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**THE DYNAMICS AND THE ORDER OF
FUNCTIONAL LOSS AMONG
NONAGENARIANS**
A four-year follow-up study

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ABSTRACT

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More people worldwide are living into the age of 85 and greater, often referred to as the oldest old. Disability is known to be prevalent in the oldest old. However, the substantial growth of this very old population has not been accompanied with exhaustive follow-up on their functioning status. This study aims to examine changes in the ability to perform daily living (ADL) and mobility activities, as well as the order of functional loss among the 90+ individuals.

The data come from two mailed-surveys of the Vitality 90+ Study conducted in 2014 (n= 1637, response rate 80%) and 2018 (n= 1878, response rate 77%). Subjects included in this study have participated in both survey years (n = 499). The study includes two ADLs (bed transferring and dressing) and three mobility activities (moving indoors, walking 400 meters, and using stairs). Changes in the ability to perform ADL and mobility activities between 2014 and 2018 are assessed in three outcomes: disability score, number of disabilities, and degree of severity in individual activities. The association between age, gender, level of education with each of the three outcomes are examined using multinomial logistic regression. The hierarchy of functional loss is established by ranking the activities from the highest to the lowest proportion of deterioration during the study period.

In terms of disability score, functioning declines in the 90+ population between 2014 and 2018. As to the number of disabilities, the nonagenarians are divided into two majorities, consisting of those who do not change and those who increase. From 2014 to 2018, the degree of severity increases for walking 400 meters and using stairs while for other activities, it stays the same as in 2014. Older age and being women are statistically significantly associated with poorer functioning in all disability outcomes. In descending order, the largest proportion of deterioration in functioning is found in using stairs, walking 400 meters, moving indoors, dressing, and bed transferring.

In conclusion, disability increases over time, and the increase is higher among people with older age and women. However, some stabilities and improvements also exist, suggesting a heterogeneity in functioning in the 90+ population. The order of functional loss found in younger populations seems to remain applicable to the current very old population. This provides an opportunity to establish public health interventions and plan suitable services.

Keywords: The oldest old, functional ability, disparity in disability

The originality of this thesis has been checked using the Turnitin OriginalityCheck service.

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ABBREVIATIONS

WHO	World Health Organization
ICF	International Classification of Functioning, Disability and Health
ADL	Activities of daily living
IADL	Instrumental activities of daily living
RRR	Relative risk ratios
CI	Confidence intervals

1. INTRODUCTION

Reaching the eight decade of life has become possible for older adults in many countries, particularly in Finland (United Nations, 2019). However, living beyond the age of 80 can be challenging as the risk of disability is higher in this age group (Berlau, Corrada, & Kawas, 2009). Disability has been defined as a progressive loss of function that causes an individual to surrender their once gained or expected social role (Nagi, 1976). Such functional loss is believed to run in a systematic order, also familiarly described as the hierarchy of functional loss. Studies have noted that functional decline is more likely to occur first in activities that require advanced neurological and physical abilities, such as using whole-body balance and lower limb muscles, and is more likely to emerge last in those that demand the least skills to perform, such as using only upper limb muscles (Ferrucci et al., 1998).

Functioning is a dynamic process (Verbrugge & Jette, 1994), suggesting that it can fluctuate over time, yet it is commonly found to worsen with age, even after the age of 85 (Guay, Dubois, Corrada, Lapointe-Garant, & Kawas, 2014). It has also been well acknowledged that there are gender and educational differences in functioning (Kingston et al., 2014; Kingston et al., 2015). In general, women are known to have higher risk of developing disabilities than men because they are more likely to contract diseases that are more disabling and seldom fatal. Men, however, are more prone to diseases that have high mortality rates (Crimmins, Shim, Zhang, & Kim, 2019). Likewise, individuals with higher education are more likely to have fewer disabilities in late-life compared to their peers with lower education (Strozza et al., 2020). Many health-deteriorating behaviors established over the course of a person's life can be attributed to lower educational attainment. Thus, such life-long exposures to risk factors may aggravate functional loss processes in old age (Kollia et al., 2018).

