4.87	11.03	<.001	5.63	21.61
Sex (ref: men)	1.00				1.00			
women	1.31	.067	0.98	1.74	0.71	.125	0.44	1.16
Education (ref: ≤ primary school)	1.00				1.00			
≥ middle school	0.66	.003	0.49	0.87	0.67	.114	0.41	1.07
Marital status (ref: married)	1.00				1.00			
unmarried	0.76	.026	0.59	0.97	1.33	.250	0.87	2.01
Household income (ref: Q1 (≤100))	1.00				1.00			
Q2 (101-500)	1.12	.441	0.84	1.47	1.05	.683	0.65	1.69
Q3 (501-1,500)	0.86	.316	0.64	1.17	0.79	.413	0.47	1.33
Q4 (≥1,501)	1.00	.982	0.74	1.35	1.09	.460	0.68	1.77
Physical activity (ref: yes)	1.00				1.00			
no	0.89	.282	0.70	1.13	1.01	.970	0.68	1.51
Breakfast (ref: yes)	1.00				1.00			
no	1.08	.810	0.62	1.86	0.96	.947	0.37	2.48
Alcohol consumption (ref: no)	1.00				1.00			
yes	0.79	.101	0.61	1.03	0.88	.452	0.56	1.37
Smoking (ref: no)	1.00				1.00			
yes	1.08	.710	0.78	1.50	0.56	.059	0.31	1.02
Sleep disturbance (ref: no)	1.00				1.00			
yes	1.57	.001	1.20	2.06	1.48	.073	0.93	2.34
Health check-ups (ref: yes)	1.00				1.00			
no	1.21	.066	0.99	1.49	2.03	<.001	1.42	2.91
Falls (ref: no)	1.00				1.00			
yes	0.96	.741	0.62	1.47	0.98	.855	0.49	1.94

CI: confidence interval, RRR: relative risk ratio.

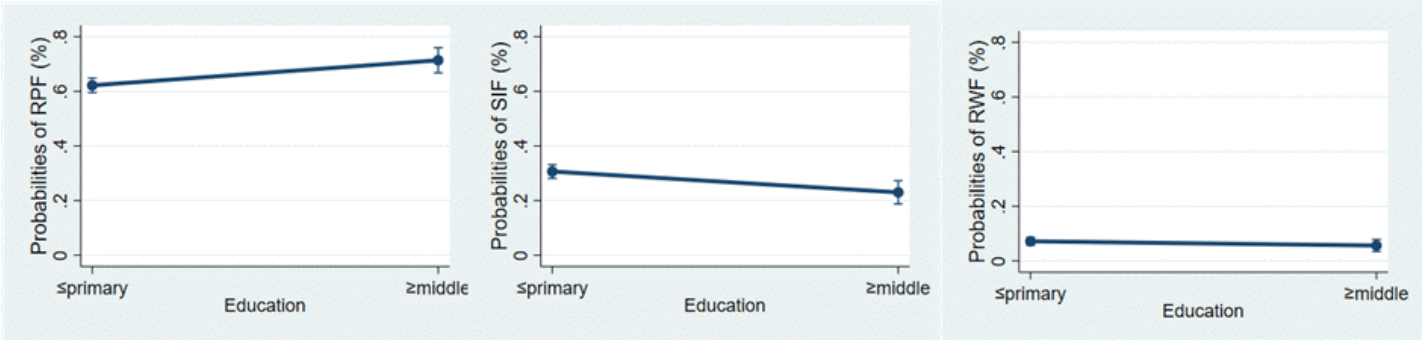


(1) Age

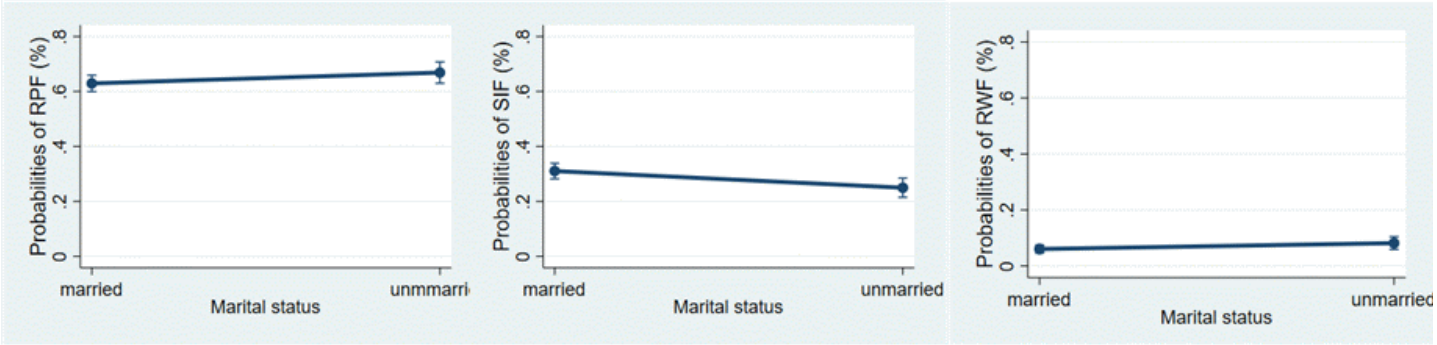


(2) Sex

Figure 8. Marginplots about predicted probabilities of life course determinants by group

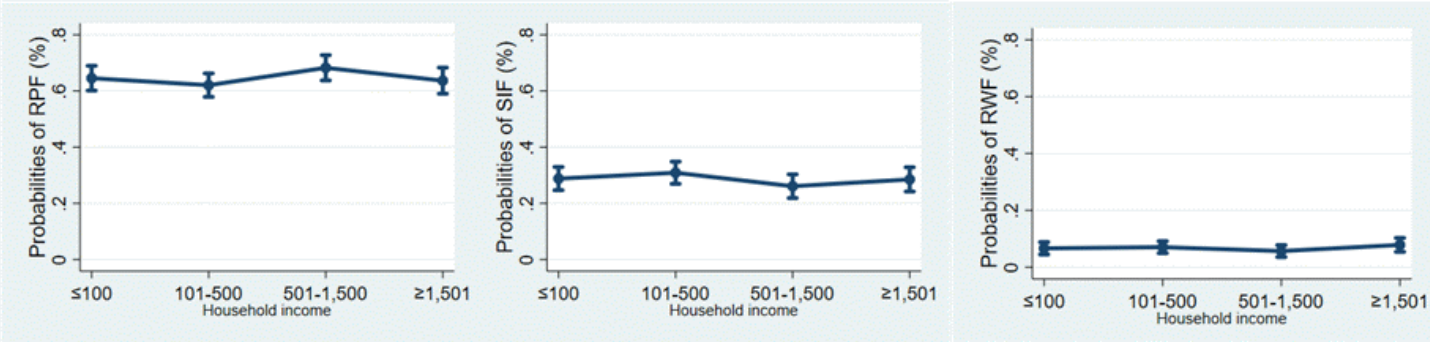


(3) Education

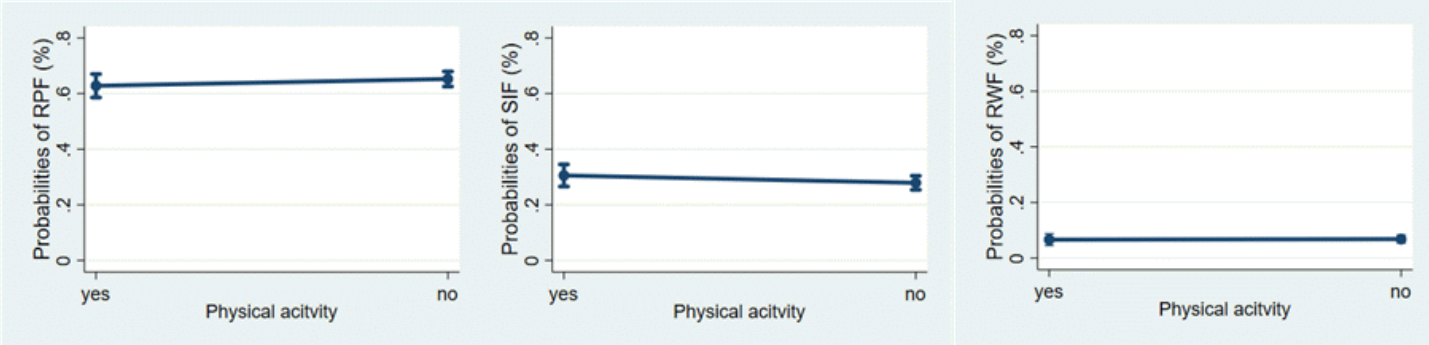


(4) Marital status

Figure 8. Marginplots about predicted probabilities of life course determinants by group (continuous)

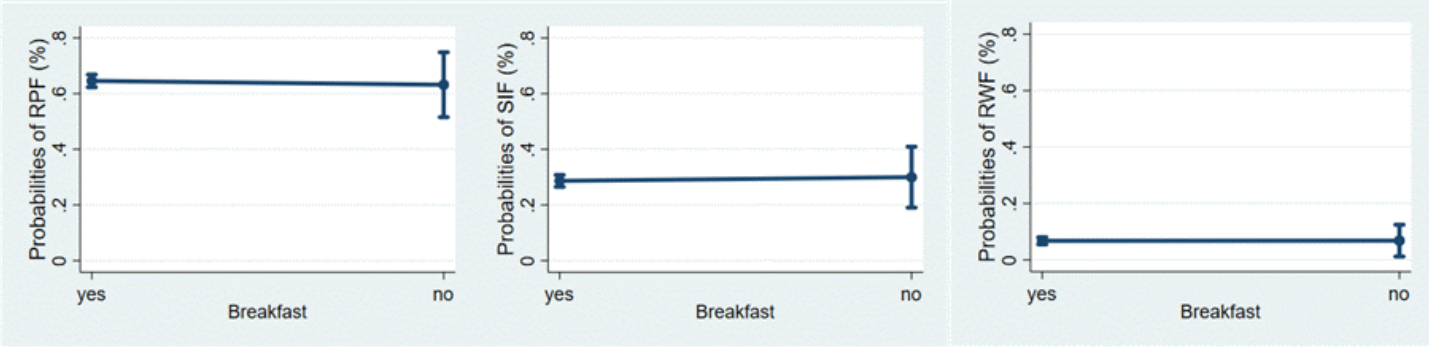


(5) Household income

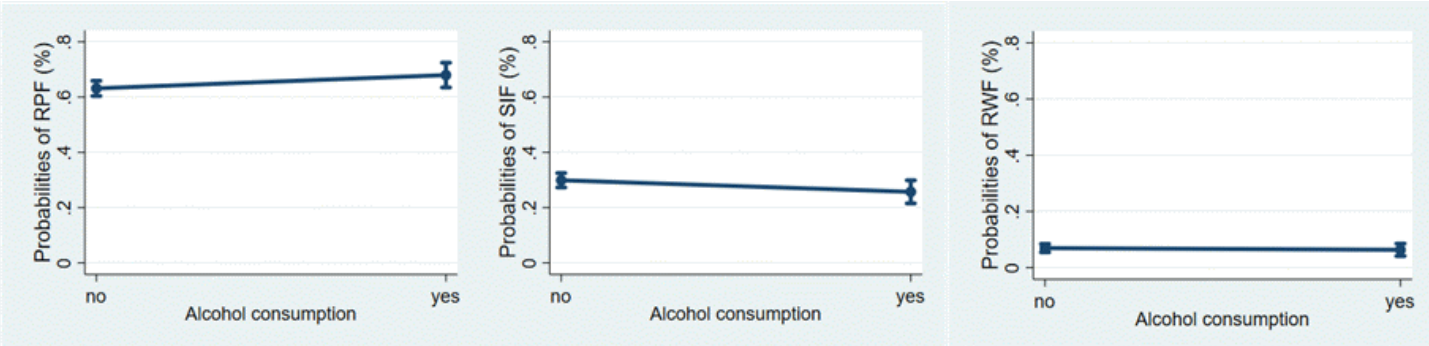


(6) Physical activity

Figure 8. Marginplots about predicted probabilities of life course determinants by group (continuous)

