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Chapter 10

GENERAL DISCUSSION
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In this thesis, we studied the compression and plasticity of old-age mortality during the epidemiologic transition. We focussed on the Netherlands, Japan and Ghana, three countries that have all experienced a different epidemiologic transition. The Netherlands has experienced a classical epidemiologic transition, in which all stages were sequential. Japan is the best known example of an accelerated classic epidemiologic transition, which only took about fifty years. Ghana is currently experiencing a protracted epidemiologic transition, in which the different stages overlap. There are several conclusions we can draw from our studies on old-age mortality trends in these epidemiologic transitions.

MAIN FINDINGS

The first two chapters describe mortality patterns in rural Ghana followed up for a period of nine years. In Chapter two we examined the role of socioeconomic status and water source on mortality and fertility decline during the epidemiologic transition. We found that both mortality and fertility declined, accompanied by a shift in the causes of death, which changed from primarily infectious causes to non-infectious. However, both the decline in mortality and fertility were found to be similar in the poor and rich groups as well as in the groups which have access to (un)safe water source. Hence there must be other determinants that drive the epidemiologic transition in this rural area in Ghana. These findings are in line with the current theories on determinants that drive the protracted transition in rural African countries. Some have shown that public health interventions, such as immunization or maternal and child health programs are the main drivers behind the protracted epidemiologic transition.

In the following chapter three we studied the seasonal variation in mortality in rural Ghana. We found that mortality due to infectious diseases occurred mainly in September during the wet season, while mortality due to non-infectious causes occurred mostly in April during the dry season. This indicates that during the epidemiologic transition mortality not only shifts from child to old-age mortality, and from infectious to non-infectious causes of death, but that the distribution of deaths over the seasons probably changes as well. This is important for future public health interventions in rural Africa.

Next to changes in seasonal variation in mortality during the epidemiologic transition, we studied the process of the compression of mortality during the epidemiologic transition in Japan and the Netherlands in chapter 4. Our observations show a continuing shift of
mortality to higher ages, together with a compression of the age-at-death distribution that appears to have reached a limit, in both Japan and the Netherlands. The observed limit to the compression of mortality is in line with the current theory on ageing, as a stochastic accumulation of damage over time. Due to the stochastic element in the ageing process, there will always be variation in the rate of ageing and hence, the limit to the compression of mortality has to be above zero. Accordingly, we have observed that the limit of mortality compression is reached at an age-band of 12 years in which fifty percent of the annual mortality occurs. This indicates that differences in lifespan within a homogeneous population can never become less than the age-band when mortality compression has reached a limit. Ultimately this limit is determined by the random variation in the pace of ageing.

In addition to the compression of mortality, we examined the compression of morbidity in chapter five. Now that life expectancy is continuously on the rise, it is questioned whether the extra years are lived in good or in ill health. Analysis of the trajectories in healthy life expectancy revealed that during the epidemiologic transition, there has been an expansion of morbidity in the Netherlands. Hence, individuals live with chronic diseases for more years, which could reflect both early diagnosis and changed lifestyles. By contrast, we observed a compression of disability in both women and men, as life expectancy without disabilities increased parallel to the increase in life expectancy. Overall, by screening for chronic diseases and proper treatment of for instance hypertension, we postpone or even prevent disability, including in this case cardiovascular disease, and increase life expectancy. We did observe sex differences in life expectancy which persisted up to old age. At the highest ages however, men and women can expect a similar number of years of healthy life expectancy. At the end of life there remains a period of disability that can be postponed, but not further compressed. Hence, the need for care will be remain to be concentrated at the end of life. In chapter six we discuss the societal implications of this and argue that it is time for people to realise that they can foresee a healthier and longer life and that they have to plan their life course accordingly.

In Chapter seven we study the plasticity of mortality at old age in a natural experiment in Japan. In general, studying factors that impact directly on old-age mortality is challenging. In most countries, improvements in the environment and living conditions that have occurred during the epidemiologic transition, has changed relatively smoothly over time. The case of Japan is exceptional because of the relatively adverse living conditions for the general population during the first half of the 20th century, after which an accelerated transition resulted in rapid improvements after 1950. Studying different birth cohorts in
Japan, that were exposed to different extents to the rapid improvements, we have shown that environmental improvements in late life can reduce old-age mortality independent of exposures in early life. This result indicates that mortality remains highly plastic up to old age. Modern preventive strategies however, are mostly focused on the young. Our observations from Japan strengthen the notion that preventive measures later in life can also have great potential benefit.