Measures of disability have been considered as an excellent marker of health status in older adults, especially because they can convey future health and social consequences (Anton et al., 2015; Ferrucci, Giallauria, & Guralnik, 2008). Restrictions in social participation due to disability are known to cause loneliness and deprived quality of life (Haider et al., 2016). As disability grows to a more critical stage, one is more likely to depend on informal care (Sjölund, Wimo, Engström, & von Strauss, 2015), and in

Finland, the providers of such care usually originate from a spouse, an adult child or other family member (Juntunen et al., 2018). Furthermore, loss of independence has been shown to predict long-term care utilization in many reports, including Finnish studies (Nosraty, Pulkki, Raitanen, Enroth, & Jylhä, 2019; Salminen et al., 2017), hence it can put pressure on the health care system. These explanations suggest that the impacts of disability are present at personal, social and national level, which is why disability assessment in late-life and timely detection of disability are crucial.

However, longitudinal data on functioning as well as the hierarchical pattern of functional loss of the very old population have been studied less extensively. At present, knowledge of changes in disability and its hierarchy is mostly obtained from younger older adults (Koster et al., 2006; Spalter, Brodsky, & Shnoor, 2014; Wloch, Kuh, & Cooper, 2016). In addition, previous studies have mainly used aggregate measures of disability while specific activities have received less attention (Finlayson & Havens, 2001). The former technique can obscure valuable information on the order with which individual activity deteriorates (Gore, Kingston, Johnson, Kirkwood, & Jagger, 2018). This sort of information offers an opportunity to establish appropriate interventions, by anticipating one's subsequent functional declines, and care plans, by determining one's stage of disability.

The purpose of this study is to examine changes in the ability to perform daily living and mobility activities among the 90-year-old individuals, as well as to explore the order of their functional loss. It is also the purpose of this study to examine whether changes in disability differ between women and men and between education groups.

2. THE OLDEST OLD POPULATION AND THE CURRENT UNDERSTANDING OF THEIR DISABILITY LEVEL

2.1 The rise of the oldest old population

While it is unquestionable that more and more people are entering the age of 65, the older people themselves are experiencing an aging phenomenon of their own. It was recently found that among the older adult population, there has been a rapid growth in the age category of 85 years and beyond, also known as the oldest old (Jylhä, 2020). Between 2000 and 2020, the world's proportion of the 65+ people has increased by 1.4 folds whereas the corresponding figure for the 85+ people has nearly doubled (United Nations, 2019). In absolute term, this means that the 85+ population in the world has risen from approximately 30 million persons to over 60 million persons. Therefore, globally, the oldest old is the fastest growing population (United Nations, 2011).

The more developed countries, located mostly in the northern hemisphere, have been leading the rise in the number of people aged 85+ (United Nations, 2011). Compared to other continents, Europe holds the largest share of the world's oldest old population. Around 2.5% of people over the age of 85 in the world currently reside in Europe, which is a 1% increase from what it was in 2000 (United Nations, 2019). During this period, the percentage increase of the 85+ population was also the greatest in Europe than in any other regions. Furthermore, the massive growth of the 85+-year-olds in Europe can be reflected in one of the Nordic countries as well, such as Finland. In Finland, the population aged 90+ has grown 2.5 times bigger during the last two decades and similarly, in the city of Tampere, where this study takes place, the respective figure has almost tripled (Statistics Finland, 2021a; Statistics Finland, 2021b). It is projected that the coming decades will witness an escalation in the number of oldest old people.