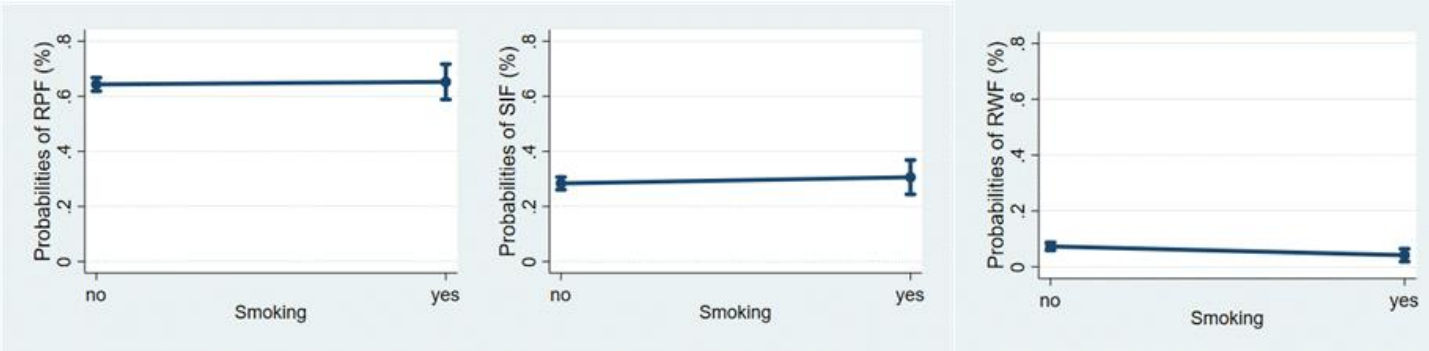


(7) Breakfast

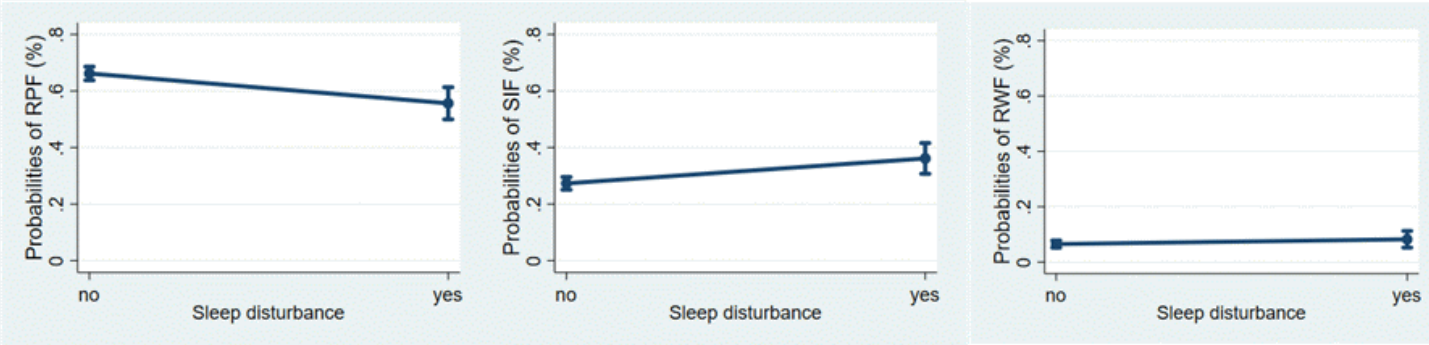


(8) Alcohol consumption

Figure 8. Marginplots about predicted probabilities of life course determinants by group (continuous)

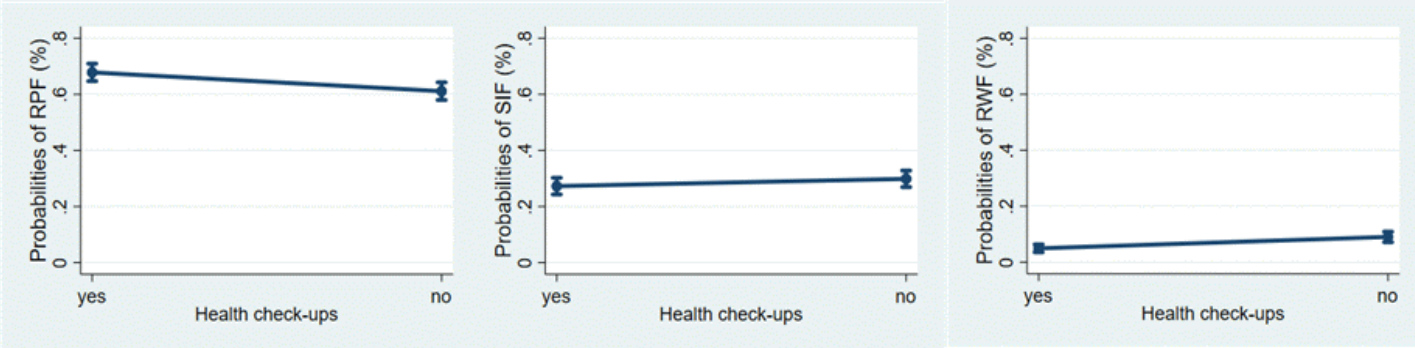


(9) Smoking

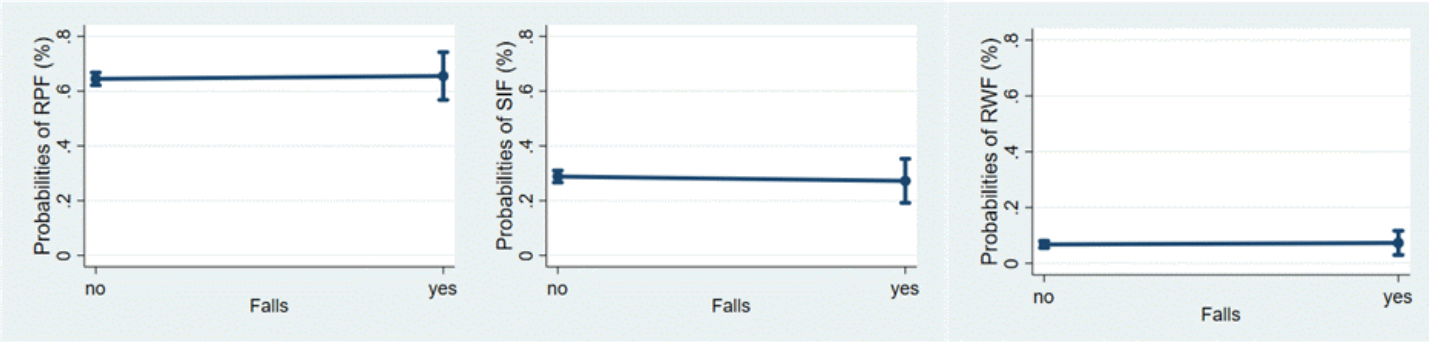


(10) Sleep disturbance

Figure 8. Marginplots about predicted probabilities of life course determinants by group (continuous)



(11) Health check-ups



(12) Falls

Figure 8. Marginplots about predicted probabilities of life course determinants by group (continuous)

RWF: Rapidly Worsening Frailty group, RPF: Remaining Pre-frailty group, SIF: Slowly Increasing Frailty group.

5.4. Adverse Health-related Outcomes and Pre-frailty Trajectory Groups

A Cox proportional hazards analysis was conducted in order to identify the risk of hospitalization and mortality in the pre-frailty trajectory groups, with the results shown in Table 11. After adjusting for variables including age, sex, education, marital status, household income, lifestyle, and falls, the remaining pre-frailty group was not associated with hospitalization and mortality compared with the slowly increasing frailty group. Participants in the rapidly worsening frailty group were 1.41 times (95% CI: 1.03–1.93) more likely to be hospitalized compared with the slowly increasing frailty group. Particip-

Table 11. Adjusted effect of pre-frailty trajectory groups on hospitalization and mortality

Groups	Hospitalization				Mortality			
	HR	***p***	**95% CI**		**HR**	***p***	**95% CI**	
Slowly increasing frailty	1.00				1.00			
Remaining pre-frailty	1.04	.619	0.88	1.24	1.06	.573	0.87	1.29
Rapidly worsening frailty	1.41	.034*	1.03	1.93	1.68	.001**	1.23	2.29

A Cox regression models was adjusted for age, sex, education, marital status, household income, lifestyle (physical activity, breakfast, alcohol consumption, smoking, sleep disturbance, and health check-ups) and life event (falls).

CI: confidence interval, HR: hazard ratio.

* $p < .05$, ** $p < .01$, *** $p < .001$.

ants who were in the rapidly worsening frailty group had a high hazard ratio (HR) for mortality (HR = 1.68, 95% CI: 1.23–2.29). Participants in the rapidly worsening frailty group were associated with increased hospitalization and mortality rate of 41% and 68%, respectively. Hospitalization and mortality were not associated with the remaining pre-frailty group, but were significantly associated with the rapidly worsening frailty group.

As a result of the survival time by groups, the estimated median survival time was the shortest in the rapidly worsening frailty group, at nine years (Table 12). The median survival time of the slowly increasing frailty and remaining pre-frailty groups was ten years, which was one year more than the rapidly worsening frailty group.

Figure 9 shows the Kaplan-Meier curve for mortality. The Kaplan-Meier survival curves by group revealed significant differences (Log-rank test, $\chi^2_{(2)} = 11.940$, $p = 0.003$). Figure 9 also visually shows that the survival times in the rapidly worsening frailty group were one year shorter than the other groups.

Table 12. Mean and median for survival time by group

Groups	Mean				Median			
	Estimate	SE	95% CI		Estimate	SE	95% CI	
			Min	Max			Min	Max
Slowly increasing frailty	9.86	0.22	9.42	10.30	10.00	0.35	9.31	10.69
Remaining pre-frailty	9.52	0.17	9.20	9.85	10.00	0.21	9.58	10.42
Rapidly worsening frailty	8.39	0.37	7.67	9.10	9.00	0.53	7.97	10.03
Total	9.50	0.13	9.26	9.75	10.00	0.17	9.67	10.33

CI: confidential interval, SE: standard error.

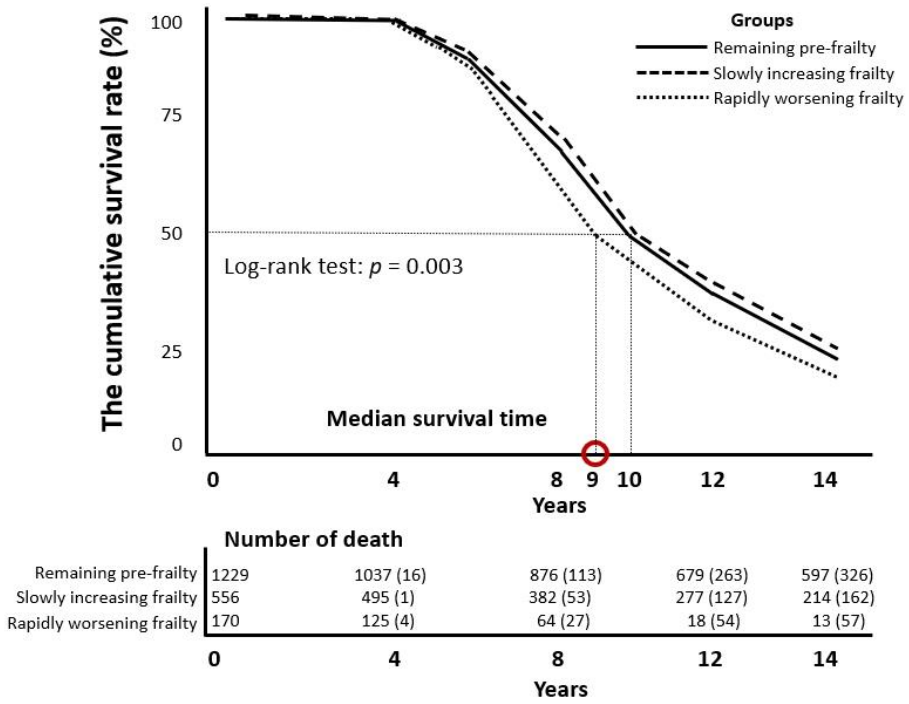


Figure 9. Kaplan–Meier survival curves by group

The X-axis of the graph represented the survival time in years and the Y-axis represented the cumulative survival rate of survivors, excluding individuals who died. Every two years, the number of survivors at that time in each group is shown. Solid line was remaining pre-frailty group, dash line was slowly increasing frailty group, and dotted line was rapidly worsening frailty group. Number of deaths means each year (i.e., 4, 8, 12 and 14 years).

6. DISCUSSION

This study was based on a longitudinal study that was conducted by the KLoSA from 2006-2020 and initially examined distinct pre-frailty trajectories in community-dwelling older adults (N = 1,955). Three pre-frailty trajectories—remaining pre-frailty, slowly increasing frailty, and rapidly worsening frailty—were identified using group-based trajectory models. Compared with the remaining pre-frailty group, the life course determinants for being in the slowly increasing frailty group were being older, high education levels, married, and experiencing more sleep disturbances. The life course determinants of the rapidly worsening frailty group were being older and avoiding health check-ups than the remaining pre-frailty group. Participants in the rapidly worsening frailty group had a higher likelihood of mortality compared with the slowly increasing frailty group. This study is significant in that it is the first study to identify the pre-frailty trajectories. The results, which are relevant to community care, contribute to an understanding of pre-frailty in older Asian adults and provide comprehensive knowledge of changes in pre-frailty. Identifying the pre-frailty trajectories among older adults can contribute to evidence-based customized nursing intervention by distinguishing each separate trajectory and predictors. A better understanding of changes in pre-frailty may provide insight for improving the transition to frailty.

