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Abstract

Alongside increasing life expectancy comes the opportunity to extend working life, but whether those extra years are spent with or without multimorbidity is unclear. Existing studies estimated healthy and unhealthy working life expectancy (WLE), defined using binary health indicators, until retirement age and used data from Western countries. However, countries with the greatest burden of population aging are in the Asia-Pacific region. Using data from eight waves of the Korean Longitudinal Study of Aging (2006-2020) and a discrete-time multistate modelling approach, we estimate WLE at age 55 with no disease, one disease, and multimorbidity and explore intersectional inequalities by sex, education, and urban/rural residence. Males, the low educated, and rural dwellers have higher WLE compared to females, the high educated, and urban dwellers. Regardless of sex, individuals with low education and from rural areas both have higher WLE with multimorbidity than their high educated and urban counterparts. These findings highlight that older adults with low education and from rural areas are most in need of additional support to help balance work and health responsibilities. This is contrary to observations from Western countries and underscores the need to better understand how patterns in work and multimorbidity vary across different contexts.

Keywords: working life expectancy, multimorbidity, intersectionality, life course, retirement

Introduction

Populations are ageing at an unprecedented rate across many countries globally, and this can largely be attributed to declining fertility and increasing life expectancy. This has implications for many aspects of society, including health and pension systems and the economic sustainability of these. The combination of increasing life expectancy with improvements in disease screening and treatment allows people to live longer lives with two or more chronic diseases (multimorbidity) (Johnston et al., 2019), though whether they are living healthier is debatable. Living longer, and potentially healthier lives, would allow people to continue working, thereby increasing their working life expectancy (WLE). Several countries have recently increased or are planning to increase retirement age and have linked future increases to changes in life expectancy (OECD, 2023). However, even though life expectancy is increasing, there is concern about how much of that time will be spent in a healthy enough state to continue working.

Healthy WLE, or its compliment unhealthy WLE (van der Noordt et al., 2019; Wind et al., 2018) have been developed to estimate how long people work in a healthy/unhealthy states (Lievre et al., 2007). Recently, studies have started to consider both healthy and unhealthy WLE together to provide a more comprehensive assessment of the relationship between work and health, with health being defined using binary indicators of single chronic disease, mental health, disability, functional limitations, self-rated health, or self-assessed work ability (Beller et al., 2024; Boissonneault & Rios, 2021; Hambisa et al., 2023; Laaksonen et al., 2022; Parker et al., 2020a, 2020b; Shiri et al., 2021; Sperlich et al., 2023). Multimorbidity (typically defined as 2 or more co-occurring conditions) is not typically incorporated, even though people with multimorbidity are more likely to exit the labour force than people without multimorbidity (Gurgel do Amaral et al., 2022; Kato et al., 2022; Van Zon et al., 2020). Additionally, almost all of these studies used data from Europe and the

United States and study pre-retirement age participants (ages 50 to 65). This perspective overlooks the most rapidly societies with the highest rates of labor force participation past age 65 – countries in the Asia-Pacific region.

To address this gap, we estimate healthy and unhealthy WLE in South Korea (Korea, hereafter). Korea provides an interesting context to investigate the relationship between work and health in older age because it is one of the most rapidly aging countries in the world. It has one of the highest life expectancies (82.7 years in 2022) (Statistics Korea, 2023c) and is predicted to become a super-aged society, where the proportion of adults aged 65+ reaches 20%, by 2025 (Statistics Korea, 2021). However, compared to other Organization for Economic Co-operation and Development (OECD) countries, it has the highest proportion of individuals aged 70+ participating in the labor force (33.1%) and about half of older persons live in relative poverty (OECD, 2018). Korea also has a unique situation in which retirement age is fixed at age 60, but pension age is gradually increasing to age 65 by 2033, resulting in a widening gap where individuals will need to find another source of income until they are eligible to receive their pension (S. Lee & Lee, 2023).

Additionally, Korea's ultra-low total fertility rate of 0.78 in 2022 will have important ramifications for the society as a whole, but especially for the older population (Statistics Korea, 2023b). Korea is a family-centered society which follows traditional gender norms, resulting in a large gap between the labor force participation of men and women. Women's labor force participation has increased from 52% in 2000 to 63% in 2023, whereas the rate for men has stayed fairly stable, fluctuating between 77-79% (OECD, 2024b). The recent shift towards individualism combined with growing economic uncertainty has resulted in young Koreans opting to delay or forego marriage, with the crude marriage rate declining from 10.6% in 1980 to 3.7% in 2022 (Park, 2015; Statistics Korea, 2023d). The average age at first marriage in 2002 was 29.8 years for men and 27 years for women, and in 2022 increased to 33.7 years and 31.3 years for men and women, respectively (Statistics Korea, 2023d). These decreases in family formation have important implications not just for future generations, but for the parents and grandparents who rely on their children for assistance.

For example, one of the major social security programs in Korea was built on the idea of family support. The Basic Livelihood Security Programme (BLSP) and the National Basic Livelihood Security System (NBLSS) are social assistance programs that were introduced in 2000 to provide cash benefits in the categories of livelihood, health, housing, and education to households living below official poverty thresholds (Hwang et al., 2022; Nam & Park, 2020). Eligibility is based on an income threshold, but also on the *family support obligation rule*, which states that an applicant is not eligible for the BLSP or NBLSS if they have a close family member that has the *capacity* to support them, not that they are actually being provided financial support (OECD, 2018). Older adults are the largest group receiving BLSP benefits, but of the 25% of adults aged 65 years or older living in absolute poverty, only 6.9% receive benefits (OECD, 2018). Of the 2.5 million people who should qualify for NBLSS, only 1.3 million were actually eligible (Nam & Park, 2020). These gaps in coverage are largely due to the family support obligation rule, and accordingly, this rule has been gradually abolished for all BLSP benefits except health (Hwang et al., 2022; Nam & Park, 2020). Maintaining the family support obligation for health benefits will contribute to growing health inequalities among those of low socioeconomic status and who lack family support, which will disproportionately affect older adults. Older adults face the additional disadvantage of having accumulated various risk factors or intersectional inequalities over their life course, and are thus more susceptible to health problems and face greater economic uncertainty than younger adults (Moon & Lee, 2010).

Thus, in this paper, we aim to assess how long individuals work beyond retirement age, how much of this time they spend with and without multimorbidity, and how that might differ across subgroups. Using discrete-time multistate Markov models, we estimate the working and not working life expectancy (WLE and NWLE) spent with no disease, one disease, and multimorbidity at age 55 and stratify analyses by sex, education, and urban/rural place of residence. We estimate at age 55 because before 2016, many people were forced to retire before age 60. We use intersectionality as a framework to contextualize our findings in light of the social norms surrounding aging and gender, and the accumulation of lived experiences on health and employment trajectories over the life course. Understanding this balance between work and health amongst older adults in a rapidly aging country has important implications for Korea, and for other aging societies globally.

Background

Health and work beyond retirement

It is generally recognized that continuing to work or gradually stopping work through part-time or bridge employment is associated with better health compared to immediate retirement, but this seems to vary by gender, socioeconomic status, amount of work, job quality, and context (Ashwin et al., 2021; Baxter et al., 2021; Kikkawa & Gaspar, 2022). The physical and overall health benefits of working (e.g., self-rated health, activities of daily living, frailty) have been identified as stronger for males, individuals with high-quality and high-reward jobs, and those who can gradually reduce to part-time work (Baxter et al., 2021). However, mental health outcomes, measured using depression symptoms or problems with sleep, are mixed, with some studies finding that working older adults had better mental health than those who retired, other studies finding no statistical significance between working beyond pension age and retiring, and some studies finding that individuals with manual labor jobs had poorer mental health compared to those with professional jobs, and that mental health decreased as pension age increased (Baxter et al., 2021). Working for income past retirement age is more common in countries that lack a comprehensive pension system or which have large informal sectors because people might need to work to supplement their living costs (OECD, 2023). However, people with chronic diseases are less likely to work beyond retirement age and might even stop working early due to their health problems (de Wind et al., 2018; Giang & Le, 2018; M. Kang et al., 2015; Y. J. Kang & Kang, 2016).

Healthy WLE estimates have been used to determine whether it is feasible to increase retirement ages. However, the way "healthy" is defined varies substantially, from using indicators of chronic diseases, to self-reported health, mental health, work ability, and the Active Aging Index (Parker et al., 2020b; Boissonneault & Rios, 2021; Laaksonen et al., 2022; Hambisa et al., 2023; Sperlich et al., 2023). Healthy WLE at age 50 is increasing over time, but due to these varying definitions, can vary from about three to eleven years, on average, with further differences by sex, education, cohort, and country (Parker et al., 2020b; Boissonneault & Rios, 2021; Laaksonen et al., 2022; Hambisa et al., 2023; Sperlich et al., 2023). WLE tends to be about 30% shorter for individuals with low education compared to high education, likely due to more unemployment and disability retirement, and about 21% (men) and 27% (women) shorter for individuals from manual occupations compared to non-manual occupations (Solovieva et al., 2024). Unhealthy WLE estimates tend to be slightly lower than healthy WLE, and are also increasing over time (Boissonneault & Rios, 2021; Laaksonen et al., 2022; Sperlich et al., 2023). Increasing evidence for healthy and unhealthy WLE, particularly using more nuanced estimates of health such as multimorbidity, and getting a better understanding of their inequalities is pertinent for retirement and pension policies because they are key indicators to help ascertain if lengthening working life is feasible and whether this might vary across groups.

Korean pension and retirement system

The Korean pension system is made up of private and public pensions. Private pensions include personal savings and retirement pensions based on employer contributions, whereas public pensions include the Basic Pension (for adults aged 65+ living below 70% of the median income), the National Pension, and special occupational pensions, both of which are partially funded by the government (Y.-M. Lee et al., 2022). From 2013 to 2033, pension eligibility age will gradually increase from 60 to 65 years old (S. Lee & Lee, 2023).