The statistics mentioned above has given rise to a number of questions pertaining the oldest old's level of health and functional ability, and what its implications will be for the society (Christensen, Doblhammer, Rau, & Vaupel, 2009). Advanced age has been associated with higher incidence and prevalence of disability (Berlau et al., 2009; Berlau, Corrada, Peltz, & Kawas, 2012). Older adults with disability are more likely to have poor quality of life, be dependent on family members or caregivers, growing needs for long-

term care or other assisted-living services, and higher comorbidity and mortality rates (Checci et al., 2020; Tiainen, Luukkaala, Hervonen, & Jylhä, 2013). Bearing in mind of the upward trend in the number of people in the older ages and their strong likelihood of acquiring disability, it is therefore necessary to better understand the dynamic nature of disability in the oldest old population. The discussions in the following sections will concentrate on the manifestation of disability as well as its occurrence among the very old individuals.

2.2 The pathways to disability

Nagi's Disablement Model

Saad Nagi is among the first researchers to explain disability and its related concepts. According to Nagi (1976), disability means “inability or limitations in performing social roles and activities such as in relation to work, family, or to independent living”. He perceives disability as a gap between a person’s capabilities and the demands created by the social and physical environments. A conceptual framework is made to distinguish disability from three other interrelated concepts: active pathology, impairment, and functional limitation, and hereby it is referred to as *Nagi's Disablement Model*. *Pathology* refers to detected or undetected disturbances (diseases) which occur at the cellular level due to infection, injury, or other reasons. The word *active* characterizes the cells’ action to respond to the source of the disease so that the cells would return to their balance (healthy) state. *Impairment* is commonly recognized as the phase following the cells’ incapability to combat the stressors. At this point, the damages caused by the disease usually have extended to the tissue, organ, and body system level, and generally appear as the symptoms of the disease. A person’s physical, emotional, and mental functions can be further restricted due to the consequences of pathology and/or impairment. These functions represent one’s basic skills to complete a task or an action in their life. Should these functions become limited it can cause disturbances at a whole person level, which is regarded as a *functional limitation*. After being functionally limited, a person may or may not advance to a certain degree of disability depending on their expected roles and regular activities in the society.

Nagi's Disablement Model can be illustrated as the following: a basketball player is diagnosed with Parkinson's disease, which emerges when nerve cells fail to regenerate sufficiently or die (pathology). As a result, rigidity, tremor, and a range of motions loss occur over time (impairment). Because of the impairments in many parts of the body, he or she becomes unable to walk, jump, and run (functional limitation). In the end, he or she can no longer play basketball at all (disability). On the other hand, when a chess player suffers from the same pathology, impairment, and functional limitation, he or she can still play since the game does not require the use of lower body strengths (without disability but functionally limited). Even if eventually his or her fingers will not be able to move freely due to the impairments, he or she can continue to play by announcing the move that he or she wants to make, then his or her opponent could make the move for him or her. This is because the game mostly demands cognitive rather than physical skills.

The Disablement Process

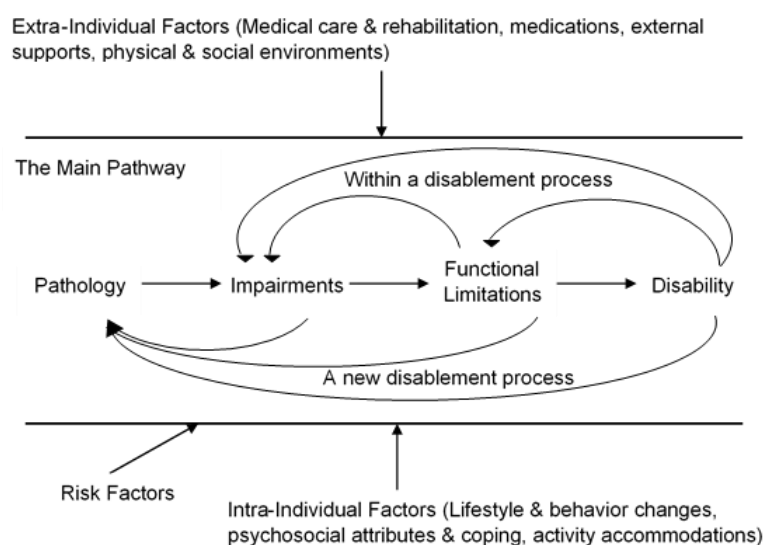


Figure 1. The Disablement Process adapted from Verbrugge & Jette (1994)