6.1. Pre-frailty Trajectories

The remaining pre-frailty group showed a trajectory of sustained pre-frailty from baseline to the follow-up period among older adults. A systematic review reported a maintain rate (pre-frailty to pre-frailty) of 58.2% over a mean follow-up of 3.9 years (Kojima et al., 2019), supporting the derivation of the remaining pre-frailty group in this study. A study using the same data from KLoSA 2006-2018 identified a similar trajectory pattern (Jang et al., 2022). The study by Jang et al. (2022) identified the difference in the frailty trajectory according to the age (middle-aged and older adults) and sex. This study differed from the current study in purpose and research method (Frailty Instrument) and statistical analysis (latent growth curve modeling). Among the results of Jang et al. (2022), the remaining pre-frailty trajectory was not identified in middle-aged adults and was reported only in the older adults. Also, the classification rate of the remaining pre-frailty group in this study was 60.2%, whereas the rates observed by Jang et al. were 31.8% and 37.2% (older adults' men and women, respectively). The current data analyzed the change in pre-frailty over a 14-year follow-up period and confirmed that more than half of older adults were more likely to remain in the pre-frailty trajectory group. Nevertheless, there is insufficient information about the remaining pre-frailty trajectory in older adults. Future longitudinal studies are necessary to obtain more knowledge about life course determinants and health-related outcomes in the remaining pre-frailty group.

In the slowly increasing frailty group, the participants showed pre-frailty at the baseline but progressed to frailty over eight years. This pre-frailty trajectory was similarly derived

from previous studies of frailty trajectories (Álvarez-Bustos et al., 2021; Peek et al., 2012; Stow et al., 2018). A previous 11-year longitudinal study of Spanish adults over 65 years of age analyzed the frailty trajectory using the Frailty Trait Scale-short form 5 (Álvarez-Bustos et al., 2021). Analysis of the trajectory groups revealed that one of the groups was similar to one of the groups in this study. In addition, a progressive moderate frailty trajectory was reported in an 11-year-longitudinal study of Mexican Americans measuring the modified Fried frailty phenotype (Peek et al., 2012). The trajectories have shown similar results despite differences in study populations, measures of frailty, the frailty level of participants at baseline and follow-up period. The slowly increasing frailty group took eight years to transition from pre-frailty to frailty in this study. These results provide a rationale for how long it takes to frailty transition and the timing of intervention. Nursing intervention strategy considering the timing prevent or delay frailty should be established.

The rapidly worsening frailty group progressed from pre-frailty to frailty over the course of just two years—a result consistent with previous studies that showed a sharp increase in frailty changes (Peek et al., 2012; Stow et al., 2018). A UK study that made monthly measurements of the FI for people aged 75 for one year classified them into rapidly rising frailty (Stow et al., 2018). Changes that hastened the progression of participants from the pre-frailty to the frailty group were identified over a short period of time. In the community setting, health professionals such as nurses must be able to more easily and routinely evaluate frailty in order to identify individuals who are at risk of rapid deterioration. This finding suggests the need for active prevention and management of

frailty within at least two years after the onset of pre-frailty, the intermediate stage. Identification of pre-frailty provides an opportunity to implement primary prevention interventions that focus on delaying or reducing the change of frailty in older adults (Hoogendijk et al., 2019; Sezgin et al., 2020). Due to the aging of the global population, the importance of routine evaluation of pre-frailty and frailty is being emphasized (Hoogendijk et al., 2019). In successful aging of the elderly population, identifying the pre-frailty trajectory is important for frailty prevention.

6.2. Differences in Life Course Determinants by Group

Sleep disturbance was identified as being a predictor of belonging in the slowly increasing frailty group. Previous studies have suggested that self-reported sleep duration is associated with an increased risk of pre-frailty (Nakakubo et al., 2018; Nakakubo et al., 2019). This association correlates with this study findings, which measured the number of days participants experienced sleep disturbance in the past week. Several potential mechanisms have been reported to explain the association between sleep and frailty. An association between sleep disturbance and increased inflammatory indicators, such as increased C-reactive protein (CRP), interleukin-6 (IL-6), tumor necrosis factor-α (TNF), and fibrinogen levels, has been reported (Newman et al., 2001). Sleep disturbance have been reported to increase the risk of frailty through a variety of pathways, for example diagnosis of sarcopenia and decreasing levels of hormones such as testosterone (Cooper et al., 2012; Pourmotabbed et al., 2020). This study provided information on modifiable risk

factors for sleep disturbance in the slowly increasing frailty group. Evidence was established for nurses, who are key personnel in community care, to provide sleep interventions to improve sleep disturbance. However, this study only measured the number of days of sleep disturbance using a questionnaire from CES-D. A further in-depth analysis is needed to understand the relationship between pre-frailty and certain sleep behaviors, such as sleep patterns, insomnia symptoms, and periods of insomnia.

Regular physical activity was not associated with the slowly increasing frailty group. Moderate or higher physical activity and prolonged sedentary behaviors in the previous study was identified as a predictor of pre-frailty (Kikuchi et al., 2021), which was different from this study's result. Kikuchi et al. (2021) measured pre-frailty in older Japanese using CHS such as exhaustion, weakness, slowness, low activity, and unintentional weight loss, and classified corresponding to one or two of five components of CHS as pre-frailty. However, there was a difference in frailty measurement between this study and Kikuchi et al.'s study. Research on the relationship between the pre-frailty and physical activity was conducted on a small number of studies and cross-sectional design. Understanding the causal relationship between the two using longitudinal data is currently limited, so further studies are necessary.

Avoiding health check-ups is another risk factor for belonging to the rapidly worsening frailty group. To the best of our knowledge, no previously published studies have included health check-ups among the modifiable factors for either pre-frailty or frailty. However, the World Health Organization (2019) actively promotes regular health check-ups since

they can enable early diagnosis of acute or chronic disease and subsequent early treatment as prevention. In South Korea, national health check-ups implement a preventive health management policy according to age, sex, and life cycle. Early disease management has the effect of preventing progression to frailty by relieving physiological stress factors (Hoogendijk et al., 2019). In the ICMF, health check-ups can be called a healthy lifestyle and disease was also explained as an antecedent of frailty by reducing physiologic reserve (Gobbens et al., 2010). Information on the effects of health check-ups including national and individual health check-ups on pre-frailty is lacking. Further studies are needed to determine whether there is a relationship between pre-frailty and health check-ups in various settings.

6.3. Adverse Health-related Outcomes and Pre-frailty Trajectory Groups

The risk of hospitalization was not significantly associated with the remaining pre-frailty group, which was consistent with the results of previous studies (Forti et al., 2014; Gill et al., 2011; Jung et al., 2014). An Italian community study conducted by Forti et al. (2014) found that frailty using the Study of Osteoporotic Fractures (SOF) was not related to hospitalization. A 5-year longitudinal study of Korean older adults also found that the relationship between the two was also not significant (Jung et al., 2014). By contrast, Hogan et al. (2012) measured frailty using the FI (83 items) adults aged 65 years and older who were in assisted living and reported an association between pre-frailty and hospitalization. Pre-frailty is the cumulative result of long-term health deficiencies (Rockwood et al., 2007).

In contrast, the purpose of hospitalization is for acute disease treatment, scheduled examinations, surgery, and emergency care. As such, hospitalization may be more associated with illness rather than pre-frailty (Liu. et al., 2018). This study measured the history of hospitalizations by self-report. To supplement this reporting method, it is necessary to identify, in detail, the length of hospitalization, rates of re-admission within 30 days, and the specific purpose of hospitalization. In addition, further research on the relationship between hospitalization and pre-frailty is needed with more objective methods, such as hospitalization records and insurance data.

Compared with the slowly increasing frailty group, participants in the rapidly worsening frailty group were at greater risk of hospitalization and mortality. This group must have the highest priority when applying interventions to improve frailty. In addition, as the level of frailty rises, functional capacity declines, leading to increasing dependence on other people (Forti et al., 2012; Gobbens et al., 2012). We suggest a frailty intervention design for community-dwelling older adults that included the target population, intervention timing, priority, intervention component, and intervention delivery strategies for the rapidly worsening frailty group. In order to select the target population, it is possible to identify changes through regular frailty assessments. Intervention timing is of paramount importance because it takes two years to change from pre-frailty to frailty. This group has a high risk of hospitalization and mortality and therefore has a high priority for intervention application. Frailty interventions are mostly focused on physical function (Frost et al., 2017; Put et al., 2017). However, multidomain interventions are needed based on the

understanding of an integrated definition of pre-frailty and frailty, including physical, psychological, functional, and cognitive domains (Gobbens et al., 2010; Put et al., 2017). For effective delivery of interventions to this group, consideration should be given to including the older adults as well as their families and caregivers. Because older adults in this group live in the community and are more likely to depend on others, families and caregivers can contribute to the design of interventions. In addition, we believe that home visits, online programs, and telemonitoring approaches to assess frailty status and lower the risk of hospitalization and mortality will be cost-effective if applied to interventions (Frost et al., 2017; Upatising et al., 2013). Currently, no studies involving hospitalization and mortality among interventional outcomes have been identified by previous studies targeting pre-frailty (Frost et al., 2017). Future studies should evaluate the effect of multimodal interventions on hospitalization and mortality by targeting the rapidly worsening frailty group.

Older adults who were pre-frailty at baseline but whose frailty rapidly worsened during the 14-year follow-up period had a higher risk of mortality. This high risk is consistent with the results of previous studies (Beak & Min, 2022; Cano et al., 2012; Lee et al., 2018). The median survival time in the rapidly worsening frailty group was nine years, one year shorter than the other groups. There are unmet needs of older adults with frailty (Hoogendijk et al., 2014). These unmet needs include difficulty with daytime activities, loneliness and social isolation, recent memory problems, verbal information about treatments or medications, and difficulty listening to others or watching television (Hoogendijk et al., 2014).

Additional efforts are needed in care support to meet these needs (Hoogendijk et al., 2019). A comprehensive road map for the efficient use, distribution, and priorities of limited medical resources, such as budget, facilities, workforce, and time, to improve frailty and adverse health-related outcomes should be established (Dent et al., 2019). Considering that the rapidly worsening frailty group had a high risk of hospitalization and mortality in this study, early identification of pre-frailty and frailty, efficient resource allocation, and cost-effective intervention delivery strategies should be a priority for this group. Short-term and long-term nursing policies that can cover health promotion and disease treatment for healthy aging and universal health management of older adults should be discussed more actively.

The findings provide an integrative perspective for developing and implementing interventions to improve frailty and adverse health-related outcomes in community-dwelling older adults. Studies on the change of pre-frailty, life course determinants and adverse health-related outcomes are limited. This study identified pre-frailty trajectories based on the ICMF and analyzed their associations with risk factors, hospitalizations, and mortality for each pre-frailty trajectory from a comprehensive view. As the prevalence of pre-frailty and frailty increases with the rapid increase in the older adults, a multidimensional approach and comprehensive management of frailty are needed to detect and improve frailty early.

7. CONCLUTIONS

This study examined pre-frailty trajectories of 1,955 Korean adults aged 65 and over using data from the longitudinal study conducted by the KLoSA between 2006 and 2020.

First, pre-frailty trajectories were identified in three groups—remaining pre-frailty, slowly increasing frailty, and rapidly worsening frailty—using group-based trajectory models.

Second, the risk factors among life course determinants in the rapidly worsening frailty group compared with the other groups were shown to be older and avoiding health check-ups.

Third, participants in who rapidly worsening frailty group had a high HR for hospitalization and mortality compared with the slowly increasing frailty group. The median survival time of the rapidly worsening frailty group was the shortest compared with the other groups.

7.1. Implications

This study has significantly enhanced our understanding of the pre-frailty condition in older Asian adults. The findings have provided a comprehensive body of knowledge regarding pre-frailty trajectories and their adverse health-related outcomes. It is hoped that these findings will increase the insight of nurses providing healthcare for community-dwelling older adults.

This study also outlines the life course determinants that can clearly distinguish pre-frailty trajectories, which are being older, having a low education level, being unmarried, having sleep disturbance, and avoiding health check-ups. The study will contribute to early detection and classification by suggesting criteria for classifying high-risk groups. Screening for frailty needs to become a routine task for health managers so that they can provide early intervention. Based on the understanding of the characteristics of pre-frailty trajectories, this study will contribute to preparing a foundation for evidence-based nursing interventions. In addition, it can assist in developing a customized intervention based on distinct pre-frailty trajectories and can present specific grounds for intervention strategies including target population, priority, intervention timing, intervention component, and intervention objectives. Through this, nurses, as primary healthcare providers, can provide evidence-based nursing interventions in community-dwelling older adults. It is hoped that our findings are will be used as basic data to improve frailty and adverse health-related outcomes.

Healthcare policymakers need to discuss the healthcare cost so that the frailty evaluation can be performed daily in the healthcare plan of older adults. Human resources and financial support are needed to ensure the quality of interventions to reduce hospitalizations and mortality owing to frailty. It is essential that individuals, caregivers, communities, medical institutions, and governments share knowledge and importance on the pre-frailty and health of older adults and establish a cooperative system to improve them.

7.2. Limitations

Among 4,164 participants aged 65 years and older, 1,955 participants were included in the final analysis, and 2,209 (53.0%) were excluded according to the selection criteria of participant. Participants were excluded from the final analysis for reasons such as missing or refusing investigations and not meeting the criteria for pre-frailty at baseline. Therefore, the results of the pre-frailty trajectories caused by exclusion bias related to non-response sampling bias among selective bias can be interpreted in consideration of the criteria for selecting participants.