In chapter eight, we have studied whether or not high intensity physical exercise has a health benefit over low intensity exercise in a cohort of former Olympic athletes. Here we show that athletes from disciplines with high intensive exercise have a similar mortality risk when compared to athletes from disciplines with low intensity exercise. Rowing for instance, has no added benefit to reduce mortality risk when compared to playing golf. However, one should have a moment of caution before engaging in disciplines with risk of bodily collision and or physical contact, since athletes from such disciplines suffered an increased mortality risk, which persisted up to old age.

Finally, in chapter nine, we studied the life expectancy of historical artists compared to the elite in the Low Countries. These data revealed that although artists belonged to the middle socioeconomic class, they had a similar life expectancy when compared to the elite of that time. We hypothesize several mechanisms through which artistic creativity could influence life expectancy. However, these hypotheses should be formally tested before any definite conclusions on effects of the arts on life expectancy can be drawn.

Overall, when countries shift from a pre- to a post-transitional stage, mortality decreases and an increasing number of people live up to old age. In addition, mortality is compressed to a narrower age interval in which most of the annual deaths occur. This compression of mortality reaches a limit as soon as countries enter the post-transitional era. Furthermore, during the last stage of the epidemiologic transition, with the appearance of ‘diseases of affluence’, we have observed an expansion of morbidity and more years are lived with chronic diseases. By contrast however, life expectancy without disability is increasing parallel to the increase in life expectancy indicating a compression of disability. Due to earlier diagnosis more years are lived with chronic diseases, but this allows for early treatment that in the end postpones or even prevents disability. In general, mortality remains highly plastic up to old age, as indicated by the continuous rise of life expectancy and the shift of the age-at-death distribution towards higher ages.
**General discussion**

**Strengths and weaknesses**

Studies on the plasticity and compression of old-age mortality have been primarily demographic and descriptive in nature, presenting time trends only.[1-6] In this thesis we not only studied time trends, but also linked mortality changes to life expectancy. Additionally, we have studied the trends in old-age mortality in the theoretical framework of the biology of ageing and we have tried to get further insight in the underlying mechanisms of both the plasticity and compression of mortality.

There are also limitations of the studies in this thesis. In general, causal relationships between determinants and outcomes are best studied using an experimental study design with a specific intervention.[7] We have tried to get a better understanding of specific determinants and the underlying process of mortality changes, based on experiments of nature. Hence, it is hard to draw any definite conclusion about causal relationships between the various determinants of old-age mortality. Experiments from nature do allow us to test some pseudo-interventions that are not possible in normal experiments. Another limitation is that we have studied the mortality patterns in three countries only. However, the Netherlands, Japan and Ghana are unique cases, providing an example of different epidemiologic transitions.

**IMPLICATIONS FOR SOCIETY**

The plasticity of mortality as we have observed during the epidemiologic transition has resulted in a rising number of people that have the privilege to live up to old age while maintaining good health. However, this trend can only continue when we adapt our society to accommodate our growing elderly population. This comes with several societal challenges in terms changes in formal and informal care, health care costs and pension policies. Some of the implications will be discussed below.

**Dependency ratio**

The epidemiologic transition has led to both low fertility and low mortality, which has resulted in ageing populations, especially in today's western societies.[8-10] The age composition in these populations has changed from predominantly young individuals towards an age composition in which the proportion of children, adults and elderly is almost equal.[10,11] This is one of the most common starting points for policy makers and is often measured as the dependency ratio [12-16]. This ratio is an age-based indicator for the burden on the productive labour population and is given as the ratio of non-productive per productive individual. Based on the observations in our studies,
however, we have several remarks concerning the dependency ratio as a measure for policy makers. First, while the old-age dependency ratio is increasing, one should not overlook that the total dependency ratio is influenced by the youth dependency ratio as well. The latter ratio (0-19 years divided by 20-64 years) has decreased during the last 50 years and will further decline in the future. The old-age dependency ratio (65+ divided by 20-64 years) has increased and is expected to do so in the coming decades. The total dependency ratio however, has not increased, and has in fact slightly decreased.[10,11] A second reason dependency ratios are inaccurate is because it categorizes all people aged 65 years or older as dependent. As it is an indicator based solely on chronological age, it overlooks that not all individuals above age 65 are dependent. Especially as we have shown that with the shift of mortality to higher ages, life expectancy in good health and without disabilities also increases. Policy makers should take this into account when using the total dependency ratio as a starting point for future policies of formal and informal care, health care costs and pension systems.