The Disablement Process is introduced as an elaboration of Nagi's basic model (Figure 1) (Jette & Keysor, 2003). It contains the same concepts (pathology, impairment, functional limitation, and disability) as the Disablement Model, however, disability here is emphasized more on the presence of difficulty in completing activities in any domain of life. The term *disablement* is described as the "impacts that chronic and acute conditions have on the functioning of specific body systems and on people's abilities to

act in necessary, usual, expected and personally desired ways in their society”. *Process*, the subsequent word, is included in the title as it indicates the dynamics of disablement, that is, the trajectories of disability and the varying factors that can determine its direction, pace and patterns of change over time. According to Verbrugge and Jette, the process of disability development is similar to a spiral. As shown in Figure 1, disability in one aspect of life may lead to two feedback effects-one that can cause a deterioration within the components of the disablement process (for example, from disability to impairment, or disability to limitation), the other that can begin a new form of pathology and eventually, disability (Verbrugge & Jette, 1994).

In addition, this model provides a more extended distinction between the activities that are categorized as functional limitation and those that are considered as disability. Here, functional limitation refers to restrictions in basic mental, emotional, and physical actions in one’s daily life without any reference to a situation or context. Moreover, Wolinsky et al. (2005), in agreement with Verbrugge and Jette, states that “functional limitation involves difficulty in musculoskeletal performance”. The example of physical actions is overall mobility, hand gripping, whole body balance, walking, lifting objects, climbing stairs, etc. On the other hand, disability covers a broad domain of activities with a situational or social feature, from hygiene to hobbies, from errands to sleep, such as dressing, getting in and out of bed, bathing, eating, managing finance, doing laundry, using the telephone, and grocery shopping. These are the activities that a person does as a member of society regardless of where they take place, both public and private, and they are based on a certain basic mental and physical function (Verbrugge & Jette, 1994). To demonstrate further, a man suffers from rheumatoid arthritis (pathology) with a sign of swelling of the hands (impairment). Because of the swelling, he cannot fully bend his fingers and grasp objects (functional limitation). Now, it takes him more than several minutes to get dressed (disability).

Furthermore, Verbrugge and Jette also bring in several enhancements into Nagi’s straightforward scheme. The new elements that are incorporated in the Disablement Process include: risk factors, interventions, and exacerbators. Risk factors are any modifiable and nonmodifiable characteristics of an individual which exist before or at the onset of the disablement process that can induce the presence and severity of impairment,

functional limitation and disability. The second element, interventions, is built by the person with disability and by others which serve to reduce restrictions or difficulties. It comprises of medical care and rehabilitation, medications and other therapeutic procedures, external supports (personal assistance and devices), modifications of the physical or social environment. They are a changeable factor that is implanted during the disablement process in order to avoid, retard or reverse outcomes. Finally, exacerbators are factors that have negative impacts on functioning and can speed up the process of disability. It may be caused by the side of effects of the intervention, adopting risky behaviors or attitudes that can put their functioning in even more danger, or unsupportive treatments from the society (Verbrugge & Jette, 1994).