Attrition bias is an important issue when studying older adults. In this study, dropouts were frequent because of the 14-year follow-up period (n = 1,131, 57.9%). The included and excluded participants have statistically significant differences in age, sex, marital status, smoking, and health check-ups by year ($p < .001$) (Appendix 10). Dropouts occurred owing to refusals to participate further in the survey, disease, nursing home admission, hospitalization, or death. Altogether, 545 (27.8%) of the 1,955 participants died between 2008 and 2020, which is to be expected in the longitudinal study of older adults over a 14-year period. Therefore, because attrition bias may threaten the generalization of the study results, caution is necessary when interpreting the effect of pre-frailty in older adults.

The 37-item FI proposed by Jung et al. (2022) was modified and measured according to the guidelines in order to measure pre-frailty (Searle et al., 2008). The FI was confirmed to have high reliability. However, further research is essential to validate the FI (37 items) for use in other study populations and settings.

7.3. Suggestions for Future Research

In this study, participants were excluded from the final analysis for various reasons, such as non-response or rejection of analysis variables, according to the selection criteria for participants. Those who did not meet the criteria for pre-frailty at the baseline and those who missed the follow-up studies were also excluded. Since attrition bias is an important issue when studying older adults, it is necessary to closely monitor and follow up the health status of the participants to reduce the bias. Additionally, it is necessary to optimize communication with participants for information collection when possible.

This study identified sleep disturbance and avoiding health check-ups as the most important pre-frailty trajectories. Research has improved our understanding of the impact of lifestyle on the pre-frailty trajectories. However, further studies are needed to research modifiable lifestyle factors including weight management, social engagement, and leisure activities.

The rapidly worsening frailty group was at greater risk of mortality. This group has a high priority for the application of interventions to improve frailty, and interventions are urgently needed. Future studies are needed to evaluate the effects of multimodal interventions on mortality involving older adults within the rapidly worsening frailty group, their families, and caregivers via randomized controlled trials.

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APPENDIX

Appendix 1. Comparison of pre-frailty measurement

Author (year)	Index	No. items	Components/ Classification of Pre-frailty	Ph	F	M	Ps	C	S
Fried (2001)	CHS	5	Weight loss, low physical activity, exhaustion, slowness, weakness; Frail: ≥ 3 items, pre-frail: 1–2 items, non-frail: none	O	X	X	X	X	X
Bilotta (2011)	SOF	3	Weight loss, exhaustion, unable to rise from chair 5 times; Frail: ≥ 2 items, pre-frail: 1 item, non-frail: none	O	X	X	X	X	X
Mitnitski (2001)	FI	over 30 (original)	Tremor, aphasia, apraxia, pulses, dependence in dressing or bathing, diabetes, Parkinson, sleep, memory complaints, mood, laboratory (urea, creatinine, calcium); Health deficit accumulation: point of 0 (none) to 1.0 (all deficits); a continuous point, frailty cut-off suggested >0.25	O	O	O	O	O	X
Jones (2004)	FI-CGA	14 (original)	Cognition, emotion, communication, mobility, balance, bladder, bowel, nutrition, ADL, social domain; Each domain 0 (no), 1 (minor), and 2 (major problem), a continuous point, frailty cut-off no suggested	O	O	O	O	O	O

Appendix 1. Comparison of pre-frailty measurement (continuous)

Author (year)	Index	No. items	Components/ Classification of Pre-frailty	Ph	F	M	Ps	C	S
Rockwood (2010)	FI-CGA	52	ADL, IADL, comorbidities, mood and cognition; A continuous point, frailty cut-off suggested >0.25	O	O	O	O	O	X
Rockwood (1999)	CSHA rules-based definition of frailty	4	Walk and transfers (with/without help), dependence ADLs, urinary/bladder continence (yes/no), and cognitive impairment (yes/no); 0: Not frail (none), 1: Bladder incontinence only, 2: Mild frailty: dependence ADL (1) or cognitive impairment, or bladder incontinence, 3: Moderate/severe frailty: dependence ADLs (≥ 2, if incontinence ≥ 3), bladder incontinence, or dementia.	O	O	O	X	O	X
Rockwood (2005)	CFS	1	Visual and written chart; terminally ill, ADL, IADL, number of chronic conditions, self-rated health, depression, engages in sport or recreational activities; Very fit (1) to terminally ill (9); frailty cut-off ≥ 5 point	O	O	O	O	X	O
Morley (2012)	FRAIL	5	Fatigue, resistance, ambulation, illness, loss of weight; Frail: ≥ 3 items, pre-frail: 1–2 items, non-frail: none	O	X	O	X	X	X

Appendix 1. Comparison of pre-frailty measurement (continuous)

Author (year)	Index	No. items	Components/ Classification of Pre-frailty	Ph	F	M	Ps	C	S
Pilotto (2008)	MPI	8	Comorbidity, polypharmacy, nutrition, cognition, pressure sore risk, ADL, IADL, living status; Frail: >0.66, pre-frail: 0.34–0.66, non-frail: <0.34	O	O	O	X	O	O

CHS: Cardiovascular Health Study, CFS: Clinical Frailty Scale, CSHA: Canadian Study of Health and Aging, FI: Frailty Index, FI-CGA: Frailty Index derived from the Comprehensive Geriatric Assessment, FRAIL: Fatigue, Resistance, Ambulation, Illness, and Loss of weight, MPI: Multidimensional Prognostic Index, SOF: Study of Osteoporotic Fractures.

Appendix 2. Review about frailty trajectories

Author (year), Country	Inclusion criteria/ Sample size	Frailty measurement	Years of follow-up	Main results
Álvarez-Bustos (2021), Spain	65 years or older; n = 975	Frailty Trait Scale-short form 5 (The higher the score, the higher the frailty)	11	1) Worsening from non-frailty (23.2%), improving to non-frailty (36.2%), developing frailty (13.0%), remaining frailty (20.8%), increasing frailty (6.8%); 2) Participants belonging to trajectories of increasing or showing higher frailty presented with an increased mortality and disability.
Buchman (2014), United states	Follow-up evaluations exceeds 90% of survivors, autopsy rate exceeds 85%; n = 2,167	CHS (3 items; The higher the score, the higher the frailty)	15	During an average follow-up of 6 years, frailty worsened by 0.09 unit/year. The rates of change of frailty and cognition were strongly correlated.
Gajic-Veljanoski (2018), Canada	50 years or older, able to communicate in English, regardless of history of fracture; n = 7,753	FI (30 items; The higher the score, the higher the frailty)	10	Incident fractures and obesity predicted frailty progression. Greater physical activity and better quality of life decreased frailty over time.

Appendix 2. Review about frailty trajectories (continuous)

Author (year), Country	Inclusion criteria/ Sample size	Frailty measurement	Years of follow-up	Main results
Howrey (2020), United states	65 years or older, Mexican American, complete data at baseline and at least one follow-up frailty measurement; n = 1,338	CHS (4 items; The higher the score, the higher the frailty)	18	1) non-frailty (25%), moderate progressive (64%), high progressive (11%); 2) Predictors of membership into both the high frailty and rapid cognitive decline groups were low education and diabetes.
Liu (2018), United states	70 years or older, independent ADLs, no cognitive impairment, terminal illness, MMSE data available at follow-up; n = 690	CHS (5 items; non-frailty [0-2], frailty [≥ 3]))	9	1) no frailty and cognitive impaired (28%), progressive frailty and slow cognitive decline (46%), progressive frailty and rapid cognitive decline (20%), cognitive frailty (7%); 2) Trajectories were associated with higher outcomes for nursing home admission, disability, excluding hospitalization.
Lohman (2017), United States	Community-dwelling individuals aged 51 and older, excluded frailty and depression symptoms at all five waves; n = 13,495	FI (30 items; non-frailty [<0.25], frailty [≥0.25])	8	Prevalence of frailty increased over the study period (24.1%-32.1%). More rapid increases of frailty and depressive symptoms were associated with higher risk of both nursing home admission and falls.

Appendix 2. Review about frailty trajectories (continuous)

Author (year), Country	Inclusion criteria/ Sample size	Frailty measurement	Years of follow-up	Main results
Peek (2012), United states	65 years or older, non-institutionalized Mexican American; n = 2,061	CHS (4 items; The higher the score, the higher the frailty)	11	1) progressive moderate frailty (73%), progressive high frailty (18%), stable low frailty (9%); 2) Stressors and financial strain were related to increases in frailty over time, whereas social support was related to decreases in frailty.
Rogers (2017), United Kingdom	non-frail adults aged 50 and over at baseline, included those with ≥30 Frailty index items; n = 8,649	FI (56 items; non-frailty [<0.25], frailty [≥0.25])	10	1) Mild physical activity was insufficient to delay the progression of frailty; 2) Moderate activity decreased the worsening frailty over 65 years older.
Rogers (2020), United Kingdom	50 years or older, excluded missing data on frail, exposure or covariates at baseline; n = 4,575	FI (56 items; non-frailty [<0.25], frailty [≥0.25])	10	The increasing frequency of cultural participation was associated with both incidence and progression of frailty.

Appendix 2. Review about frailty trajectories (continuous)

Author (year), Country	Inclusion criteria	Frailty measurement	Years of follow-up	Main results
Stow (2018), United Kingdom	Age 75 years and over who died between 2015 and 2016 from electronic healthcare records; n = 13,149	FI (36 items; The higher the score, the higher the frailty)	1 (monthly intervals)	1) Rapidly rising frailty (2.2%), moderately increasing frailty (21.2%), stable frailty (76.6%); 2) Rapidly rising frailty was associated with a 180% increase in mortality. Moderately increasing frailty was associated with a 65% increase in mortality.

ADL: Activities of Daily Fiving, CHS: Cardiovascular Health Study Index, FI: Frailty index, MMSE: Mini-Mental State Examination, N/A: not applicable, SD: standard deviation.

Appendix 3. Review about life course determinants influencing pre-frailty

Category	First author (year)	Statistically significant	Type of association
Demographic factors			
Age			
Older (yes)	Norazman (2020)	Yes	Positive
Older (non-frail to pre-frail)	Romero-Ortuno (2021)	Yes	Positive
Older (pre-frail to frail)	Fan (2021), Romero-Ortuno (2021)	Yes	Positive
Sex (women)	Fan (2021), Romero-Ortuno (2021)	Yes	Positive
Education level			
High school (pre-frail to frail)	Fan (2021)	No	N/A
College or over (pre-frail to frail)	Fan (2021)	No	N/A
Low (pre-frail to frail)	Romero-Ortuno (2021)	Yes	Negative
High (pre-frail to non-frail)	Romero-Ortuno (2021)	Yes	Positive
Marital status			
Unmarried (pre-frail to frail or death)	Pollack (2017)	No	N/A
Income (continuous)	Norazman (2020)	No	N/A
Lifestyle			
Physical activity			
Light-intensity physical activity (METs 1.5-2.9)	Kikuchi (2021)	No	N/A
Moderate to vigorous physical activity (METs ≥3.0)	Kikuchi (2021)	Yes	Negative

Appendix 3. Review about life course determinants influencing pre-frailty (continuous)

Category	First author (year)	Statistically significant	Type of association
Sedentary behaviors			
Short-bout sedentary behavior (METs <1.5 and <30 mins)	Kikuchi (2021)	No	N/A
Prolonged sedentary behavior (METs <1.5 and ≥30 mins)	Kikuchi (2021)	Yes	Positive
Leisure-time activity			
Moderate (yes)	Savela (2013)	No	N/A
High (yes)	Savela (2013)	No	N/A
Malnutrition (MNA-SF, yes)	Norazman (2020)	No	N/A
Healthy diet (aHEI/DASH/MED scores, high)	Ward (2021)	Yes	Negative
Alcohol consumption			
Ex-drinking (pre-frail to frail)	Fan (2021)	No	N/A
Current drinking (pre-frail to frail)	Fan (2021)	No	N/A
Smoking			
Ex-smoking (pre-frail to frail)	Fan (2021)	No	N/A
Current smoking (pre-frail to frail)	Fan (2021)	No	N/A

Appendix 3. Review about life course determinants influencing pre-frailty (continuous)

Category	First author (year)	Statistically significant	Type of association
Sleep disturbance			
Wake after sleep onset (continuous)	Guida (2021)	No	N/A
Sleep fragmentation index (continuous)	Guida (2021)	No	N/A
Nighttime total sleep time (<7/≥8 hours)	Guida (2021)	No	N/A
(≤6 hours)	Nakakubo (2018)	Yes	Positive
(≥9 hours)	Nakakubo (2018), Nakakubo (2019)	Yes	Positive
Weight management			
BMI (<18.5, pre-frail to frail)	Fan (2021)	No	N/A
BMI (24.0-28.0, pre-frail to frail)	Fan (2021)	No	N/A
BMI (>28.0, pre-frail to frail)	Fan (2021)	Yes	Positive
Mid-upper arm circumference (high)	Norazman (2020)	No	N/A
Waist circumference (high)	Crow (2019)	Yes	Positive
	Norazman (2020)	No	N/A

Appendix 3. Review about life course determinants influencing pre-frailty (continuous)

Category	First author (year)	Statistically significant	Type of association
Life event			
History of falls			
Environment (indoors home/outdoors, indoor public space)	Gratza (2019)	No	N/A
Activity before fall (standing/movement)	Gratza (2019)	No	N/A
Time of day (morning/afternoon/evening/ night)	Gratza (2019)	No	N/A
Biologic factors			
Cortisol (salivary, high)	de Almeida Holanda (2012)	No	N/A
Testosterone (low)	Carcaillon (2012)	Yes	Positive
Vitamin D (serum, low)	Sergi (2015), Sousa-Santos (2018)	Yes	Positive

aHEI: Alternative Healthy Eating Index, BMI: body mass index, DASH: Dietary Approaches to Stop Hypertension, MED: Mediterranean Diet, MET: Metabolic Equivalent of Task, MNA-SF: Mini-Nutrition Assessment-Short Form, N/A: not applicable.