In 2016, a law was implemented setting mandatory retirement age to at least 60 years old because prior to this, individual companies set their mandatory retirement age to be between ages 55 to 58 (T. Lee & Cho, 2022). Retirement age was increased due to several reasons: the longer healthy life expectancy of the population, the predicted decline in the working-age population due to declining fertility, and the increasing gap between retirement and pension eligibility age (T. Lee & Cho, 2022).

As pension age increases and retirement age stays constant, the time between when individuals retire and when they start receiving pension will continue increasing, resulting in a period of income interruption. Thus, many individuals try to compensate by finding bridge employment or reducing to part-time work, but a large proportion can only find temporary low-wage jobs (S. Lee & Lee, 2023). Additionally, there are also retired individuals who return to work to supplement their inadequate monthly pensions (OECD, 2018; T. Lee & Cho, 2022). This has also been observed in other countries, and particularly for older adults living in rural areas (Di Gessa et al., 2018; Giang & Le, 2018). In Korea, those who tend to work at older ages are more likely to be male, skilled manual workers or self-employed (Y. Lee & Yeung, 2021). It is unclear whether individuals who continue to work past retirement are doing so out of need or voluntarily. Additionally, while it is generally recognized that people who work longer have better overall and physical health than people who retire earlier, there may be some instances in which people work despite their poor health (Di Gessa et al., 2018; Giang & Le, 2018; Baxter et al., 2021).

Chronic diseases and the Korean health system

Chronic diseases are the leading causes of death in Korea (Park et al., 2023). For females, there is a shift towards aging-related diseases like Alzheimer's disease, and for males, liver and lung cancer are more prevalent (Park et al., 2023). The recent increase in prevalence of liver and lung cancer is a delayed outcome of historically high rates of smoking and alcohol use, which have declined substantially in recent years (Chang et al., 2019; Y. Choi et al., 2007; E. Lee et al., 2015). Using longitudinal panel data, T.W. Lee et al. (2022) have shown that multimorbidity has been increasing over time, with a cumulative incidence of 31.8% from 2008-2018. It was also found to be more prevalent in rural areas and amongst the lower educated (I.-Y. Jang et al., 2016; Yi et al., 2019).

Korea has had universal health coverage since 1989, with 97.1% of the population covered under the National Health Insurance Service and the remaining 2.9% covered by a subsidized Medical Aid program for low-income individuals (M. J. Kim, 2023). A general health check-up is offered every two years and includes chronic disease screening, anthropometric measures, and biomarker testing; the screening rate in 2019 was 74% (H.-T. Kang, 2022). Healthcare utilization is very high, with 15.7 doctor visits annually per capita, compared to the OECD average of 6.0 (OECD, 2024a). These visits tend to be outpatient hospital visits, because the primary care system is not well-established and patients do not require referrals to seek specialty care (Y. Cho et al., 2020). However, the number of practicing doctors per 1,000 is 2.6, which is below the OECD average (3.7 per 1,000). Additionally, there are stark urban/rural inequalities in healthcare availability. In 2012, 87% of hospitals and hospital beds were in urban areas (Kwon et al., 2015). This leaves residents from smaller cities and rural areas to face longer transportation times, reduced access to health and emergency services, and a greater unmet need for care (Kwon et al., 2015).

The roles of age and gender in the workplace

In Korea and many other Asian countries, the concepts of filial piety and respect towards elders are ingrained in the culture. Despite this, age discrimination towards older adults is a growing issue, especially in light of changing social norms (M.-A. Lee & Song, 2022). Age discrimination is something that can be experienced throughout the life course and has been shown to be associated with both physical and mental health problems, and is more common for women (Allen, 2016; H. Kim et al., 2019; G. Kim & Lee, 2020; Allen et al., 2022; H. Kang & Kim, 2022; M.-A. Lee & Song, 2022). It is also a major issue in the workplace, disproportionately affecting women, minorities, and the low-income (Bae & Choi, 2023; Suh, 2021). Discriminatory hiring practices or forced retirement of older workers also pushes them into more informal work, usually agricultural and based in rural areas, which prevents them from accumulating additional pension savings and having better access to healthcare services (UN ESCAP, 2020).

Regardless of age, there are also pervasive, but declining, gender discrimination practices against women in the workplace that negatively affect their recruitment and hiring, earnings, and promotions, which can have cumulative effects over the life course (Patterson & Walcutt, 2013). These discriminatory practices are rooted in Confucian beliefs and a patriarchal culture which emphasizes traditional gender norms, relegating women to home-based and caregiving roles and causing career interruptions (Brinton & Oh, 2019; Son & Neufeld, 2020; C. Kim & Oh, 2022; Rim & Kim, 2024). Workplace gender discrimination against women has been found to be associated with decreased odds of pregnancy planning and childbirth and increased odds of depressive symptoms (G. Kim et al., 2020; J.-H. Kim et al., 2019; Rim & Kim, 2024). The labor force participation rate of women in Korea over their life course is characterized by an M-shaped curve, in which there are high rates of labor force participation in their 20s, followed by a drop around childbearing age, and a return to employment after children have completed their education (OECD, 2018; Brinton & Oh, 2019). Of married women aged 15-54, 19.2% had career interruptions, largely due to childcare, marriage, and pregnancy/childbirth (Statistics Korea, 2019).

The intersection of age and gender highlights how disadvantages can accumulate over the life course, with older women being especially vulnerable to poverty due to having lower educational attainment, limited job opportunities, and experiencing widowhood (Moon & Lee, 2010). In older ages, unmarried women, those of lower social class, and those with limited family resources (e.g., financial transfers from their children) are more likely to work than men, likely because of their need for social and financial support and resources (Y. Lee & Yeung, 2021). Additionally, in rural areas, due to the migration of young people to urban centers, more females and older adults work as farmers (H. Lee et al., 2019). In contrast, men face the societal pressures of being the primary breadwinners and they tend to associate that role with their status in the family, which is something that could be threatened by retirement and pressure them to continue working despite potential health issues (Y. Lee & Yeung, 2021). Due to these gender roles, differences in the reporting of activities of daily living (ADLs) and instrumental ADLs have been observed amongst older adults (S. Jang & Kawachi, 2019). Older men tend to report that they are unable to do household tasks (e.g., laundry, cooking) because they had never done them before, whereas older women had difficulties managing money and using public transportation or driving, again due to lack of experience (Won et al., 2002). Older women also spend more of their time taking care of grandchildren than older men (Chung & Lee, 2017). Thus, older adults, particularly women, face this complex experience of intersectional age and gender inequalities and norms, which likely has negative effects on their health and is probably exacerbated by additional factors such as socioeconomic status, place of residence, and family composition and support.

Intersectionality and the life course

To better explain how age and gender interact within the context of other characteristics in their environment, we will use intersectionality as a framework to discuss and interpret our findings within the context of a life course approach. Intersectionality describes how human experiences are shaped by the combination of an individual's characteristics and the social and structural environment in which they live (Hankivsky, 2012, 2014). The foundational example stems from Kimberlé Crenshaw (1989), when she describes that being Black and being a woman is a uniquely synergistic experience more complex than each experience independently. Although most often used to describe the interactions between race, gender, and socioeconomic class through a feminist lens, many recent studies have used it to frame research around health disparities (Bauer, 2014; Gkiouleka et al., 2018; Bowleg, 2021; Harari & Lee, 2021; Holman & Walker, 2021).

Researchers have also proposed combining intersectionality with a life course approach to better understand health inequalities at the macro and micro-level and over time (Holman & Walker, 2021). A life course perspective implies that experiences from earlier in an individual's life affect their later life health (Ben-Shlomo et al., 2016). The life course has also been framed as being institutionalized and therefore structured by timings defined by institutional systems (Kohli, 1985, 2007; Wingens, 2022). Education systems determine the ages when individuals start and end school, employment systems define working-life, and pension systems demarcate retirement. This period of life past retirement age, regardless of whether someone is actually retired, tends to be viewed as the culmination of life course processes rather than a continuation. The life course approach has roots in developmental science, which explains why life course research usually focuses on how early-life risk factors will affect later-life health (e.g., fetal origins hypothesis, critical period model) (Kuh et al., 2003). However, disadvantages can also accumulate in older age. If we think about chronic diseases as a type of disadvantage which usually emerges in middle to older age and accumulates over time (i.e., the development of multimorbidity), then this post-retirement period could be thought of as a sensitive period for disease accumulation. Thus, in this paper, we use a combination of intersectionality and life course approaches to frame our understanding of the relationship between multimorbidity and working life expectancy beyond retirement. We consider how the intersecting relationships of age, gender, socioeconomic status, and place of residence might change and be influenced by life course experiences within the context of the current Korean healthcare and pensions systems.

Hypotheses

Based on previous studies, we would expect that males, the high educated, and people from urban areas would have higher WLE than females, the low educated, and people from rural areas, respectively. However, drawing from our knowledge of the Korean context, we make the following hypotheses:

1. Males will have higher WLE than females, but females will spend more of their WLE with multimorbidity.
2. Considering the intersection of sex and socioeconomic position, where education and place of residence are taken as indicators of socioeconomic position, we expect low educated and rural dwelling males to have higher WLE than high educated and urban dwelling males, respectively. We also expect that low educated and rural dwelling females will spend more of their WLE with multimorbidity compared to high educated and urban dwelling females, respectively.

Methods

Data source

Data are from waves 1-8 of the nationally-representative Korean Longitudinal Study of Aging (KLoSA) (Korea Employment Information Service, 2023). Surveys were conducted biennially from 2006-2020 for adults ≥45 years old, and collected information on demographics, family, health, employment, and socioeconomic status. The baseline sample included 10,254 participants and a refreshment sample of 920 individuals was added in the fifth wave. Our analytical sample was limited to participants aged 55-105 years old who were present for at least two waves, resulting in a total of 8,991 individuals. Any missing demographic, health, or employment data was imputed based on the prior wave (i.e., last observation carried forward).