Model of Functioning and Disability

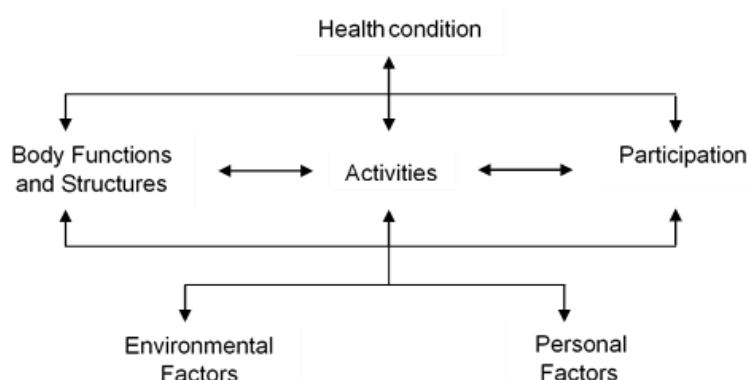


Figure 2. Model of Functioning and Disability

A model of functioning and disability (Figure 2), *International Classification of Functioning, Disability and Health* (ICF), has been created by the World Health Organization (WHO) (World Health Organization, 2001). Within the ICF, the terms *functioning* and *disability* do not represent specific elements in the model but instead are used as umbrella terms in the same manner that the term *disablement* is applied within the Nagi's model. There are three levels of human functioning according to the ICF: functioning at the level of body or body parts (body functions and structures), the whole person (activities), and the whole person in their complete environment (participation). Similarly, disability can occur at corresponding level, that is, impairment, an activity limitation, and a participation restriction. Here, the term *functioning* is used to express nonproblematic or neutral aspects of health and health-related states whereas *disability* is

used to indicate problems. Each term in the ICF can be made equivalent to that in Nagi's model, the term *health condition* here refers to diseases, disorders, injuries and traumas, which is similar to Nagi's formulation of active pathology. Likewise, the terms *body functions and structures*, *activities*, and *participation* are parallel to Nagi's classification of impairment, functional limitation, and disability, respectively (Jette, 2009).

Functioning and disability in the ICF are no longer considered as the outcome of diseases, rather as an integral part of health. Thus, the model is not depicted as a spiral, rather a diagram. An individual's functioning at any level (body functions and structures, activities, and participation) is an interaction or complex relationship between the health condition and contextual factors (environmental and personal factors). There is a bidirectional interaction within the levels of functioning, as well as between the levels of functioning and health conditions, and contextual factors. Given the dynamic relationship between the entities, interventions in one entity have the potential to modify one or more of the other entities. Moreover, the model recognizes that in experiencing health, functioning and disability can occur independently or at the same time (World Health Organization, 2001). For example, even though there is a well-established association between impairments (diseases and chronic conditions) and activity limitations, a person diagnosed with type two diabetes does not necessarily immediately lose his or her ability to execute basic physical or mental actions. Likewise, a person may have difficulties in doing physical actions, such as lifting heavy items and walking long distances, without knowing that he or she has hypertension because the condition has not been checked yet, for instance.

2.3 Concepts of the study

Mobility

Ferrucci et al. (2016) has argued that "Mobility is the most studied and most relevant physical ability affecting quality of life". Mobility concerns an individual's ability to move freely and safely, and it involves movement in all of its forms (Satarino et al., 2012). The everyday life tasks are basically built upon the mobility skills, for example, "moving by changing body position or location or by transferring from one place to another, by carrying, moving or manipulating objects, by walking, running or climbing, and by using

various forms of transportation” (World Health Organization, 2001). Thus, mobility is a prerequisite physical skill for accessing commodities, making use of public facilities, and participation in meaningful social, cultural, and physical activities (Rantanen, 2013).

Existing studies have been interested in different types of mobility activity. Mobility ability in the InCHIANTI study was assessed in walking 4 meters at usual and fast speed and walking 400 meters as fast as possible (Ferrucci et al., 2016). In the Survey on Assets and Health Dynamics among the Oldest Old (AHEAD), mobility was defined as the ability to climb up and down one flight of stairs, walk several blocks, push and or pull heavy objects, and lift or carry 10 pounds or over (Wolinsky et al., 2011). The Longitudinal Study of the Living Conditions of the Oldest Old (SWEOLD) had two questions on mobility, which were walking 100 meters and/or walking up and down stairs (Fors & Thorslund, 2015). In the work of Bleijenberg et al. (2017), a single item of mobility, that is walking, was used to represent overall mobility skills. In this study, mobility activities refer to walking 400 meters, using stairs and moving around indoors. It is also worth to note that combining mobility measures with other measures of functioning, such as the self-care or independent living tasks, are usual in one disability assessment (Andrews, 2012).