Appendix 4. Pre-frailty associated with hospitalization among adverse health-related outcomes

Author (year)	Sample/ Age range (year)	Measurement		Years of follow-up	Results
		Pre-frailty	Hospitalization		
Ávila-Funes (2009), Mexico	6,030; community; 65-95	CHS (non-frailty [0], pre-frailty [1–2], frailty [≥ 3])	yes or no	4	1) HR of pre-frailty: 1.15 (95% CI 0.99–1.32) compared to non-frail 2) HR of frailty: 1.41 (95% CI 1.06–1.87) compared to non-frail
Bandeen-Roche (2006), United States	1,002; community, ≥ 65	CHS (non-frailty [0], pre-frailty [1–2], frailty [≥ 3])	yes or no	3	1) HR of pre-frailty: 0.99 (95% CI 0.67−1.47) 2) HR of frailty: 0.67 (95% CI 0.33–1.35)
Bouillon (2013), United Kingdom	5,169; Community; 55-79	CHS (non-frailty [0], pre-frailty [1–2], frailty [≥ 3])	National records	2	1) HR of pre-frailty: 2.40 (95% CI 1.83−3.14) 2) HR of frailty: 1.20 (95% CI 1.06–1.35) * Adjusted for age and sex

Appendix 4. Pre-frailty associated with hospitalization among adverse health-related outcomes (continuous)

Author (year)	Sample/ Age range (year)	Measurement		Years of follow-up	Results
		Pre-frailty	Hospitalization		
Forti (2014) , Italy	766; Community; ≥ 65	SOF (non-frailty [0], pre-frailty [1], frailty [≥ 2])	yes or no	3	1) OR of pre-frailty: 0.97 (95% CI 0.98−5.63) 2) OR of frailty: 2.35 (95% CI 0.98–5.63)
Gill (2011) , United States	754; Community; ≥ 70	CHS (non-frailty [0], pre-frailty [1], frailty [≥ 2])	yes or no	1.5 (18 months)	1) HR of pre-frailty: 0.94 (95% CI 0.79−1.11) 2) HR of frailty: 1.33 (95% CI 1.06–1.66)
Hogan (2012), Canada	1,066; assisted living/ supportive housing facilities; ≥ 65	CHS (non-frailty [0], pre-frailty [1–2], frailty [≥ 3]), FI (43 and 83 items; non-frailty [< 0.2], pre-frailty [0.2-0.3], frailty [> 0.3])	yes or no	1	1) CHS: OR of pre-frailty 1.06 (95% CI 0.82−1.38) and frailty 1.45 (95% CI 1.15–1.83) 2) FI (43 items): OR of pre-frailty 0.91 (95% CI 0.68-1.22) and frailty 1.16 (95% CI 10.87-1.53) 3) FI (83 items): OR of pre-frailty 1.37 (95% CI 1.13−1.66) and frailty 1.28 (95% CI 1.04–1.57)

Appendix 4. Pre-frailty associated with hospitalization among adverse health-related outcomes (continuous)

Author (year)	Sample/ Age range (year)	Measurement		Years of follow-up	Results
		Pre-frailty	Hospitalization		
					* Adjusted for age, sex, and co-morbidity (Charlson co-morbidity index score).
Jung (2014), South Korea	693; Community; ≥ 65	CHS (non-frailty [0], pre-frailty [1–2], frailty [≥ 3]), SOF (non-frailty [0], pre-frailty [1], frailty [2–3]), KLoSHA (pre-frailty [≥0.2], frailty [≥ 0.35])	yes or no	5-6	1) CHS : HR of pre-frailty 1.44 (95% CI 0.87−2.39), HR of frailty 2.24 (95% CI 1.05–4.76), 2) SOF : HR of pre-frailty 0.94 (95% CI 0.60−1.47), HR of frailty 1.43 (95% CI 0.68–3.01), 3) KLoSHA : HR of pre-frailty 0.90 (95% CI 0.57−1.41), HR of frailty 2.13 (95% CI 1.04–4.35)

Appendix 4. Pre-frailty associated with hospitalization among adverse health-related outcomes (continuous)

Author (year)	Sample	Measurement		Years of follow-up	Results
		Pre-frailty	Hospitalization		
Kiely (2009), United States	765; Community; ≥ 70	CHS (non-frailty [0], pre-frailty [1–2], frailty [≥ 3]), SOF (non-frailty [0], pre-frailty [1], frailty [2 – 3])	yes or no	1.5	1) CHS : Adjusted OR of pre-frailty 1.97 (95% CI 1.37–2.84), OR of frailty 4.45 (95% CI 2.42–8.18), 2) SOF : Adjusted OR of pre-frailty 2.64 (95% CI 1.74–4.01), OR of frailty 3.49 (95% CI 1.53–7.98) * Adjusted for age, sex, race, diabetes mellitus, stroke, hypertension, hyperlipidemia, education, and income
Paulson (2015), United States	8,844; Community; ≥ 65	PLFI (5 items; non-frailty [0], pre-frailty [1–2], frailty [≥ 3])	yes or no	4, 8	1) Adjusted OR of pre-frailty 1.23 (95% CI 1.09–1.39) and frailty 1.80 (95% CI 1.49–2.17) over 4 years 2) Adjusted OR of pre-frailty 1.23 (95% CI 1.10–1.37) and frailty 1.60 (95% CI 1.33–1.92) over 8 years

Appendix 4. Pre-frailty associated with hospitalization among adverse health-related outcomes (continuous)

Author (year)	Sample/ Age range (year)	Measurement		Years of follow-up	Results
		Pre-frailty	Hospitalization		
					* Adjusted for age, sex, minority status, income, chronic diseases, disability, self-rated health, cognitive function, and depression

CHS: Cardiovascular Health Study Index, CI: confidence interval, FI: Frailty index, HR: hazard ratio, OR: odds ratio, KLoSHA: Korean Longitudinal Study on Health and Aging, PLFI: Paulson-Lichtenberg Frailty Index, SOF: Study of Osteoporotic Fractures.

Appendix 5. Pre-frailty associated with mortality among adverse health-related outcomes

Author (year)	Sample	Age range	Pre-frailty Measurement	Years of follow-up	Results
Ávila-Funes (2009)	6,030; Mexico	65-95	CHS (non-frailty [0], pre-frailty [1–2], frailty [≥ 3])	4	1) HR of pre-frailty: 1.23 (95% CI 0.94–1.60) 2) HR of frailty: 1.30 (95% CI 0.83–2.04) Adjusted age, sex, education level, income, smoking, drinker status, number of chronic diseases, self-reported health, depression, mobility, IADL, and ADL
Beak (2022)	10,254; South Korea	45-98	FI (41 items, non-frailty [≤ 0.10], pre-frailty [0.10 < FI < 0.25], frailty [≥0.25])	12	1) HR of pre-frailty: 1.37 (95% CI 1.20 – 1.56) 2) HR of frailty: 2.57 (95% CI 2.20 - 3.00)
Cano (2012)	1,815; United States	≥ 65	CHS (non-frailty [0], pre-frailty [1–2], frailty [≥ 3])	10	1) HR of pre-frailty: 1.39 (95% CI 1.17-1.64) 2) HR of frailty: 1.97 (95% CI 1.53-2.55) Adjusted age, sex, education, marital status, diabetes, heart attack, stroke, cancer, hip fracture, hypertension, and arthritis

Appendix 5. Pre-frailty associated with mortality among adverse health-related outcomes (continuous)

Author (year)	Sample	Age range	Pre-frailty Measurement	Years of follow-up	Results
Lee (2018)	12,087; South Korea	≥ 65	CHS (non-frailty [0], pre-frailty [1–2], frailty [≥ 3])	3	1) HR of pre-frailty: 1.38 (95% CI 1.10 – 1.73) 2) HR of frailty: 1.78 (95% CI 1.29, 2.46) Adjusted sociodemographic, health behaviors, and chronic conditions
Jacobs (2011)	840; Israel	≥ 85	CHS (non-frailty [0], pre-frailty [1–2], frailty [≥ 3])	5	1) HR of pre-frailty: 1.56 (95% CI 1.02 – 2.38) 2) HR of frailty: 3.86 (95% CI 2.40 – 6.21) Adjusted frailty, sex, cognitive function, and education
Kim (2019)	725,759; South Korea	66	THE frailty index (8 items; non-frailty [0-2], pre-frailty [3-4], frailty [≥ 5])	3-7	1) Men: HR of pre-frailty: 1.56 (95% CI 1.51-1.62), HR of frailty: 2.65 (95% CI 2.48-2.89) 2) Women: HR of pre-frailty: 1.54 (95% CI 1.47-1.61), HR of frailty: 2.73 (95% CI 2.51-2.96)

Appendix 5. Pre-frailty associated with mortality among adverse health-related outcomes (continuous)

Author (year)	Sample	Age range	Pre-frailty Measurement	Years of follow-up	Results
Nari (2021)	3,578; South Korea	≥ 65	MPI (low [< 0.33], moderate [0.33 - 0.66], severe [> 0.66] risk of frailty)	10	1) HR of moderate risk frailty: 1.52 (95% CI 1.37 – 1.69) 2) HR of severe risk frailty: 3.10 (95% CI 2.55 – 3.77)
Malmstrom (2014)	998; United States	49-65	FI (25 items, non-frailty [< 0.20], pre-frailty [0.20–0.25], frailty [>0.25])	9	1) OR of pre-frailty: 1.77 (95% CI 0.92-3.41) 2) OR of frailty: 2.28 (95% CI 1.46-3.55) Adjusted age and sex

ADL: Activity of Daily Living, CHS: Cardiovascular Health Study Index, CI: confidence interval, FI: Frailty index, HR: hazard ratio, IADL: Instrumental Activity of Daily Living, MPI: Multidimensional Prognostic Index, OR: odds ratio, THE frailty index: The Lifetime Transition Period Health Examination version of the Korean Frailty Index.

Appendix 6. Questionnaire in this study

조사설문지

노인의 전허약 궤적의 생애결정요인 및 부정적 건강결과:
2006-2020 고령화연구패널조사을 이용하여

[생애결정요인]

1. [응답자 이름]님의 태어나신 해는 어떻게 되십니까? _____년도

2. [응답자 이름]님은 성별이 어떻게 되십니까?
[1] 남자 [2] 여자

3. [응답자 이름]님께서는 학교를 어디까지 다니셨습니까?
[1] 무학(문자해독 불가) [2] 무학(문자해독 가능)
[3] 초등학교(보통학교) [4] 중학교(공민학교, 고입검정고시)
[5] 고등학교(대입검정고시) [6] 전문대학(사범학교)
[7] 대학교 [8] 대학원 석사
[9] 대학원 박사 [97] 기타
[98] 모르겠음 [99] 응답거부

4. 다니신 학교를 졸업하셨습니까, 중퇴하셨습니까, 아니면 학교를 마치지 않으셨어도 검정고시로 자격취득을 하셨습니까?
[1] 재학 [2] 졸업 [3] 중퇴 [4] 수료
[5] 검정고시 자격취득

5. [응답자 이름]님께서는 현재 결혼상태가 어떻게 되십니까?
[1] 혼인 중 [2] 별거
[3] 이혼 [4] 사별 또는 실종이산가족)
[5] 결혼한 적 없음 [98] 모르겠음 [99] 응답거부

6. 작년 한 해 ____님을 포함해서 함께 사시는 가구원의 총소득은 얼마나 됩니까?
(단위: 만원) _____만원

7. 평소에 일주일에 1 회 이상 운동을 하십니까?
[1] 예 [5] 아니오

8. 지난 이틀 동안 식사에 대하여 여쭈어 보겠습니다. 먼저 어제를 생각해 보십시오. 아침, 점심, 저녁 모두 드셨습니까? 모두 선택해 주세요.
[1] 아침식사 했음 [2] 점심식사 했음
[3] 저녁식사 했음 [4] 아침, 점심, 저녁 모두 안(못)먹음

9. 그저께를 생각해보시오. 아침, 점심, 저녁 모두 드셨습니까?
[1] 아침식사 했음 [2] 점심식사 했음
[3] 저녁식사 했음 [4] 아침, 점심, 저녁 모두 안(못)먹음

10. 평소에 가끔 또는 자주 술(소주, 맥주, 막걸리 등)을 드십니까?
[1] 예, 마십니다 [5] 아니오, 마시지 않습니다

11. 현재 담배를 피우고 계십니까? [1] 예 [5] 아니오

12. 지난 일주일간 잠을 잘 이루지 못하셨다고 생각하십니까?
[1] 잠깐 그런 생각이 들었거나, 그런 생각이 들지 않았음 (하루미만)
[2] 가끔 그런 생각이 들었음 (하루 이틀 정도)
[3] 자주 그런 생각이 들었음 (3 일~4 일 정도)
[4] 항상 그런 생각이 들었음 (5 일~7 일 정도)

13. 최근 2 년 동안 국민건강보험과 의료급여제도에서 무료로 제공되는 1 차 건강검진을 받으신 적이 있습니까? [1] 예 [5] 아니오

14. 지난 2년 중 낙상을 하신 적이 있습니까? [1] 예 [5] 아니오

[Frailty Index]

■ 주관적 건강상태

1. 다음으로 건강상태에 관한 질문을 드리겠습니다. 본인의 건강상태에 대해 어떻게 생각하십니까?