Variables

All information from the variables included in the analysis are based on self-reported information. A count of the following chronic conditions is used to define disease status: arthritis, cancer, chronic lung disease, diabetes, heart disease, hypertension, liver disease, psychiatric problems, and stroke. Participants were asked if a doctor had ever diagnosed them with one of these diseases. Participants who answered "yes" were not asked again in subsequent waves, which indicates the chronicity of the diseases. These diseases were chosen because they were asked about in each survey wave, are among the leading causes of death and disability (Vos et al., 2020), and except hypertension, are included in a core list of multimorbid conditions (Ho et al., 2021). Although hypertension is not included in Ho et al.'s (2021) list of core conditions, which are defined as those with high disability-adjusted life years or high years of life lost, it was included in 70% of the studies they reviewed, making it an important contributor to multimorbidity. Multimorbidity is defined as the presence of two or more of the abovementioned chronic diseases.

An individual was categorized as “Working” if they reported that they were employed for income or if they were unpaid family workers working at least 18 hours a week, and “Not working” if they were unemployed but looking for a job, if they were unpaid family workers working less than 18 hours a week, if they were retired, or if they did not have a clear job. Unpaid family workers are family members of business owners who work without receiving payment. Age was included as a continuous variable from 55-105 years. Fifty-five was chosen as the baseline age because prior to the 2016 implementation of the law which extended retirement age to at least 60 years old, retirement age was usually between 55 and 58 years (T. Lee & Cho, 2022). Sex was defined as male or female. Marital status was defined as married or not married, of which the latter group includes individuals who are divorced, widowed, or never married. Household size was included as a count of the total number of household members. Education was dichotomized into low (middle school or less) and high (at least secondary school). Place of residence was defined as urban or rural.

At each wave, participants are categorized into different origin states of working and disease and they can either remain in that state or transition to a subsequent destination state, as depicted by the direction of the arrows in Figure 1.We include the following seven states in our analysis: “No disease, Working”, “No disease, Not working”, “One disease, Working”, “One disease, Not working”, “Multimorbidity, Working”, “Multimorbidity, Not working”, and “Death”. Death is considered an absorbing state, so individuals cannot leave once they enter. Individuals can move between working statuses, but we do not allow for reverse transitions between disease statuses because of the chronic nature of the included conditions.

Statistical analysis

We use multinomial logit models to predict the probability of transitioning between different origin and destination states. The models include terms for linear age, quadratic age, marital status, and household size, stratify by sex, education, and place of residence, and are weighted using the longitudinal weights provided by KLoSA which correct for attrition. All covariates are interacted with the origin state to allow each transition to have its own set of coefficients. The predicted transition probabilities are input into discrete-time multistate Markov models to estimate state and life expectancy from age 55, separately by sex, education, and place of residence using the standard approach. This involves computing expectancies conditional on an initial age of 55 and then obtaining a weighted average for each sex across these values. The weights correspond to the distribution of males and females separately across each of the six states at age 55, and to account for small sample sizes we take the average distribution for ages 55-64. This results in the removal of existing inequalities from education and place of residence, essentially equalizing the characteristics of participants from age 55 for each sex. This approach is taken because sex is an innate characteristic that strongly affects work, health, and mortality outcomes and all models are stratified by sex. Additionally, we are mainly interested in understanding how individuals' education and place of residence influence the transitions between states after age 55, since our focus is on how work and health develop after retirement age. The 95% confidence intervals were computed based on asymptotic theory and the delta method, and the underlying variance-covariance matrix of the multinomial logit model accounts for the complex survey design of the data (Schneider, 2023).

Statistical analyses were conducted in Stata 17 (StataCorp, 2021) and figures were created in R version 4.2.1 (R Core Team, 2020). Expectancy estimates and confidence intervals were obtained using the *dtms* package (Schneider, 2023).

Sensitivity analysis

We conduct one sensitivity analysis excluding hypertension from the multimorbidity definition because there is some disagreement as to whether hypertension is a multimorbid condition or if it is merely a risk factor. In another sensitivity analysis, we separate Seoul out from other urban areas because it is home to half the Korean population and the majority of healthcare services (M. Kim et al., 2021; Statistics Korea, 2023a).

Results

Table 1 provides information on participant characteristics at baseline. Our sample includes slightly more females (56.7%) than males and the average age of participants is 66.9 years. Only 26.1% of females are working at their entry wave compared to 53.1% of males. Over 90% of males are married, whereas only 63.5% of females are married, largely because 34% of unmarried females are widowed. Females tend to be lower educated, with 77.4% having low education compared to 51.2% of males. Three-quarters of participants live in urban areas and the average household size is 2.7 persons. Regardless of disease status, there is a larger proportion of males in a working state and a larger proportion of females in a not working state.

Transition probabilities

Figure 2 displays a sample of transition probability plots which represent each type of working transition (e.g., working to not working) and for which sex differences could be clearly seen. All 30 transition plots can be seen in Appendix I. Females have a higher probability of remaining in not working states and transitioning from working to not working states, regardless of disease status than males. In contrast, males have a higher probability of remaining in working states and transitioning to death. Regardless of disease status, for several of the transitions from working to not working or for remaining in the not working state, the probability of transitioning increases with age more for females than males, increasing the sex gap at older ages. The opposite pattern is observed for the transitions from no disease/multimorbidity, not working to no disease/multimorbidity, working, where the sex difference decreases with age.

Life expectancy

As expected, females and individuals with high education have higher life expectancy at age 55 than males and individuals with low education, respectively (Table 2). Sex-specific life expectancy estimates are also similar to those from the UN World Population Projections 2015 (Male: 25.9, Female: 31.9) and the WHO Global Health Observatory 2015 (Male: 26.5, Female, 31.6) (HMD, 2024; United Nations Population Division, Department of Economic and Social Affairs, 2022; World Health Organization, 2020). Individuals from rural areas have slightly higher life expectancy than individuals from urban areas, but the difference is not significant. Detailed estimates of life expectancy, WLE, and NWLE from each origin state is displayed in Section I, Supplementary material.

Sex differences in working life expectancy

In line with our first hypothesis, we found that males have about twice the WLE in both absolute years and as a percentage of life expectancy compared to females: 12.2 years, 46% vs. 7.3 years, 22% (Table 2, Figure 3). Accordingly, females have a much greater NWLE than males: 25.3 years, 78% vs. 14 years, 54%. Females spend 45% (14.6 years) of their remaining life expectancy at age 55 with multimorbidity, of which almost 90% of that time is spent not working. In contrast, males spend 35% (9.1 years) of remaining life expectancy with multimorbidity, and about 75% of that time not working.

Socioeconomic differences in working life expectancy

Both low educated males and females have about one year more WLE than high educated individuals and about 4.5 fewer years of NWLE, but relative differences are smaller (Table 2, Figure 4A). Larger differences are observed by place of residence, where rural males and females spend 59% (15.8 years) and 32% (10.3 years) of their life expectancy working, respectively, compared to 43% (11.1 years) and 19% (6.2 years) for urban males and females, respectively (Table 2, Figure 4B). While males with low education have slightly higher WLE than NWLE, the WLE of males from rural residences exceeds their NWLE by 4.8 years.

There are minor differences in WLE with and without multimorbidity when comparing the low and high education groups, with the largest observed difference being 0.6 years for males with multimorbidity (Table 2). Larger differences of over two years are seen in NWLE with no disease. Similar to above, place of residence displays greater disparities, with males and females from rural areas working 1.7 and 1.5 more years with multimorbidity than their urban counterparts, respectively. These findings support our second hypothesis, but we did not expect that the differences by place of residence would be as large as we observed, especially compared to the estimates by education. This highlights that urban/rural differences seem to play a larger role in determining work and health patterns in older age than educational attainment, especially for males.

Sensitivity analysis

The sensitivity analysis excluding hypertension from the definition of multimorbidity resulted in an increase in the number of people with no disease and decreases in the numbers of people with one disease and multimorbidity, as expected. This caused the distribution of life expectancy across disease states to shift, with the most time spent with no disease, followed by one disease, then multimorbidity (Section II, Supplementary Material). However, the trends of WLE and NWLE across the disease states was consistent with the main analysis. Sensitivity analysis separating Seoul from other urban areas showed similar patterns to those observed for urban dwellers, but with slightly more time spent with multimorbidity (Section III, Supplementary Material).

Discussion

Labor force participation beyond retirement age is increasing, particularly in countries undergoing rapid population aging. This makes it especially pertinent to understand the balance between employment and the health capacity to work and to identify who is more likely to work in older age. In this paper, we use a discrete-time multistate modelling approach to estimate WLE at age 55 in Korea and examine how that time is distributed into states of no disease, one disease, and multimorbidity. We also examine inequalities by sex, education, and place of residence. Our findings were in line with our hypotheses: males have higher WLE than females, while females spend more of their WLE with multimorbidity; individuals with low education and from rural areas have higher WLE and spend more of their WLE with multimorbidity compared to individuals with high education and from urban areas, and this pattern was stronger for males compared to females. We also observed that inequalities by place of residence were larger than those by education, highlighting the importance of urban/rural differences on health and working beyond retirement in Korea.

Our finding that males have higher WLE beyond retirement than females concords with many previous studies from Asia, Europe, and the US (Adhikari et al., 2011; Dudel &

Myrskylä, 2017; Tan et al., 2017; Chattopadhyay et al., 2022; Kikkawa & Gaspar, 2022; Dudel et al., 2023), but Leinonen et al. (2018) found that females have longer WLE than males in Finland. On the other hand, our finding that individuals with low education and from rural areas both have higher WLE compared to their high educated and urban counterparts is in line with other Korean studies (J. Cho et al., 2016; J. Cho & Lee, 2014), but contradicts previous findings from the US and Europe which show that the high educated have higher WLE (Dudel et al., 2023; Dudel & Myrskylä, 2017; Solovieva et al., 2024). The rural Korean extension of working life was still gendered, though, as rural males, and to a lesser extent low educated males, spend over half of their life expectancy at age 55 still working, whereas their female counterparts spend closer to 30% of their remaining life expectancy working.