Activities of daily living (ADL)

To examine basic self-care tasks, also known as the activities of daily living (ADL) or Basic ADL (BADL) or Physical ADL (PADL) or higher-order function, many researchers have created their own index. Sidney Katz is one of the pioneers to develop a screening instrument for this type of functioning (Katz, Sidney, Downs, Cash, & Grotz, 1970). Since the launch of Katz Index, the measure has been used not only for studying disability among older adults but also among adult populations in a variety of clinical, policy and research contexts (Palmer & Harley, 2012). Katz et al. (1963) posited a list of six ADLs to measure the patient’s degree of independence in bathing, dressing, toileting, transferring (moving in or out of chair or bed), continence, and feeding. The index can be operated by means of, for example, interviews and observations, during which the person in charge of the evaluation determines the level of ADL functioning of the subject.

The original index, the six-item Katz, has been modified into different versions over the past decades (Liebzeit, King, & Bratzke, 2018). For instance, a five-item as well as a seven-item ADL indexes have been established (Cohen-Mansfield et al., 2013; Sjölund et al., 2015). The former version might include all items from the original index except continence whereas the latter version, all six activities and an additional activity related to walking. Moreover, several studies have examined self-care with fewer ADLs as well, such as in that of Burns et al. (2019), who assessed two activities (dressing and bathing), and in that of Hardy & Gill (2004), who examined four activities (bathing, dressing, walking, and transferring). Regardless of the variations in the number of ADLs, it is generally accepted that the more ADLs with which a person has difficulty the more severe his or her disability (Guralnik, Fried, & Salive, 1996). Self-care activities in the current study will involve dressing and bed transferring.

Furthermore, it is known that difficulty is among the most common response scales to rate individual ADLs (Jette, 1994; Palmer & Harley, 2012). Questions using difficulty scale concern a subject's level of difficulty in performing any given ADL. To answer this question, several response categories can be offered, for example, a four-response category might have the subsequent options: no difficulty, some difficulty, a lot of difficulty, and cannot do. The Vitality 90+ Study, where the data of this study came from, has been using difficulty scale to assess disability as well. According to Jette (1994), in terms of estimating the prevalence of disability among older adults, difficulty scale performs better than the assistance scale.

Self-reported measure of functioning

The present study will use self-reported information on ADL and mobility. Self-report is the most common method to collect data on measures of functioning from large populations. An important feature of this self-administered instrument lies in its ability to reflect one's confidence in their own physical capacity that is hard to detect by objective assessment (Bravell, Zarit, & Johansson, 2011). It is also known to subjectively evaluate one's functional ability in their immediate surroundings, therefore containing immediate relevance to people's lives (Rantanen, 2013). Other advantages of self-reported functioning include cost efficient, time economy and requires no special space or equipment (Wang, Hu, Chen, & Li, 2012). Although its subjective nature is not without

limitations (Nielsen et al., 2016), many investigations have shown that self-reported ADL and mobility correlate with performance-based measures of function (Bravell et al., 2011; Portegijs, Rantakokko, Viljanen, Sipilä, & Rantanen, 2016). In general, the clinometric properties of self-reported mobility are considered to be good by Andrews et al. (2012) and Mänty et al. (2007) whereas according to Wang et al. (2012), they are moderate. The five-item Katz is shown to be of, on average, good reliability, validity and responsiveness (Hopman-Rock, van Hirtum, de Vreede, & Freiburger, 2019). Furthermore, Fried et al. (2001) found in their study that self-reported instruments have a physiologic basis, thus providing criterion validity.