[1] 매우 좋음 [2] 좋은 편 [3] 보통
[4] 나쁜 편 [5] 매우 나쁨

■ 우울

2. 지난 일주일간 도무지 무얼 해나갈 엄두가 나지 않으셨습니까?

[1] 잠깐 그런 생각이 들었거나, 그런 생각이 들지 않았음 (하루미만)
[2] 가끔 그런 생각이 들었음 (하루 이틀 정도)
[3] 자주 그런 생각이 들었음 (3일~4일 정도)
[4] 항상 그런 생각이 들었음 (5일~7일 정도)

3. 지난 일주일간 동안 많이 우울하시다고 생각하셨습니까?

[1] 잠깐 그런 생각이 들었거나, 그런 생각이 들지 않았음 (하루미만)
[2] 가끔 그런 생각이 들었음 (하루 이틀 정도)
[3] 자주 그런 생각이 들었음 (3일~4일 정도)
[4] 항상 그런 생각이 들었음 (5일~7일 정도)

4. 지난 일주일간 세상에 홀로 있는 듯한 외로움을 느끼셨습니까?

[1] 잠깐 그런 생각이 들었거나, 그런 생각이 들지 않았음 (하루미만)
[2] 가끔 그런 생각이 들었음 (하루 이틀 정도)
[3] 자주 그런 생각이 들었음 (3일~4일 정도)
[4] 항상 그런 생각이 들었음 (5일~7일 정도)

■ 체중감소

5. 지난 1년(현재 기준) 중 체중은 5킬로그램 이상 늘거나 줄었습니까?

[1] 증가했음 [2] 감소했음 [3] 증가했다가 감소했음
[4] 감소했다가 증가했음 [5] 변화가 없었음

■ 일상생활 수행능력 (Activities of Daily Living) 제한

최근 일주일 동안의 활동을 기준으로 말씀해 주시기 바랍니다.

6. “옷 갈아입기” 옷을 꺼내서 단추, 지퍼를 올리기까지 포함해서 모두 혼자 하실 수 있으십니까? 다른 사람의 도움이 필요하십니까?

[1] 도움 필요 없음 [3] 부분적인 도움이 필요함

[5] 전적으로 도움이 필요함

7. “세수하기, 양치질하기, 머리감기.” 모두 혼자 하실 수 있으십니까? 다른 사람의 도움이 필요하십니까?

[1] 도움 필요 없음 [3] 부분적인 도움이 필요함

[5] 전적으로 도움이 필요함

8. “목욕 또는 샤워하기(혼자 등을 못 미는 것은 상관없음).” 모두 혼자 하실 수 있으십니까? 다른 사람의 도움이 필요하십니까?

[1] 도움 필요 없음 [3] 부분적인 도움이 필요함

[5] 전적으로 도움이 필요함

9. “차려놓은 음식 식사하기(포크나 다른 도구 이용도 상관없음).” 모두 혼자 하실 수 있으십니까? 다른 사람의 도움이 필요하십니까?

[1] 도움 필요 없음 [3] 부분적인 도움이 필요함

[5] 전적으로 도움이 필요함

10. “이부자리서 일어나 방 밖으로 나가기(도구를 사용해서 일어나도 상관없음).” 모두 혼자 하실 수 있으십니까? 다른 사람의 도움이 필요하십니까?

[1] 도움 필요 없음 [3] 부분적인 도움이 필요함

[5] 전적으로 도움이 필요함

11. “화장실 이용하기(실내용 변기 이용 무관, 옷을 벗고 용변 후 처리까지 말함).” 모두 혼자 하실 수 있으십니까? 다른 사람의 도움이 필요하십니까?

[1] 도움 필요 없음 [3] 부분적인 도움이 필요함

[5] 전적으로 도움이 필요함

12. “대소변 흘리지 않고 보기(카데터(도관), 장루를 본인이 도움 없이 사용해도 상관없음).” 모두 혼자 하실 수 있으십니까? 다른 사람의 도움이 필요하십니까?

[1] 도움 필요 없음 [3] 부분적인 도움이 필요함
[5] 전적으로 도움이 필요함

■ 도구적 일상생활 수행능력 (Instrument Activities of Daily Living) 제한

최근 일주일 동안의 활동을 기준으로 말씀해 주시고, 지금은 잠시 다른 사정으로 도움을 받으시지만, 앞으로 3 개월 이내에 고쳐질 것으로 예상되는 것은 도움 필요 없는 것으로 말씀해 주십시오.

13. “몸단장하기 (머리 빗기, 손발톱 깍기, 화장(여자), 면도(남자) 포함)” 모두 혼자 하실 수 있으십니까? 다른 사람의 도움이 필요하십니까?

[1] 도움 필요 없음 [3] 부분적인 도움이 필요함
[5] 전적으로 도움이 필요함

14. 일상적으로 집에서 하는 청소나 정리정돈, 침구정리, 설거지 등을 하는 데 다른 사람의 도움이 필요하십니까?

[1] 도움 필요 없음 [3] 부분적인 도움이 필요함
[5] 전적으로 도움이 필요함

15. 식사준비를 하실 때 다른 사람의 도움이 필요하십니까? 식사준비란 음식재료를 준비하고, 요리하고, 상을 차리는 모든 과정을 말합니다.

[1] 도움 필요 없음 [3] 부분적인 도움이 필요함
[5] 전적으로 도움이 필요함

16. “빨래하기” 즉 손빨래 또는 세탁기를 이용하여 세탁한 후 빨래를 널고 말리실 때 다른 사람의 도움이 필요하십니까?

[1] 도움 필요 없음 [3] 부분적인 도움이 필요함
[5] 전적으로 도움이 필요함

17. 교통수단을 이용하지 않고 “가까운 거리를 외출”하실 때 다른 사람의 도움이 필요하십니까?

[1] 도움 필요 없음 [3] 부분적인 도움이 필요함
[5] 전적으로 도움이 필요함

18. 버스나 전철, 택시 혹은 승용차 등 “교통수단을 이용하여 외출”하실 때, 다른 사람의 도움이 필요하십니까?
[1] 도움 필요 없음 [3] 부분적인 도움이 필요함
[5] 전적으로 도움이 필요함

19. “물건사기” 즉, 사야 할 물건을 결정하시고, 돈을 지불하시고 거스름돈을 받으시는데 다른 사람의 도움이 필요하십니까?
[1] 도움 필요 없음 [3] 부분적인 도움이 필요함
[5] 전적으로 도움이 필요함

20. “금전관리” 작은 용돈관리 및 통장관리 그 밖에 재산관리를 하시는데 다른 사람의 도움이 필요하십니까?
[1] 도움 필요 없음 [3] 부분적인 도움이 필요함
[5] 전적으로 도움이 필요함

21. 전화를 거시고 받으실 때 다른 사람의 도움이 필요하십니까?
[1] 도움 필요 없음 [3] 부분적인 도움이 필요함
[5] 전적으로 도움이 필요함

22. “약 챙겨먹기” 즉, 약을 드신다면 제시간에 정해진 양의 약을 챙겨 잡수시는데 다른 사람의 도움이 필요하십니까?
[1] 도움 필요 없음 [3] 부분적인 도움이 필요함
[5] 전적으로 도움이 필요함

■ 질병
23. 의사로부터 암이나 악성종양(경미한 피부암 등은 제외) 진단을 받으신 적이 있습니까?
[1] 예 [5] 아니오

24. 의사로부터 당뇨병이 있거나 혈당이 높다는 진단을 받으신 적이 있습니까?
[1] 예 [5] 아니오

25. 의사로부터 관절염 또는 류마티스이라는 진단을 받으신 적이 있습니까?
[1] 예 [5] 아니오

26. 의사로부터 고혈압이라는 진단을 받으신 적이 있습니까?
[1] 예 [5] 아니오

27. 의사로부터 기관지염이나 폐기종과 같은 만성 폐질환 진단을 받으신 적이 있습니까?
[1] 예 [5] 아니오

28. 의사로부터 심장발작이나 협심증, 심근경색, 울혈성 심부전증, 또는 기타 심장 질환이 있다고 진단을 받으신 적이 있습니까?
[1] 예 [5] 아니오

29. 의사로부터 뇌혈관질환(뇌졸증, 뇌출혈, 뇌경색 등)이라는 진단을 받으신 적이 있습니까?
[1] 예 [3] 뇌졸중 의증 혹은 일시적 허혈성 발작 [5] 아니오

■ 시각 및 청각으로 인한 활동제한
30. 현재 시력 때문에 일상적인 활동을 하는데 어려움을 느끼십니까?
[1] 예 [5] 아니오

31. 현재 청력 때문에 일상적인 활동을 하는데 어려움을 느끼십니까?
[1] 예 [5] 아니오

■ 지남력 : 시간
32-1. 오늘은 몇 년도 몇 월 몇 일입니까?
[1] 년도, 월, 일 중 한 가지만 정답 [2] 년도, 월, 일 중 두 가지 정답
[3] 년도, 월, 일 세 가지 모두 정답 [5] 세 가지 모두 오답

32-2. 그러면 오늘은 무슨 요일 입니까?
[1] 요일 정답 [5] 요일 오답
32-3. 지금이 어떤 계절이지요?
[1] 계절 정답 [5] 계절 오답

■ 지남력 : 장소

33-1. 현재 있는 이곳에 대해 말씀해 주십시오. 여기가 어디입니까?

[1] 장소 정답 [5] 장소 오답

33-2. [응답자 이름]님의 주소는 어떻게 되시는지요?

시(도), 구(시,군), 동(읍,군,면), 번지 (세부주소) 4 가지를 모두 말씀해 주세요.

[1] 시(도), 구(시, 군), 동(읍, 군, 면), 번지(세부주소) 중 한 가지만 정답

[2] 시(도), 구(시, 군), 동(읍, 군, 면), 번지(세부주소) 중 두 가지만 정답

[3] 시(도), 구(시, 군), 동(읍, 군, 면), 번지(세부주소) 중 세 가지만 정답

[4] 시(도), 구(시, 군), 동(읍, 군, 면), 번지(세부주소) 중 네 가지 모두 정답

[5] 네 가지 모두 오답(주소를 하나도 알지 못함)

■ 주의력

34. 지금부터 뺄셈을 몇 개 해보겠습니다.

100 에서 7 을 빼면 얼마가 되지요? _____

그러면 거기서 7 을 빼면 얼마가 되나요? _____

그러면 거기서 또 7 을 빼면 얼마가 되나요? _____

그러면 거기서 또 7 을 빼면 얼마가 되나요? _____

마지막으로 그럼 거기서 7 을 빼면 얼마가 되나요? _____

■ 지연된 기억력

35. 제가 조금 전에 외우고 계시라고 했던 단어 3 개 기억나세요? 모두 말씀해 주세요.