Our findings also identify a low education and rural penalty, where these individuals are subject to combined health-work disadvantages, working for more years despite their poorer health while their high educated and urban counterparts stop working earlier. These patterns may be attributed to a combination of several factors. Older adults with Medical Aid or the NBLSS (i.e., individuals with low socioeconomic status) have higher rates of disease and disability than those who have the regular National Health Insurance or do not have NBLSS (Jeon et al., 2017; A.-Y. Kim et al., 2022). Low-income individuals without NBLSS also have the lowest healthcare utilization compared to other income groups and low-income individuals with NBLSS, but they have the highest health expenditures (Jeon et al., 2017). This suggests that older adults of low socioeconomic status without access to adequate social security might be foregoing healthcare treatment due to the high financial burden. Access to social security may be a greater determinant of continued employment rather than health status (Milligan & Wise, 2015). This could explain the rural penalty we observe because people in rural areas tend to be self-employed and work in agriculture-related jobs which do not usually provide sufficient pensions like those from large companies in urban centers (S.-

H. Lee et al., 2024). Further, people working in rural areas are less subject to mandatory retirement, whereas people working for companies in urban areas are more likely to be forced into early retirement due to company policies, which could explain why we observe higher WLE amongst people from rural areas, regardless of health status (S.-H. Lee et al., 2024).

This paper highlights how intersectional inequalities in age, sex, education, and place of residence contribute to differing work-health life course profiles, and how these are highly context specific. Some of these factors can produce experiences which peak or accumulate over the life course, such as potential increasing age discrimination over time, gender discrimination around childbearing age, the effect of different levels of education on career and income throughout life, and the access to opportunities and resources based on place of residence. The pathways through which these factors operate are best understood within the context of current and past social and cultural norms which have largely shaped how different individuals are viewed within society. Culturally, elders in East Asian countries should be well-respected, however high levels of age discrimination are still observed across various domains. Korea showed the highest level of ageism in terms of economic factors, meaning that older adults in Korea are most likely to have financial difficulties and face discrimination compared to older adults from other OECD countries (J.-H. Kim et al., 2021). However, they had the lowest level of ageism in terms of employment status, largely due to the high rate of older age labor force participation (J.-H. Kim et al., 2021). These observations need to be considered as a cyclical relationship, whereby older adults who do not have sufficient pension savings or other forms of financial support continue to work in older age, but the jobs they are able to hold tend to be temporary and low paying. This is compounded by employers either not hiring or firing older people because of views that older adults are less competent than their younger peers (E. Y. Choi et al., 2021).

In addition to these age discrimination practices, older women face the additional burden of gender discrimination, particularly in the workplace and at home. This view has strong foundations in Korea's historical preference for sons and skewed sex ratio because sons are believed to provide greater economic returns, but also because sons are able to continue the family lineage (E. J. Choi & Hwang, 2020). Although son preference and the skewed sex ratio have declined in recent years (E. J. Choi & Hwang, 2020), the older adults in our study were subject to these gender regimes and the lasting impact of these inequalities. For example, older men are more highly educated than older women and faced fewer employment barriers throughout their life course, thus making up the majority of older age employment categories (i.e., employer, self-employer, non-precarious worker or precarious worker), whereas older women comprise 96% of unpaid family workers (J. Lee & Kim, 2017). These older women, likely because they have had less secure careers over their life course, often end up taking care of grandchildren and doing housework, with one example stating that a mother-in-law quit her part-time job help her family (Brinton & Oh, 2019). If grandmothers provide childcare so that their daughters can continue working, that helps increase female labor force participation. However, if more women are choosing to remain childless, then when they reach retirement age, will they have a higher likelihood to continue working because they will have less familial obligations and face less workplace gender discrimination over their life course? This has important implications for the future of older age workers, especially because females have longer life expectancy and thus should have the capacity to work for more years than males. With the uncharacteristically fast declines in fertility, Korea and other countries in similar demographic situations must shift their focus to support older adults while simultaneously designing social policies which account for how intersectional inequalities will affect different groups of people.

A caveat regarding our methodological choice to equalize initial proportions at age 55 is its effect on the inequalities we observe. The initial proportions we used describe how males and females were distributed across the different states in our model, taking the assumption that there were no differences in education or place of residence before age 55 that would influence the starting proportions. These inequalities are accounted for in our transition probabilities, but this still likely results in an underestimation of inequalities which have accumulated over the life course. However, we are still able to capture inequalities that accumulate after age 55, which represents the portion of the life course that is of most relevance for this paper.

This study has some limitations. First, longitudinal survey data and self-reported measures are prone to recall bias, survival bias, and attrition. Second, our measure of multimorbidity is only based on the nine diseases which were asked about in all survey waves. Thus, we are likely overestimating the number of people with no disease and underestimating the number of people with one disease and multimorbidity. Third, some subgroups had small sample sizes based on our current categorizations, which prevented us from examining additional details, such as more complex multimorbidity, different occupation types, and smaller geographic regions. Fourth, we could not account for additional variables on family circumstances, such as financial transfers from children, due to high amounts of missing data.

Despite these limitations, our findings have important implications for the welfare of older Korean adults, particularly those with low education and living in rural areas, who are working longer and in poorer health than their high educated, urban counterparts. This underscores the importance for countries to provide sufficient support for older adults within the realms of healthcare and social security, but also in terms of reducing inequalities based on age, gender, socioeconomic status, and geography. Our findings also contradict many studies from Western countries, highlighting the need to geographically broaden the evidence base on the relationship between work and health in ageing societies. More evidence from non-Western contexts will contribute to theory development, and the formation of more context-appropriate policy to manage ageing populations.

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Tables

Table 1. Sample characteristics based on individuals' entry wave: males and females, South Korea, 2006–20

	Male (N=3,895)	Female (N=5,096)	Overall (N=8,991)
Age (years)			
Mean (SD)	66.3 (8.48)	67.2 (9.46)	66.9 (9.06)
Median [Min, Max]	64.4 [55.6, 95.6]	65.3 [55.8, 102]	64.9 [55.6, 102]
Employment status			
Not working	1,825 (46.9%)	3,767 (73.9%)	5,592 (62.2%)
Working	2,070 (53.1%)	1,329 (26.1%)	3,399 (37.8%)
Marital status			
Married	3,538 (90.8%)	3,238 (63.5%)	6,776 (75.4%)
Never married	357 (9.2%)	1,858 (36.5%)	2,215 (24.6%)
Education			
Low	1,994 (51.2%)	3,946 (77.4%)	5,940 (66.1%)
High	1,901 (48.8%)	1,150 (22.6%)	3,051 (33.9%)
Residence			
Urban	2,922 (75.0%)	3,808 (74.7%)	6,730 (74.9%)
Rural	973 (25.0%)	1,288 (25.3%)	2,261 (25.1%)
Household size			
Mean (SD)	2.80 (1.21)	2.61 (1.32)	2.69 (1.28)
Median [Min, Max]	2.00 [1.00, 8.00]	2.00 [1.00, 12.0]	2.00 [1.00, 12.0]
Origin state			
No disease, Working	1,557 (40.0%)	897 (17.6%)	2,454 (27.3%)
No disease, Not working	793 (20.4%)	1,728 (33.9%)	2,521 (28.0%)
One disease, Working	404 (10.4%)	254 (5.0%)	658 (7.3%)
One disease, Not working	588 (15.1%)	1,158 (22.7%)	1,746 (19.4%)
Multimorbidity, Working	156 (4.0%)	109 (2.1%)	265 (2.9%)
Multimorbidity, Not working	397 (10.2%)	950 (18.6%)	1,347 (15.0%)

Table 2. Years spent in each state and total working life expectancy, not working life expectancy, and life expectancy at age 55: South Korea, 2006–20

		Years spent in each state (95% confidence interval)						Totals		
		Working, No disease	Working, One disease	Working, Multimorbidity	Not working, No disease	Not working, One disease	Not working, Multimorbidity	WLE	NWLE	LE
	Male	6.6 (6.3-7.0)	3.2 (2.9-3.5)	2.4 (2.1-2.7)	3.5 (3.2-3.8)	3.8 (3.5-4.1)	6.7 (6.2-7.2)	12.2	14.0	26.3 (25.7-26.9)
	Female	3.5 (3.3-3.7)	2.1 (1.9-2.2)	1.7 (1.5-1.9)	5.9 (5.5-6.2)	6.5 (6.1-6.9)	12.9 (12.1-13.7)	7.3	25.3	32.5 (31.7-33.3)
Males	**Education**									
	Low	6.6 (6.2-7.0)	3.3 (3.0-3.7)	2.7 (2.3-3.0)	2.6 (2.3-2.9)	3.3 (2.9-3.6)	6.5 (5.9-7.1)	12.6	12.4	25.0 (24.2-25.8)
	High	6.6 (6.2-7.0)	3.1 (2.8-3.4)	2.1 (1.8-2.5)	4.7 (4.2-5.2)	4.7 (4.2-5.1)	7.4 (6.6-8.2)	11.8	16.8	28.5 (27.6-29.5)
	Residence									
	Rural	7.8 (7.2-8.4)	4.3 (3.8-4.8)	3.7 (3.2-4.3)	2.7 (2.4-3.1)	2.9 (2.5-3.3)	5.6 (5.0-6.3)	15.8	11.2	27.1 (26.1-28.1)
	Urban	6.2 (5.9-6.5)	2.9 (2.6-3.1)	2.0 (1.7-2.2)	3.8 (3.5-4.1)	4.1 (3.8-4.5)	7.1 (6.6-7.6)	11.1	15.0	26.1 (25.4-26.7)
Females	**Education**									
	Low	3.7 (3.4-3.9)	2.2 (2.0-2.4)	1.8 (1.6-2.0)	5.2 (4.8-5.5)	6.3 (5.9-6.7)	12.9 (12.1-13.8)	7.7	24.4	32.1 (31.2-32.9)
	High	3.2 (3.0-3.5)	1.7 (1.5-2.0)	1.4 (1.1-1.7)	7.8 (7.1-8.6)	7.5 (6.7-8.3)	13.8 (12.4-15.1)	6.3	29.1	35.5 (34.2-36.8)
	Residence									
	Rural	4.5 (4.1-4.9)	3.0 (2.6-3.3)	2.8 (2.4-3.2)	5.5 (4.9-6.0)	5.6 (5.1-6.2)	11.3 (10.3-12.4)	10.3	22.4	32.7 (31.7-33.8)
	Urban	3.2 (3.0-3.4)	1.7 (1.5-1.9)	1.3 (1.1-1.4)	6.0 (5.7-6.4)	6.8 (6.4-7.3)	13.5 (12.6-14.3)	6.2	26.3	32.5 (31.6-33.3)

Note: WLE and NWLE are the sum of the years spent in the working and not working states, respectively. WLE and NWLE should sum to equal LE but may be slightly different due to rounding.
WLE: Working life expectancy, NWLE: Not working life expectancy, LE: Life expectancy.