**Health care costs**

The average level of long-term care expenditure has been shown to rise with age [13]. It is questionable however, whether an ageing population is the major driver of the ever increasing health care expenditure. For example, it has been shown that health care costs are concentrated in the last years of life.[17,18] This is in line with our findings of a fixed period of disability at the end of life that cannot be further compressed. This implies that irrespective of how old one gets, the disability burden and the highest health care costs will be in the last year of life. In addition, the demand for health care will be postponed to higher ages. All in all, although higher ages are known to be associated with higher long-term care expenditure, it is not the main explanation for the rise in health care costs. Alternatively, there has been an expansion in the use of medical technology during the last decades. These technical innovations have fostered the rise in health care expenditure and hence have played a major role in the overall increase of health care costs.[19,20]

**Pension policies**

We have shown that human lifespan is continuously on the rise. This plasticity not only results in longer lives for individuals, but also for more people reaching old age. This has several consequences for many countries that offer their older citizens financial security through pension systems. In a social pension system, financial resources are redistributed from the working population to the retired population.[10] In other words, as the old-age dependency ratio increases, a smaller working population is responsible for a relatively larger retired population. This will become a major burden for pension
systems. Although life expectancy and healthy life expectancy are still increasing, many countries still have a relatively early withdrawal from the labour market, at an average age below 60.[11-13] Increasing pension age not only helps to reduce the burden for pension systems, but it also results in a larger labour force.[13] Most countries however, are hesitant to take the necessary measures in order to achieve this.[14] It is now time to act and make sustainable policies that meet the needs from ageing societies.

**IMPLICATIONS FOR MEDICINE**

Next to the societal implications of the plasticity of old-age mortality, there are also some specific implications for medicine. Below we will briefly discuss the implications in terms of ‘evidence-based medicine’, ‘evidence-based prevention’, health care structure and medical education.

*Evidence-based medicine*

Now that in most countries more and more people reach old age, we should rethink ‘evidence-based medicine’. Currently the evidence is still based on studies in middle aged adults, with a single disease. This is problematic in two ways. First, most elderly have multiple diseases at the same time, which brings new challenges.[24] There are little to no randomized clinical trials including elderly with multimorbidity.[25] Second, ageing comes with some physiological changes that change the pharmacokinetics and pharmacodynamics.[26] Consequently, known effective treatments at middle age might lead to different health outcomes at old age. Hence, future research should focus on clinical trials with elderly having multimorbidity in order to get evidence-based medicine for this group and address the current needs of our society. Although our studies indicated a continuous rise in life expectancy and healthy life expectancy, this can only continue to increase if we adapt our medicine to fit the new older patient population. It is important to mention here that the primary aim should be to improve quality of life and that only as a result life expectancy will increase.

*Evidence-based prevention*

We have observed that mortality remains highly plastic up to old age. This indicates that in addition to life-course approaches to improving health and well-being, preventive measures at older ages can deliver great benefits. Apart from physical exercise, evidence for effective preventive measures is poor, especially when it comes to prevention at old age.[27] Since most age-related diseases are highly determined by life-style, development of ‘evidence-based prevention’ for elderly should be primary objective for ageing societies.
The observed plasticity of ageing should be encouraging to study specific preventive measures. This urgently needs to be placed on the research agenda[27].

Health care structure
With the increase in life expectancy, there has been an expansion of chronic diseases, which increases the need for long-term care. In addition, there has been an increase in the prevalence of multimorbidity, which is becoming the norm rather than the exception. Nowadays, health care structure is insufficient and not adapted to the current older patient population. Current health care is mainly focussed on acute problems and short-term solutions. Chronic diseases demand for long-term care with active involvement of patients themselves. In the current system, patients with multiple chronic diseases do not receive optimal care. It has been shown that enhancing self-management of chronically ill patients not only leads to patients being in control of their own health, but it also improves health care outcomes.[28] In addition, formal care should shift towards a multidisciplinary approach, where different specialists work together as a team. Multimorbidty requires a patient-centred approach with a multidisciplinary team that provides holistic care. Overall, we have to rearrange our health care structure in a way that patients become actively involved as being their own health manager and formal care is patient-centred with a holistic approach.

Medical Education
Due to the plasticity of mortality, the proportion of elderly patients has increased rapidly during the last decades. Since this trend is expected to continue, future medical doctors should be prepared for a patient population containing predominately elderly. However, medical education on the treatment of elderly patients is currently unsatisfactory.[29] Both medical students and current medical specialists are trained to treat patients with single diseases and hence, are not prepared for the largest group of their patient population. In order to improve medical care for the elderly, it is essential that all health care professionals receive a basic training about the complex care for elderly in terms of multimorbidity, as well as in how to deal with the physiological changes that come with age.

Final conclusion
Overall, our studies show the plasticity of old-age mortality. There is no indication that we have reached the limits of this plasticity, which is an encouraging finding. Hence, we can be optimistic about the future, but we also have to adapt to the new reality that people live longer and more years are lived in good health.
REFERENCE LIST