[1] 순서와 상관없이 세 단어 중 한 단어만 정답

[2] 순서와 상관없이 세 단어 중 두 단어만 정답

[3] 순서와 상관없이 세 단어 중 세 단어 모두 정답

[5] 세 단어 모두 외우지 못함

[부정적 건강결과]

■ 입원

1. 지난 1 년 중 아프거나 다치셔서 병원, 간호요양병원 또는 요양원에 입원하신 적이 있으십니까? 있으시다면 몇 번 입원하셨습니까? (단위: 회) _____회

Appendix 7. The GRoLTS Checklist in the study

No.	Checklist Item	Reported?
1.	Is the metric of time used in the statistical model reported?	Yes
2.	Is information presented about the mean and variance of time within a wave?	Yes
3a.	Is the missing data mechanism reported?	No
3b.	Is a description provided of what variables are related to attrition/missing data?	No
3c.	Is a description provided of how missing data in the analyses were dealt with?	Yes
4.	Is information about the distribution of the observed variables included?	Yes
5.	Is the software mentioned?	Yes
6a.	Are alternative specifications of within-class heterogeneity considered (e.g., LGCA vs. LGMM) and clearly documented? If not, was sufficient justification provided as to eliminate certain specifications from consideration?	No
6b.	Are alternative specifications of the between-class differences in variance–covariance matrix structure considered and clearly documented? If not, was sufficient justification provided as to eliminate certain specifications from consideration?	N/A
7.	Are alternative shape/functional forms of the trajectories described?	Yes
8.	If covariates have been used, can analyses still be replicated?	N/A
9.	Is information reported about the number of random start values and final iterations included?	Yes
10.	Are the model comparison (and selection) tools described from a statistical perspective?	Yes
11.	Are the total number of fitted models reported, including a one-class solution?	Yes

Appendix 7. The GRoLTS Checklist in the study (continuous)

No.	Checklist Item	Reported?
12.	Are the number of cases per class reported for each model (absolute sample size, or proportion)?	Yes
13.	If classification of cases in a trajectory is the goal, is entropy reported?	Yes
14a.	Is a plot included with the estimated mean trajectories of the final solution?	Yes
14b.	Are plots included with the estimated mean trajectories for each model?	N/A
14c.	Is a plot included of the combination of estimated means of the final model and the observed individual trajectories split out for each latent class?	N/A
15.	Are characteristics of the final class solution numerically described (i.e., means, SD/SE, n, CI, etc.)?	Yes
16.	Are the syntax files available (either in the appendix, supplementary materials, or from the authors)?	Yes

CI: confidence interval, LGCA: latent class growth analysis, LGMM: latent growth mixture modeling, N/A: not applicable, SD: standard deviation, SE: standard error.

Reference: van De Schoot, R., Sijbrandij, M., Winter, S. D., Depaoli, S., & Vermunt, J. K. (2017). The GRoLTS-checklist: guidelines for reporting on latent trajectory studies. *Structural Equation Modeling: A Multidisciplinary Journal*, *24*(3), 451-467.

Appendix 8-1. Mean for each item of Frailty Index in the remaining pre-frailty group by year

Deficit Indicators	2006 n=1,229	2008 n=1,170	2010 n=1,037	2012 n=960	2014 n=876	2016 n=773	2018 n=679	2020 n=597
Self-rated health	0.59	0.56	0.56	0.57	0.58	0.59	0.59	0.60
Feel everything is an effort	0.11	0.10	0.15	0.11	0.11	0.14	0.15	0.08
Feel depressed	0.07	0.08	0.07	0.04	0.07	0.07	0.06	0.06
Feel lonely	0.07	0.07	0.07	0.05	0.06	0.06	0.06	0.06
Lost more than 5kgs in last year	0.06	0.07	0.07	0.05	0.06	0.05	0.06	0.05
Dressing	0.00	0.00	0.01	0.00	0.00	0.02	0.02	0.02
Washing	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.02
Bathing	0.00	0.00	0.01	0.01	0.01	0.02	0.03	0.03
Eating	0.00	0.00	0.01	0.00	0.01	0.02	0.02	0.01
Transferring	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.02
Toileting	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.02
Incontinence	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.01
Grooming	0.00	0.00	0.01	0.01	0.01	0.02	0.03	0.02
Housework	0.01	0.02	0.02	0.02	0.03	0.05	0.05	0.05
Meal preparations	0.03	0.03	0.03	0.03	0.04	0.07	0.06	0.07
Laundry	0.03	0.04	0.04	0.04	0.04	0.06	0.07	0.07
Outgoing	0.01	0.01	0.01	0.02	0.03	0.05	0.06	0.10
Using transportation	0.02	0.02	0.02	0.03	0.03	0.06	0.07	0.14
Shopping	0.00	0.01	0.01	0.02	0.02	0.04	0.04	0.07
Finances	0.03	0.01	0.02	0.02	0.03	0.04	0.05	0.09
Telephone	0.01	0.00	0.01	0.01	0.02	0.03	0.03	0.05
Taking medication	0.00	0.00	0.01	0.01	0.01	0.03	0.03	0.03
Cancer	0.02	0.03	0.04	0.05	0.07	0.09	0.11	0.13
Diabetes	0.14	0.17	0.20	0.23	0.27	0.31	0.36	0.41
Arthritis	0.28	0.33	0.37	0.41	0.45	0.49	0.54	0.59
High blood pressure	0.41	0.46	0.52	0.58	0.62	0.67	0.72	0.76
Lung disease	0.03	0.03	0.04	0.05	0.06	0.07	0.08	0.10
Heart disease	0.07	0.09	0.11	0.12	0.14	0.17	0.20	0.24
Stroke	0.02	0.03	0.04	0.05	0.06	0.08	0.10	0.12
Vision	0.13	0.07	0.04	0.05	0.05	0.03	0.04	0.04
Hearing	0.07	0.05	0.05	0.05	0.05	0.08	0.08	0.09
Body mass index	0.18	0.15	0.17	0.18	0.18	0.20	0.18	0.18
Handgrip strength	0.59	0.56	0.63	0.60	0.55	0.53	0.57	0.58
Orientation time	0.23	0.17	0.19	0.17	0.18	0.17	0.23	0.27
Orientation place	0.22	0.17	0.17	0.18	0.19	0.20	0.28	0.30
Attention	0.60	0.52	0.52	0.49	0.52	0.53	0.54	0.58
Recall	0.64	0.66	0.58	0.56	0.62	0.67	0.64	0.73
Frailty Index (FI)	0.13	0.13	0.13	0.13	0.14	0.14	0.15	0.16

Appendix 8-2. Mean for each item of Frailty Index in the slowly increasing frailty group by year

Deficit Indicators	2006 n=556	2008 n=528	2010 n=495	2012 n=456	2014 n=382	2016 n=337	2018 n=277	2020 n=214
Self-rated health	0.66	0.66	0.67	0.70	0.72	0.73	0.75	0.76
Feel everything is an effort	0.12	0.21	0.22	0.17	0.21	0.26	0.29	0.26
Feel depressed	0.08	0.15	0.14	0.16	0.19	0.22	0.22	0.21
Feel lonely	0.08	0.13	0.13	0.16	0.17	0.19	0.22	0.19
Lost more than 5kgs in last year	0.07	0.12	0.13	0.18	0.18	0.19	0.21	0.16
Dressing	0.00	0.01	0.02	0.04	0.05	0.07	0.11	0.13
Washing	0.00	0.01	0.02	0.04	0.04	0.07	0.11	0.14
Bathing	0.01	0.02	0.04	0.07	0.09	0.14	0.17	0.22
Eating	0.00	0.00	0.01	0.04	0.04	0.06	0.09	0.10
Transferring	0.00	0.01	0.03	0.04	0.05	0.07	0.11	0.13
Toileting	0.00	0.01	0.02	0.04	0.05	0.06	0.09	0.11
Incontinence	0.00	0.00	0.02	0.03	0.04	0.06	0.10	0.10
Grooming	0.00	0.01	0.03	0.05	0.05	0.09	0.14	0.18
Housework	0.03	0.05	0.07	0.11	0.15	0.19	0.24	0.31
Meal preparations	0.04	0.08	0.10	0.14	0.19	0.23	0.28	0.39
Laundry	0.05	0.10	0.12	0.16	0.20	0.24	0.29	0.38
Outgoing	0.01	0.04	0.08	0.14	0.18	0.26	0.32	0.54
Using transportation	0.03	0.07	0.12	0.17	0.22	0.31	0.35	0.60
Shopping	0.01	0.04	0.08	0.11	0.15	0.23	0.28	0.52
Finances	0.02	0.05	0.10	0.11	0.16	0.23	0.29	0.50
Telephone	0.02	0.02	0.05	0.07	0.10	0.13	0.19	0.35
Taking medication	0.00	0.01	0.03	0.04	0.06	0.09	0.15	0.31
Cancer	0.04	0.06	0.07	0.09	0.11	0.14	0.18	0.23
Diabetes	0.25	0.29	0.34	0.37	0.45	0.50	0.57	0.64
Arthritis	0.36	0.43	0.50	0.54	0.61	0.66	0.71	0.79
High blood pressure	0.52	0.59	0.67	0.72	0.79	0.83	0.88	0.92
Lung disease	0.06	0.08	0.09	0.11	0.13	0.15	0.19	0.23
Heart disease	0.13	0.16	0.19	0.22	0.28	0.31	0.37	0.46
Stroke	0.04	0.06	0.09	0.12	0.17	0.22	0.27	0.33
Vision	0.15	0.12	0.12	0.10	0.10	0.13	0.16	0.10
Hearing	0.12	0.12	0.13	0.12	0.15	0.24	0.32	0.27
Body mass index	0.21	0.20	0.22	0.23	0.24	0.22	0.22	0.23
Handgrip strength	0.65	0.70	0.77	0.71	0.69	0.75	0.69	0.72
Orientation time	0.30	0.32	0.38	0.36	0.45	0.52	0.61	0.67
Orientation place	0.28	0.34	0.34	0.38	0.46	0.50	0.62	0.60
Attention	0.67	0.70	0.70	0.72	0.78	0.79	0.84	0.90
Recall	0.69	0.79	0.77	0.76	0.85	0.88	0.90	0.96
Frailty Index (FI)	0.16	0.19	0.21	0.22	0.25	0.29	0.32	0.36

Appendix 8-3. Mean for each item of Frailty Index in the rapidly worsening frailty group by year

Deficit Indicators	2006 n=170	2008 n=159	2010 n=125	2012 n=90	2014 n=64	2016 n=37	2018 n=18	2020 n=13
Self-rated health	0.65	0.74	0.79	0.81	0.85	0.85	0.88	0.86
Feel everything is an effort	0.14	0.24	0.31	0.24	0.33	0.42	0.30	0.29
Feel depressed	0.07	0.29	0.24	0.34	0.39	0.33	0.30	0.32
Feel lonely	0.09	0.21	0.20	0.26	0.29	0.22	0.20	0.18
Lost more than 5kgs in last year	0.04	0.17	0.19	0.28	0.29	0.24	0.20	0.11
Dressing	0.01	0.08	0.20	0.28	0.44	0.43	0.45	0.54
Washing	0.00	0.07	0.23	0.29	0.45	0.47	0.43	0.50
Bathing	0.01	0.16	0.30	0.37	0.57	0.56	0.73	0.75
Eating	0.01	0.07	0.16	0.24	0.39	0.33	0.38	0.39
Transferring	0.00	0.09	0.22	0.26	0.44	0.47	0.50	0.57
Toileting	0.00	0.07	0.20	0.22	0.41	0.42	0.40	0.43
Incontinence	0.00	0.07	0.16	0.20	0.40	0.34	0.40	0.36
Grooming	0.00	0.10	0.23	0.30	0.46	0.50	0.50	0.61
Housework	0.02	0.23	0.43	0.49	0.65	0.72	0.75	0.89
Meal preparations	0.04	0.33	0.49	0.59	0.71	0.79	0.80	0.93
Laundry	0.07	0.35	0.52	0.61	0.75	0.80	0.88	0.89
Outgoing	0.03	0.28	0.45	0.55	0.71	0.73	0.88	0.93
Using transportation	0.06	0.38	0.51	0.60	0.74	0.79	0.90	1.00
Shopping	0.01	0.27	0.44	0.53	0.69	0.77	0.90	1.00
Finances	0.04	0.28	0.42	0.49	0.69	0.80	0.88	1.00
Telephone	0.03	0.19	0.29	0.34	0.51	0.52	0.68	0.93
Taking medication	0.01	0.12	0.23	0.31	0.46	0.48	0.53	1.00
Cancer	0.05	0.05	0.12	0.15	0.20	0.30	0.44	0.53
Diabetes	0.24	0.28	0.37	0.46	0.54	0.66	0.81	0.87
Arthritis	0.25	0.34	0.41	0.51	0.62	0.77	0.89	0.93
High blood pressure	0.45	0.54	0.68	0.77	0.85	0.91	0.95	0.96
Lung disease	0.04	0.07	0.09	0.13	0.19	0.29	0.44	0.55
Heart disease	0.09	0.10	0.15	0.21	0.30	0.40	0.60	0.70
Stroke	0.06	0.09	0.14	0.25	0.37	0.50	0.72	0.82
Vision	0.19	0.25	0.20	0.24	0.30	0.32	0.35	0.31
Hearing	0.11	0.25	0.24	0.39	0.44	0.65	0.50	0.43
Body mass index	0.21	0.21	0.24	0.24	0.33	0.37	0.25	0.27
Handgrip strength	0.71	0.74	0.75	0.78	0.66	0.52	0.50	0.56
Orientation time	0.20	0.51	0.59	0.69	0.83	0.81	0.88	1.00
Orientation place	0.11	0.45	0.52	0.64	0.83	0.89	0.88	0.92
Attention	0.20	0.77	0.79	0.84	0.91	0.96	0.94	1.00
Recall	0.73	0.84	0.82	0.87	0.96	0.95	0.94	1.00
Frailty Index (FI)	0.17	0.29	0.37	0.44	0.53	0.56	0.61	0.62