Figures

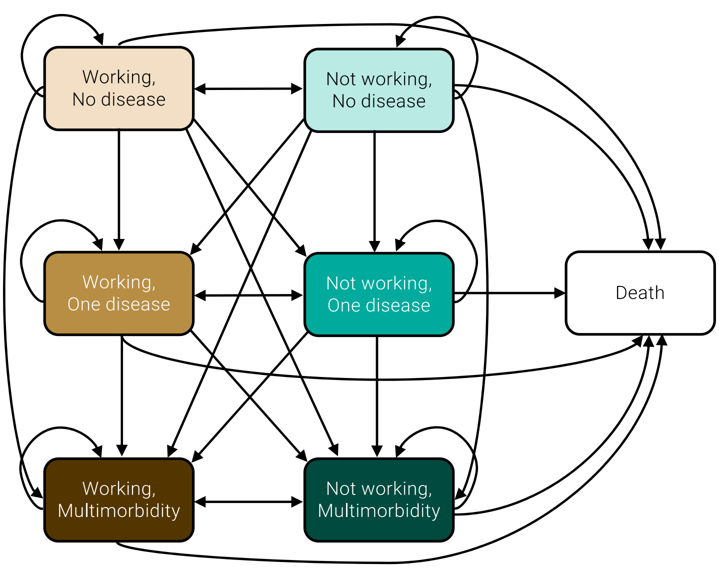

Figure 1. State space of the Markov model

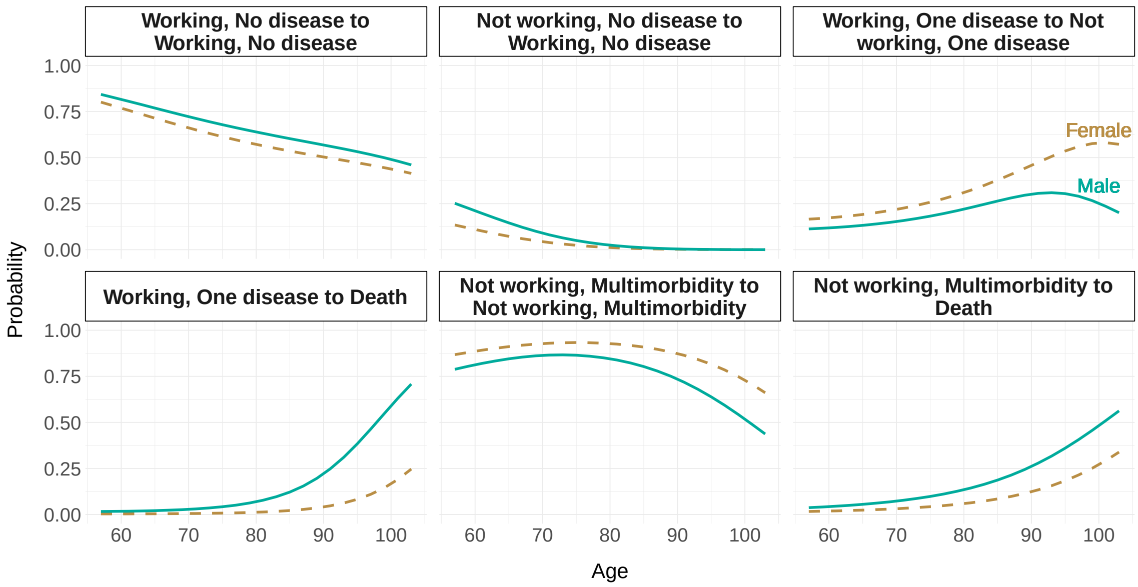

Figure 2. Sample of transition probabilities by age: males and females, South Korea, 2006–20

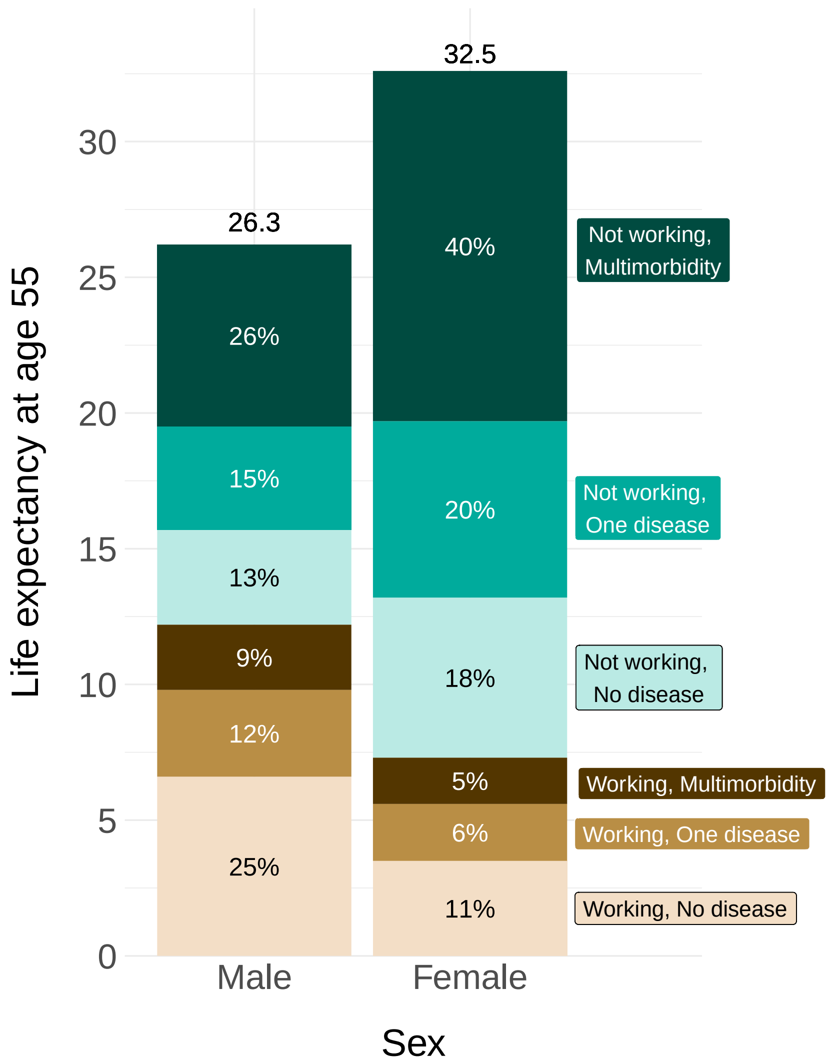

Figure 3. Weighted life expectancy from age 55 split by time spent in each state: males and females, South Korea, 2006–20.
Note: Coloured bars display the percentages of remaining life expectancy in each state; total weighted life expectancy in years is displayed at the top of each bar.

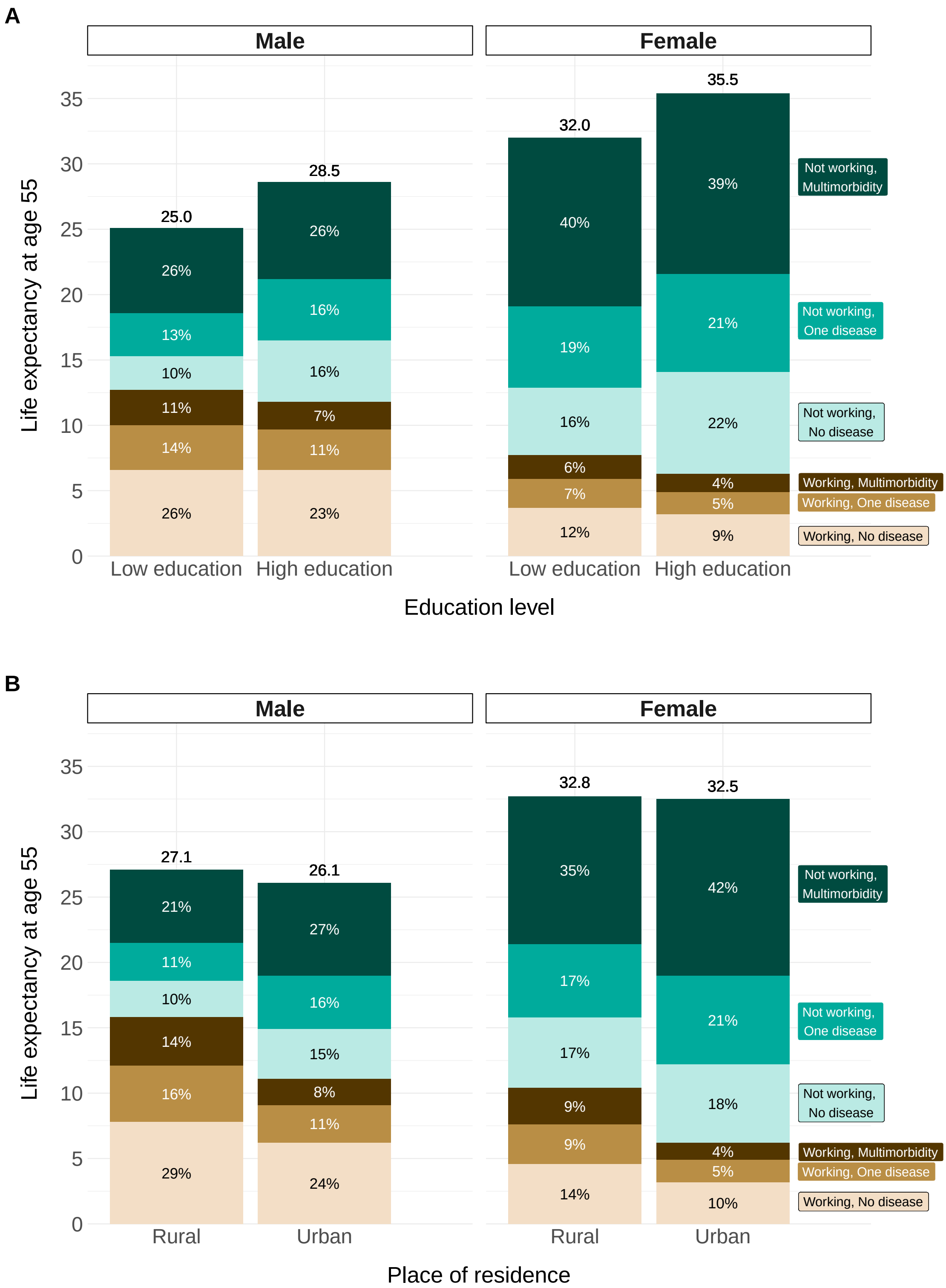

Figure 4. Weighted life expectancy from age 55 split by time spent in each state, by (A) education and (B) place of residence: males and females, South Korea, 2006–20.
Note: Coloured bars display the percentages of remaining life expectancy in each state; total weighted life expectancy in years is displayed at the top of each bar.