Appendix 9. Predicted probabilities of life course determinants by group

Variables	Remaining pre-frailty (n=1,229)	Slowly increasing frailty (n=556)	Rapidly worsening frailty (n=170)
Age			
65-74 years	70.9%	24.6%	4.5%
75-84 years	50.7%	36.1%	13.2%
≥ 85 years	38.5%	34.8%	26.7%
Sex			
men	66.3%	25.0%	8.7%
women	63.1%	31.2%	5.7%
Education			
≤ primary school	62.1%	30.7%	7.2%
≥ middle school	71.4%	23.0%	5.6%
Marital status			
married	62.9%	31.0%	6.1%
unmarried	66.8%	25.0%	8.2%
Household income (Unit: 10,000 KRW)			
Q1 (≤100)	64.5%	28.8%	6.6%
Q2 (101-500)	62.1%	30.9%	7.0%
Q3 (501-1,500)	68.2%	26.1%	5.7%
Q4 (≥1,501)	63.7%	28.5%	7.8%
Physical activity			
yes	62.8%	30.6%	6.6%
no	65.3%	27.9%	6.8%
Breakfast			
yes	64.6%	28.7%	6.7%
no	63.2%	30.0%	6.8%
Alcohol consumption			
yes	68.0%	25.7%	6.3%
no	63.2%	29.9%	6.9%
Smoking			
yes	65.2%	30.6%	4.2%
no	64.3%	28.4%	7.3%
Sleep disturbance			
yes	55.6%	36.1%	8.3%
no	66.2%	27.3%	6.5%
Health check-ups			
yes	67.8%	27.3%	4.9%
no	61.1%	29.9%	9.0%
Falls			
yes	65.5%	27.2%	7.3%
no	64.5%	28.8%	6.7%

Appendix 10. Differences in characteristics of excluded and included participants by year

Variables	2008			2010			2012			2014		
	OR	*p*	95% CI	OR	*p*	95% CI	OR	*p*	95% CI	OR	*p*	95% CI
Age (ref: 65-74 years)												
75-84 years	0.69		0.42 1.13	2.18	***	1.67 2.86	2.09	***	1.65 2.64	2.53	***	2.04 3.13
≥ 85 years	0.57		0.13 2.43	4.14	***	2.37 7.24	6.20	***	3.66 10.53	7.01	***	3.99 12.34
Sex (ref: men)												
women	0.69		0.40 1.20	0.62	**	0.43 0.88	0.63	**	0.46 0.85	0.59	***	0.45 0.78
Education (ref: ≤ primary school)												
≥ middle school	1.31		0.80 2.14	1.22		0.88 1.69	1.18		0.89 1.56	1.24		0.96 1.61
Marital status (ref: married)												
unmarried	0.98		0.59 1.64	1.39	*	1.02 1.89	1.51	**	1.15 1.97	1.44	**	1.13 1.84
Household income (ref: Q1 (≤ 100))												
Q2 (101-500)	0.99		0.58 1.71	0.95		0.67 1.35	0.88		0.65 1.19	0.80		0.61 1.05
Q3 (501-1,500)	0.73		0.39 1.35	0.96		0.66 1.39	0.99		0.72 1.36	0.83		0.62 1.10
Q4 (≥ 1,501)	0.91		0.51 1.64	1.01		0.71 1.45	0.98		0.72 1.34	0.85		0.64 1.13
Physical activity (ref: yes)												
no	0.86		0.55 1.36	0.82		0.62 1.09	0.87		0.68 1.12	1.11		0.88 1.39
Breakfast (ref: yes)												
no	0.87		0.27 2.83	0.68		0.32 1.47	0.85		0.46 1.56	1.41		0.84 2.35
Alcohol consumption (ref: no)												
yes	1.08		0.66 1.77	0.83		0.60 1.14	0.87		0.66 1.14	0.83		0.65 1.07
Smoking (ref: non-smoker)												
yes	0.88		0.48 1.62	1.01		0.69 1.48	1.39	*	1.01 1.92	1.26		0.94 1.71
Sleep disturbance (ref: no)												
yes	0.78		0.43 1.43	1.37		0.99 1.90	1.03		0.82 1.28	1.45	**	1.11 1.89
Health check-ups (ref: yes)												
no	1.20		0.79 1.81	1.27		0.98 1.64	1.06		0.85 1.32	1.11		0.90 1.35
Falls (ref: no)												
yes	1.35		0.61 3.03	1.26		0.77 2.08	1.26		0.81 1.95	1.19		0.79 1.80

Appendix 10. Differences in characteristics of excluded and included participants by year (continuous)

Variables	2016			2018			2020		
	OR	*p*	95% CI	OR	*p*	95% CI	OR	*p*	95% CI
Age (ref: 65-74 years)									
75-84 years	2.92	***	2.37 3.60	3.11	***	2.51 3.86	3.77	***	2.99 4.75
≥ 85 years	9.65	***	4.93 18.88	16.33	***	6.44 41.39	64.19	***	8.83 466.80
Sex (ref: men)									
women	0.57	***	0.43 0.74	0.53	***	0.41 0.69	0.50	***	0.39 0.66
Education (ref: ≤ primary school)									
≥ middle school	1.10		0.86 1.41	1.07		0.83 1.36	1.00		0.77 1.28
Marital status (ref: married)									
unmarried	1.50	**	1.19 1.89	1.46	**	1.17 1.84	1.41	**	1.12 1.78
Household income (ref: Q1 (≤ 100))									
Q2 (101-500)	0.87		0.67 1.13	0.94		0.73 1.22	0.96		0.74 1.26
Q3 (501-1,500)	0.80		0.60 1.05	0.87		0.66 1.15	0.94		0.71 1.24
Q4 (≥ 1,501)	0.80		0.60 1.05	0.80		0.60 1.05	0.81		0.61 1.07
Physical activity (ref: yes)									
no	1.00		0.80 1.24	0.95		0.77 1.18	1.03		0.83 1.28
Breakfast (ref: yes)									
no	1.30		0.78 2.16	1.70	*	1.01 2.84	1.49		0.88 2.54
Alcohol consumption (ref: no)									
yes	0.85		0.66 1.08	0.82		0.64 1.04	0.88		0.69 1.12
Smoking (ref: non-smoker)									
yes	1.35	*	1.01 1.80	1.45	*	1.08 1.95	1.46	*	1.07 2.00
Sleep disturbance (ref: no)									
yes	1.22		0.94 1.58	1.10		0.85 1.43	0.97		0.75 1.27
Health check-ups (ref: yes)									
no	1.24	*	1.02 1.51	1.43	***	1.18 1.73	1.49	***	1.23 1.81
Falls (ref. no)									
yes	1.00		0.67 1.49	1.16		0.78 1.72	0.88		0.59 1.32

CI: confidence interval, OR: odds ratio.
* p <.05, ** p <.01, *** p <.001.

Appendix 11. Syntax of this study

1. Panel Tobit regression on pre-frailty

```
xttobit FI w01_age_G w01gender_01 w01edu_G w01marital_01 w01_income
    w01_exercise_01 w01_breakfast_01 w01_alcohol_01 w01_smoking_01 w01_sleep_01
    w01_health_check_01 w01_falls
```

2. Pre-frailty trajectory

```
traj, model(cnorm) var(FI*) indep(y*) order(3 1 3) min(0) max(1)
```

▪ **Trajplot syntax**

```
trajplot, xtitle("Years") ytitle("Frailty Index(score)")
```

3. Pre-frailty trajectories by multinomial logistic regression and margin

```
mlogit _traj_Group i.w01_age_G i.w01gender_01 i.w01edu_G i.w01marital_01
    i.w01_income i.w01_exercise_01 i.w01_breakfast_01 i.w01_alcohol_01
    i.w01_smoking_01 i.w01_sleep_01 i.w01_health_check_01 i.w01_falls, base(1)
mlogit, rrr
```

▪ **Margin analysis for age avariable**

```
margins w01_age_G, atmeans predict(outcome(1))
margins w01_age_G, atmeans predict(outcome(2))
margins w01_age_G, atmeans predict(outcome(3))
```

▪ **Marginsplot syntax**

```
margins w01_age_G, atmeans predict(outcome(1))
marginsplot, name(remaining)
margins w01_age_G, atmeans predict(outcome(2))
marginsplot, name(slowly)
margins w01_age_G, atmeans predict(outcome(3))
marginsplot, name(rapidly)
graph combine remaining slowly rapidly, ycommon
```

ABSTRACT IN KOREAN

노인의 전허약 궤적의 생애결정요인 및 부정적 건강결과: 2006-2020년 고령화연구패널조사를 이용하여

이 수 미
연세대학교 일반대학원
간호학과

전허약은 비허약과 허약의 중간 단계로, 허약으로 악화되거나 비허약 상태로 돌아갈 수 있는 잠재적으로 가역적인 특징을 가지고 있다. 전허약은 생리적 예비능력을 유지하거나 증가시켜 허약과 부정적 건강결과를 예방할 수 있는 기회를 제공하기 때문에 중요하다. 본 연구의 목적은 지역사회에 거주하는 노인의 전허약 궤적을 식별하고, 전허약 궤적 그룹에 영향을 미치는 생애결정요인을 조사하고, 그리고 전허약 궤적 그룹과 입원 및 사망 사이의 관련성을 파악하고자 함이었다.

Gobbens 등(2010)의 통합적 허약개념모델은 노화 과정에서 생애결정요인이 허약에 영향을 미치고 허약의 변화와 허약으로 인한 부정적인 결과를 설명하였다. 허약과 부정적인 결과는 간호중재를 통해 예방, 지연 및 감소시킬 수 있다고 제시하였다. 본 연구에서는 생애결정요인이 전허약 궤적 그룹에 미치는 영향과 전허약 궤적 그룹과 부정적 건강결과 사이의 관련성을 규명하고자 개념적 기틀을 구성하여 분석하였다.

본 연구는 2006-2020년 고령화연구패널조사 자료를 이용한 이차자료 분석연구이다. 전허약은 정유경 등(2022)이 고령화연구패널조사로부터 구성한 Frailty Index를 수정하여 37개 문항으로 측정하였다. 분류기준은 Frailty Index 점수가 0.08 이하를 비허약으로, 0.08 초과부터 0.25 미만을 전허약으로, 그리고

0.25 이상을 허약으로 분류하였다. 선정기준은 65세 이상이며, 기준선에서 전허약 상태이며, 14년간 추적조사에 최소 한 차례 이상 허약을 측정한 경우이다. 전허약 궤적을 식별하기 위해 집단중심 궤적모형을, 전허약 궤적 그룹에 영향을 미치는 생애결정요인을 조사하기 위해 다형 로지스틱 회귀분석을, 전허약 궤적 그룹과 입원 및 사망 사이의 관련성을 파악하기 위해 생존분석을 하였다.

연구결과, 최종분석 대상자는 1,955명으로, 평균 연령은 72.7세이었으며, 여성은 60.9%였다. 14년간 노인의 전허약 궤적의 종단적 변화는 다음 3가지 그룹으로 구분되었다. 1) 전허약 유지 (n=1,229, 62.9%), 2) 점진적 허약 증가 (n=556, 28.4%), 그리고 3) 급격한 허약 악화 (n=170, 8.7%). 전허약 유지그룹에 비해 점진적 허약 증가그룹에서는 생애결정요인 중 높은 연령, 낮은 교육수준, 결혼상태, 그리고 수면장애가 영향을 미쳤다. 급격한 허약 악화그룹의 생애결정요인은 연령과 건강검진 미수검으로 밝혀졌다. 부정적 건강결과 중 입원의 위험은 점진적 허약 증가그룹에 비해 급격한 허약 악화그룹에서 1.41배 높았다(95% confidence interval [CI]: 1.03-1.93). 급격한 허약 악화그룹에 속한 대상자가 사망의 위험이 높았다(Hazard ratio [HR]: 1.68, 95% CI: 1.23-2.29). 급격한 허약 악화그룹의 생존기간의 중위수는 9년으로 가장 짧았고, 다른 그룹에 비해 1년 짧았다. 그러나 전허약 유지그룹은 점진적 허약 증가그룹에 비해 입원 및 사망률과 관련성이 없었다.

따라서 본 연구는 지역사회에 거주하는 노인의 전허약 궤적 그룹을 식별한 최초 연구이다. 고령과 건강검진 미수검은 급격한 허약 악화그룹을 예측하는 요인으로 확인되었다. 이처럼 본 연구에서 전허약 궤적과 각 궤적의 생애결정요인을 구별함으로써 근거기반 맞춤형 간호중재에 기여할 수 있다. 또한 노인의 허약 및 부정적 건강결과를 개선하기 위한 간호중재의 중재적용대상, 우선순위, 중재적용 시기 및 중재구성요소에 대한 근거를 마련했다. 노인의 조기 허약선별평가, 맞춤형 중재전략 개발, 그리고 교육 및 간호정책을 마련하기 위한 기초자료로 활용될 수 있을 것이라 기대한다.

주요어: 허약, 전허약, 입원, 사망, 궤적, 노인, 종단연구