Supplementary Material

Working Longer Despite Poorer Health? Inequalities in Working and Health Expectancies at Older Ages in South Korea

Section I. Full expectancy estimates and 95% confidence intervals for transitions from origin to destination states, with weighted averages. Results presented by sex, education, and place of residence. *Note:* None: No disease, One: One disease, MM: Multimorbidity, WLE: Working life expectancy, NWLE: Not working life expectancy, LL: Lower limit, UL: Upper limit

Male

	Origin state																				
Destination state	WLE: None	LL	UL	NWLE: One	LL	UL	WLE: One	LL	UL	NWLE: One	LL	UL	WLE: MM	LL	UL	NWLE: MM	LL	UL	Weighted average	LL	UL
WLE: None	9.6	9.2	10.1	5.4	4.8	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.6	6.3	7.0
NWLE: None	4.1	3.7	4.5	7.6	7.0	8.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	3.2	3.8
WLE: One	2.7	2.5	3.0	2.3	2.0	2.6	8.0	7.2	8.7	4.0	3.3	4.8	0.0	0.0	0.0	0.0	0.0	0.0	3.2	2.9	3.5
NWLE: One	3.8	3.5	4.1	4.2	3.8	4.5	4.2	3.6	4.8	7.6	6.9	8.4	0.0	0.0	0.0	0.0	0.0	0.0	3.8	3.5	4.1
WLE: MM	1.5	1.3	1.7	1.4	1.2	1.5	4.0	3.4	4.6	2.8	2.4	3.2	10.7	9.4	12.0	5.5	4.4	6.7	2.4	2.1	2.7
NWLE: MM	5.3	4.9	5.7	5.5	5.0	6.0	9.1	8.3	9.8	9.5	8.7	10.4	13.5	12.1	14.9	17.3	15.8	18.7	6.7	6.2	7.2
Total	27.0	26.4	27.7	26.3	25.5	27.0	25.3	24.2	26.3	24.0	22.9	25.1	24.3	22.5	26.0	22.8	21.2	24.4	26.3	25.7	26.9

Male, Low education

	Origin state																				
Destination state	None, W	LL	UL	NWLE: One	LL	UL	WLE: One	LL	UL	NWLE: One	LL	UL	WLE: MM	LL	UL	NWLE: MM	LL	UL	Weighted average	LL	UL
WLE: None	9.5	8.9	10.2	5.7	5.0	6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.6	6.2	7.0
NWLE: None	3.0	2.6	3.4	5.9	5.3	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	2.3	2.9
WLE: One	2.9	2.6	3.3	2.6	2.2	3.0	7.7	6.8	8.6	4.1	3.3	4.9	0.0	0.0	0.0	0.0	0.0	0.0	3.3	3.0	3.7
NWLE: One	3.2	2.9	3.6	3.6	3.2	4.0	3.4	2.8	4.0	6.7	5.9	7.5	0.0	0.0	0.0	0.0	0.0	0.0	3.3	2.9	3.6
WLE: MM	1.8	1.5	2.1	1.6	1.4	1.9	4.5	3.7	5.3	3.1	2.6	3.6	10.8	9.3	12.3	5.6	4.3	6.9	2.7	2.3	3.0
NWLE: MM	5.2	4.6	5.7	5.4	4.8	5.9	8.5	7.6	9.4	8.8	7.8	9.7	12.8	11.3	14.4	16.3	14.8	17.9	6.5	5.9	7.1
Total	25.7	24.8	26.5	24.8	23.9	25.7	24.2	22.8	25.5	22.7	21.4	24.1	23.6	21.7	25.6	22.0	20.2	23.8	25.0	24.2	25.8

Male, High education

Destination state	Origin state: None, W	LL	UL	NWLE: One	LL	UL	WLE: One	LL	UL	NWLE: One	LL	UL	WLE: MM	LL	UL	NWLE: MM	LL	UL	Weighted average	LL	UL
WLE: None	9.6	9.1	10.2	5.1	4.5	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.6	6.2	7.0
NWLE: None	5.6	5.0	6.2	9.4	8.6	10.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7	4.2	5.2
WLE: One	2.5	2.2	2.9	2.0	1.7	2.3	8.2	7.3	9.0	4.0	3.2	4.8	0.0	0.0	0.0	0.0	0.0	0.0	3.1	2.8	3.4
NWLE: One	4.6	4.1	5.1	5.0	4.5	5.6	5.2	4.4	6.0	8.7	7.7	9.6	0.0	0.0	0.0	0.0	0.0	0.0	4.7	4.2	5.1
WLE: MM	1.3	1.0	1.5	1.1	0.9	1.3	3.6	2.9	4.2	2.6	2.1	3.0	10.7	9.2	12.2	5.5	4.1	6.8	2.1	1.8	2.5
NWLE: MM	5.8	5.1	6.5	6.0	5.2	6.7	10.1	9.0	11.2	10.8	9.6	12.0	14.8	12.9	16.6	18.7	16.9	20.6	7.4	6.6	8.2
Total	29.4	28.5	30.4	28.7	27.7	29.8	27.1	25.7	28.4	26.0	24.6	27.4	25.4	23.2	27.6	24.2	22.2	26.2	28.5	27.6	29.5

Male, Rural

Destination state	Origin state: None, W	LL	UL	NWLE: One	LL	UL	WLE: One	LL	UL	NWLE: One	LL	UL	WLE: MM	LL	UL	NWLE: MM	LL	UL	Weighted average	LL	UL
WLE: None	11.2	10.3	12.0	7.2	6.3	8.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.8	7.2	8.4
NWLE: None	3.0	2.6	3.5	6.5	5.8	7.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	2.4	3.1
WLE: One	3.8	3.2	4.3	3.2	2.8	3.7	9.5	8.3	10.7	6.1	4.9	7.2	0.0	0.0	0.0	0.0	0.0	0.0	4.3	3.8	4.8
NWLE: One	2.9	2.5	3.3	3.2	2.8	3.6	2.9	2.3	3.6	6.3	5.5	7.2	0.0	0.0	0.0	0.0	0.0	0.0	2.9	2.5	3.3
WLE: MM	2.4	1.9	2.9	2.2	1.8	2.6	6.4	5.2	7.6	4.9	4.1	5.8	14.9	13.0	16.8	9.8	7.7	11.8	3.7	3.2	4.3
NWLE: MM	4.5	3.9	5.1	4.5	3.9	5.1	7.6	6.6	8.6	7.9	6.9	8.9	10.6	8.9	12.3	14.4	12.7	16.2	5.6	5.0	6.3
Total	27.7	26.8	28.7	26.9	25.9	27.9	26.4	24.9	27.9	25.2	23.7	26.6	25.5	22.9	28.2	24.2	22.1	26.3	27.1	26.1	28.1

Male, Urban

Destination state	Origin state: None, W	LL	UL	NWLE: One	LL	UL	WLE: One	LL	UL	NWLE: One	LL	UL	WLE: MM	LL	UL	NWLE: MM	LL	UL	Weighted average	LL	UL
WLE: None	9.1	8.6	9.6	4.8	4.3	5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.2	5.9	6.5
NWLE: None	4.4	4.0	4.9	7.9	7.3	8.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	3.5	4.1
WLE: One	2.4	2.1	2.6	1.9	1.7	2.2	7.6	6.9	8.3	3.5	2.8	4.2	0.0	0.0	0.0	0.0	0.0	0.0	2.9	2.6	3.1
NWLE: One	4.1	3.8	4.4	4.5	4.1	4.9	4.5	3.9	5.2	8.0	7.2	8.8	0.0	0.0	0.0	0.0	0.0	0.0	4.1	3.8	4.5
WLE: MM	1.2	1.0	1.4	1.1	0.9	1.2	3.4	2.8	3.9	2.2	1.9	2.6	9.8	8.6	11.1	4.6	3.6	5.7	2.0	1.7	2.2
NWLE: MM	5.6	5.1	6.1	5.8	5.3	6.4	9.5	8.7	10.3	10.0	9.1	10.9	14.2	12.7	15.6	17.9	16.4	19.4	7.1	6.6	7.6
Total	26.8	26.1	27.5	26.1	25.3	26.8	25.0	23.9	26.1	23.7	22.6	24.9	24.0	22.2	25.7	22.5	20.9	24.1	26.1	25.4	26.7

Female

Destination state	Origin state: None, W	LL	UL	NWLE: One	LL	UL	WLE: One	LL	UL	NWLE: One	LL	UL	WLE: MM	LL	UL	NWLE: MM	LL	UL	Weighted average	LL	UL
WLE: None	7.7	7.3	8.1	2.8	2.5	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	3.3	3.7
NWLE: None	6.1	5.6	6.6	10.3	9.8	10.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9	5.5	6.2
WLE: One	2.1	1.9	2.4	1.4	1.3	1.6	6.6	6.0	7.2	2.6	2.1	3.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	1.9	2.2
NWLE: One	6.4	5.9	6.8	6.9	6.4	7.3	6.5	5.7	7.2	10.2	9.4	10.9	0.0	0.0	0.0	0.0	0.0	0.0	6.5	6.1	6.9
WLE: MM	1.1	0.9	1.3	0.9	0.8	1.0	3.3	2.7	3.8	2.0	1.7	2.2	9.8	8.6	11.0	4.1	3.3	4.9	1.7	1.5	1.9
NWLE: MM	9.9	9.1	10.7	10.2	9.5	11.0	16.4	15.3	17.5	16.8	15.6	17.9	22.0	20.3	23.6	26.8	25.3	28.2	12.9	12.1	13.7
Total	33.3	32.5	34.1	32.6	31.8	33.4	32.7	31.8	33.7	31.4	30.3	32.5	31.7	30.2	33.3	30.8	29.4	32.3	32.5	31.7	33.3

Female, Low education

Destination state	Origin state: None, W	LL	UL	NWLE: One	LL	UL	WLE: One	LL	UL	NWLE: One	LL	UL	WLE: MM	LL	UL	NWLE: MM	LL	UL	Weighted average	LL	UL
WLE: None	7.9	7.4	8.3	3.1	2.8	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7	3.4	3.9
NWLE: None	5.3	4.8	5.8	9.1	8.5	9.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.2	4.8	5.5
WLE: One	2.3	2.1	2.6	1.6	1.4	1.8	6.6	6.0	7.3	2.7	2.2	3.1	0.0	0.0	0.0	0.0	0.0	0.0	2.2	2.0	2.4
NWLE: One	6.2	5.7	6.6	6.7	6.2	7.1	6.0	5.3	6.8	9.7	8.9	10.5	0.0	0.0	0.0	0.0	0.0	0.0	6.3	5.9	6.7
WLE: MM	1.2	1.0	1.4	1.0	0.8	1.1	3.5	2.9	4.1	2.1	1.8	2.4	9.8	8.6	11.1	4.1	3.3	4.9	1.8	1.6	2.0
NWLE: MM	10.0	9.2	10.8	10.5	9.7	11.3	16.3	15.2	17.4	16.5	15.4	17.7	21.8	20.1	23.4	26.5	25.0	28.0	12.9	12.1	13.8
Total	32.9	32.0	33.7	32.0	31.1	32.8	32.5	31.5	33.4	31.0	29.8	32.1	31.6	30.0	33.1	30.6	29.2	32.1	32.1	31.2	32.9

Female, High education

Destination state	Origin state: None, W	LL	UL	NWLE: One	LL	UL	WLE: One	LL	UL	NWLE: One	LL	UL	WLE: MM	LL	UL	NWLE: MM	LL	UL	Weighted average	LL	UL
WLE: None	7.4	6.9	7.9	2.4	2.0	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	3.0	3.5
NWLE: None	8.7	7.7	9.7	13.3	12.2	14.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.8	7.1	8.6
WLE: One	1.7	1.5	2.0	1.0	0.9	1.2	6.5	5.7	7.3	2.3	1.7	2.8	0.0	0.0	0.0	0.0	0.0	0.0	1.7	1.5	2.0
NWLE: One	7.5	6.6	8.3	7.9	7.0	8.8	8.0	6.8	9.2	11.6	10.4	12.9	0.0	0.0	0.0	0.0	0.0	0.0	7.5	6.7	8.3
WLE: MM	0.8	0.6	1.0	0.7	0.5	0.8	2.6	2.0	3.2	1.6	1.2	2.0	9.6	8.0	11.3	3.9	2.7	5.0	1.4	1.1	1.7
NWLE: MM	10.3	9.1	11.6	10.6	9.3	11.9	18.1	16.3	19.9	18.7	16.8	20.5	24.1	21.6	26.6	29.2	26.9	31.6	13.8	12.4	15.1
Total	36.4	35.2	37.6	35.9	34.6	37.1	35.2	33.6	36.7	34.2	32.5	35.9	33.7	31.4	36.0	33.1	30.9	35.3	35.5	34.2	36.8

Female, Rural

Destination state	Origin state: None, W	LL	UL	NWLE: One	LL	UL	WLE: One	LL	UL	NWLE: One	LL	UL	WLE: MM	LL	UL	NWLE: MM	LL	UL	Weighted average	LL	UL
WLE: None	9.3	8.6	10.0	4.2	3.6	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	4.1	4.9
NWLE: None	5.1	4.4	5.8	10.0	9.1	10.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5	4.9	6.0
WLE: One	3.1	2.7	3.6	2.2	1.9	2.5	8.1	7.2	9.1	4.1	3.3	4.9	0.0	0.0	0.0	0.0	0.0	0.0	3.0	2.6	3.3
NWLE: One	5.4	4.9	6.0	5.9	5.3	6.5	5.2	4.3	6.1	9.3	8.3	10.3	0.0	0.0	0.0	0.0	0.0	0.0	5.6	5.1	6.2
WLE: MM	1.8	1.4	2.1	1.5	1.2	1.7	5.2	4.3	6.2	3.5	2.9	4.1	13.4	11.8	15.0	7.3	5.7	8.8	2.8	2.4	3.2
NWLE: MM	8.8	7.8	9.7	8.8	7.9	9.8	14.7	13.3	16.0	14.9	13.5	16.3	18.8	16.9	20.7	24.0	22.0	25.9	11.3	10.3	12.4
Total	33.5	32.5	34.5	32.6	31.6	33.7	33.2	32.0	34.5	31.9	30.5	33.2	32.2	30.1	34.2	31.3	29.5	33.1	32.7	31.7	33.8

Female, Urban

Destination state	Origin state: None, W	LL	UL	NWLE: One	LL	UL	WLE: One	LL	UL	NWLE: One	LL	UL	WLE: MM	LL	UL	NWLE: MM	LL	UL	Weighted average	LL	UL
WLE: None	7.1	6.7	7.5	2.4	2.1	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	3.0	3.4
NWLE: None	6.4	5.9	7.0	10.4	9.8	11.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	5.7	6.4
WLE: One	1.7	1.5	1.9	1.1	1.0	1.3	6.0	5.4	6.6	2.1	1.7	2.5	0.0	0.0	0.0	0.0	0.0	0.0	1.7	1.5	1.9
NWLE: One	6.8	6.3	7.3	7.2	6.7	7.7	7.0	6.2	7.8	10.4	9.6	11.2	0.0	0.0	0.0	0.0	0.0	0.0	6.8	6.4	7.3
WLE: MM	0.8	0.6	0.9	0.6	0.5	0.7	2.4	2.0	2.9	1.4	1.2	1.6	8.4	7.2	9.5	3.1	2.4	3.8	1.3	1.1	1.4
NWLE: MM	10.4	9.6	11.2	10.8	9.9	11.6	17.1	16.0	18.3	17.4	16.2	18.6	23.2	21.5	24.9	27.6	26.1	29.2	13.5	12.6	14.3
Total	33.2	32.4	34.1	32.6	31.7	33.4	32.5	31.5	33.6	31.3	30.2	32.5	31.6	30.0	33.1	30.7	29.2	32.2	32.5	31.6	33.3

Section II. Sensitivity analysis excluding hypertension from multimorbidity definition

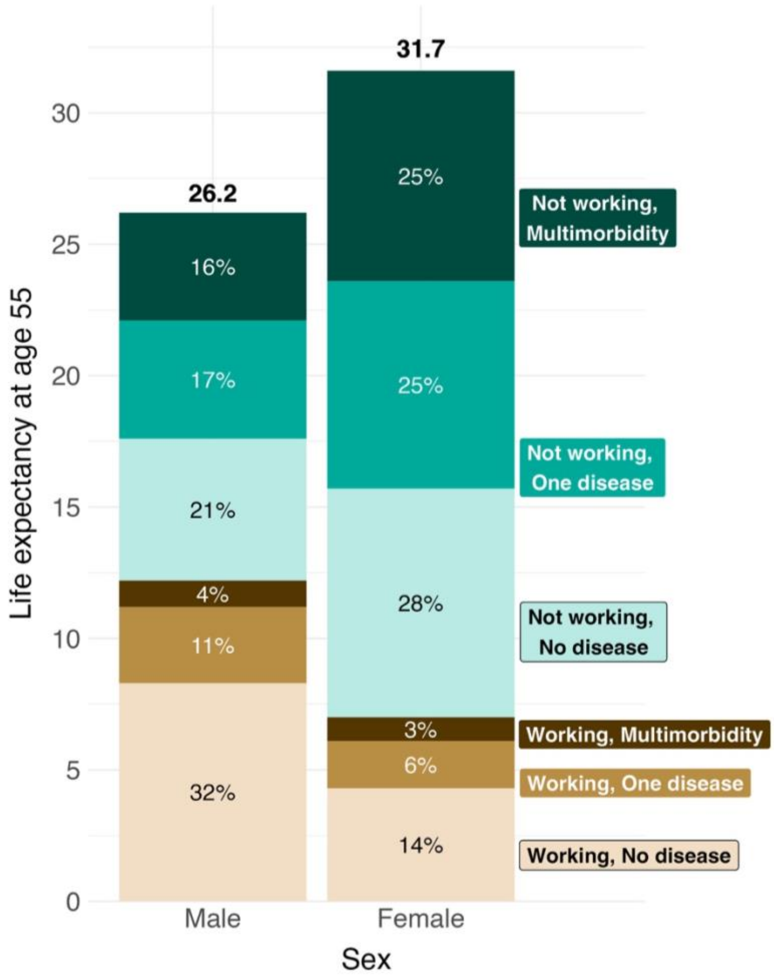

Figure S1. Weighted life expectancy from age 55 split by time spent in each state: males and females, South Korea, 2006–20.

Note: Coloured bars display the percentages of remaining life expectancy in each state; total weighted life expectancy in years is displayed at the top of each bar.

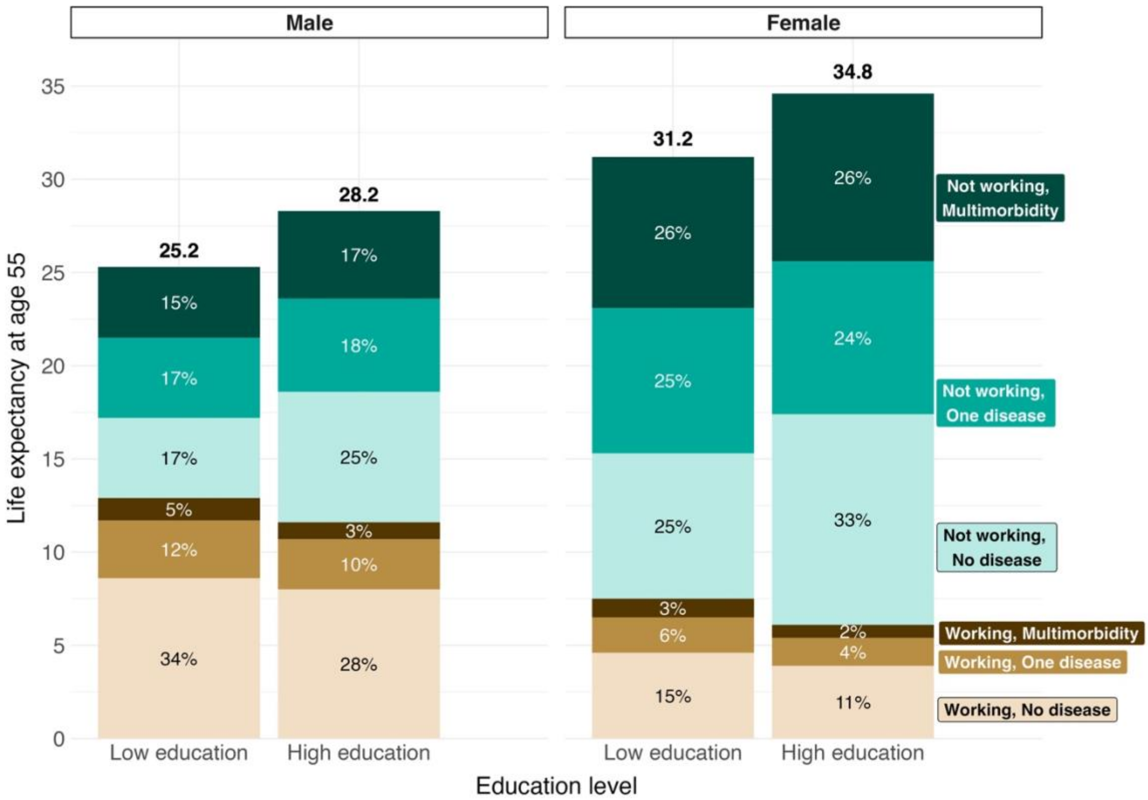

Figure S2. Weighted life expectancy from age 55 split by time spent in each state, by education: males and females, South Korea, 2006–20.

Note: Coloured bars display the percentages of remaining life expectancy in each state; total weighted life expectancy in years is displayed at the top of each bar.

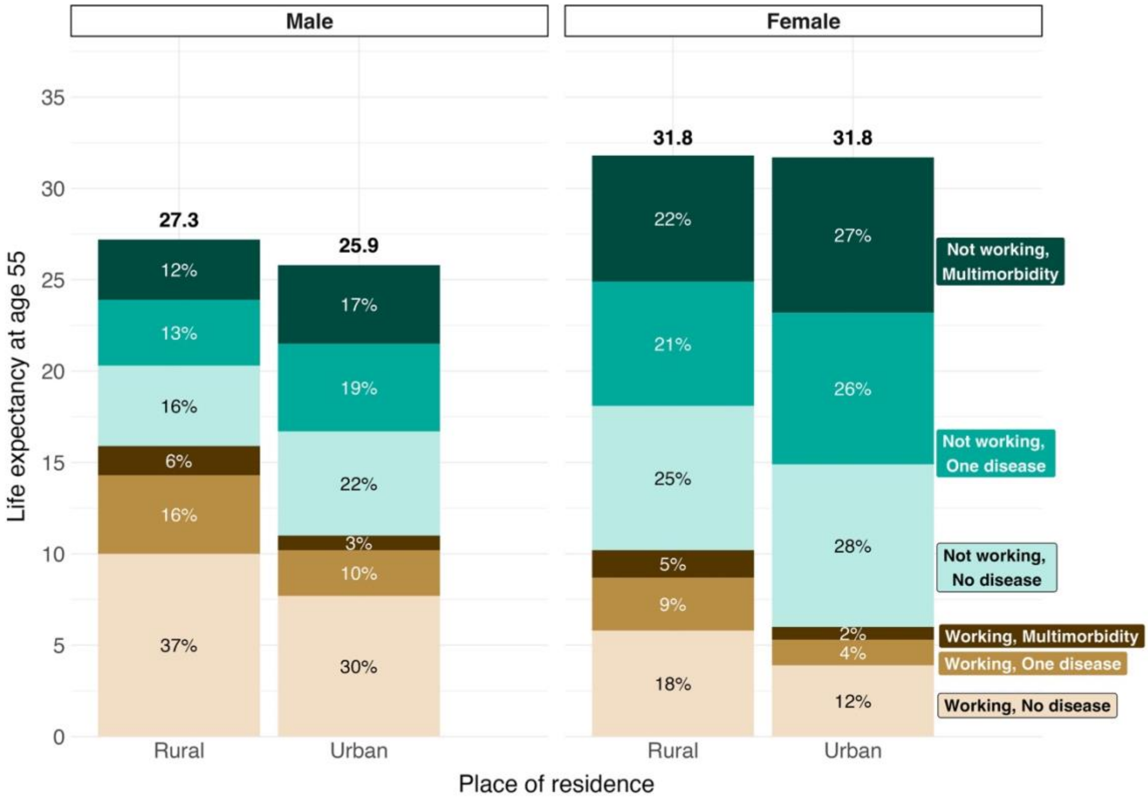

Figure S3. Weighted life expectancy from age 55 split by time spent in each state, by place of residence: males and females, South Korea, 2006–20.

Note: Coloured bars display the percentages of remaining life expectancy in each state; total weighted life expectancy in years is displayed at the top of each bar.

Section III. Sensitivity analysis separating Seoul out from other urban areas

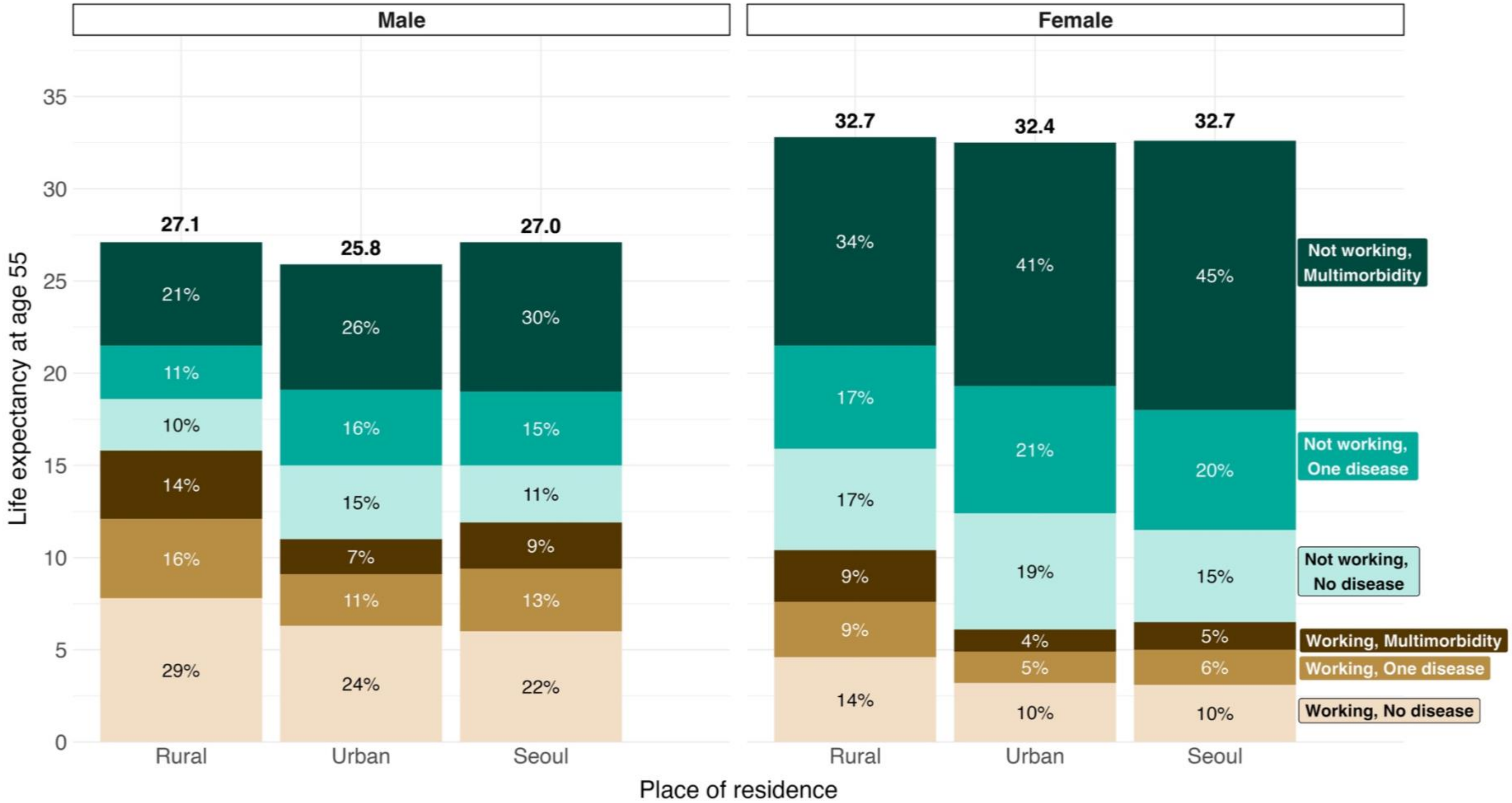

Figure S4. Weighted life expectancy from age 55 split by time spent in each state, by place of residence: males and females, South Korea, 2006–20.

Note: Coloured bars display the percentages of remaining life expectancy in each state; total weighted life expectancy in years is displayed at the top of each bar.