Hierarchical functioning loss

Earlier research shows that decline in physical functions unfolds in an organized manner (Dunlop, Hughes, & Manheim, 1997; Ferrucci et al., 1998; Kingston et al., 2012; Wloch et al., 2016; Yeh et al., 2012). It has been suggested that the activities that require the exercise of whole-body balance, eye-hand coordination, agility, as well as lower body muscles are likely to be the first to deteriorate. These physical skills are often represented in mobility tasks and in the instrumental activities of daily living (IADL). Conversely, the ability to perform activities that demand a profound control of the upper limb muscles and joints can decline far along in the disablement process. These physical requirements are usually the foundations of ADL. Although the pattern of functional loss between studies may differ, such as the one found in Katz et al. (1970), the main idea persists, that is when functional ability is lost gradually from one physical function to another, the eventually result can be complete disability.

Because the loss of functional ability in various domains of activity does not emerge all at once, individuals may struggle in executing certain types of activities while maintaining a very low to moderate level of difficulty in the other activities at any given time (Ferrucci et al., 1998). This condition has enabled the identification of an individual's position in the disablement process (Hennessy et al., 2015; Stineman et al., 2012). As previously described, disability in mobility tasks and IADL often occurs prior to that of ADL. It has been considered that having more problems with the overall motor functions and complex domestic activities signify an early stage of disability, whereas those with self-care activities denote a more severe, advanced stage (Forjaz, Ayala, &

Abellán, 2015; Guralnik et al., 1996; Mänty et al., 2007). Thus, it is necessary to detect people who are not fully disabled yet, but are at high risk for future functional decline (Mänty et al., 2007). Early identification and prompt treatment of high-risk individuals may delay or even reverse the disablement process, allowing them to have the possibility of sustaining their functional independence longer.

2.4 Disability among the oldest old

Prevalence of disability

Previous investigations, primarily in developed countries, have reported that the prevalence of disability among the oldest old tends to be high. Findings from the U.S. 90+ Study showed that difficulty in five to six ADLs was established in 51% of the participants while the corresponding number for dependency was 28% (Berlau et al., 2009). In the Canadian Community Health Survey (CCHS), the proportion of ADL disability in at least one activity was most prominent in people over the aged of 95, reaching as high as 46.9% (Guay et al., 2014). Likewise, 57% men and 70% women aged 90 and beyond responded ‘need help’ in executing daily living activities in the 2016 Australian Census (Gibson & Goss, 2020). The similarly high rates of disability are found in the European oldest old as well. A study on Italian nonagenarians, Mugello Study, reported that a great majority of the subjects (85.1%) displayed disability in at least one instrumental (IADL) or daily living activities (ADL) (Checci et al., 2020). The Leiden 85+ Study from the Netherlands noted that 58% of the 90-year-old participants had ADL disability (van Houwelingen et al., 2014). Furthermore, in the Finnish Vitality 90+ Study, survey year 2018, mobility dependency was seen in 36.7% of men and 58% of women whilst the respective figures for ADL dependency were 17.3% and 23.3% (Enroth, Raitanen, Halonen, Tiainen, & Jylhä, 2020).

Changes in disability

Functioning is dynamic by nature (Verbrugge & Jette, 1994). Thus, people can move between the different states of the disablement process, from healthy to disability and vice versa (Manini, 2011). This suggests that the direction of change of functional ability is not limited to deteriorations, a reverse trend, that is improvements and maintenances, can

be detected as well (Spalter et al., 2014). Older adults who have been disabled can restore their independence though such occurrence is known to be scarce in many studies (Holstein, Due, Almind, & Avlund, 2007; Tang et al., 2016; van Houwelingen et al., 2014; Vochteloo et al., 2013; Wolinsky et al., 2011). Alternatively, in some cases, the level of independence does not change over time. Studies with a variety of follow-up time have supported this notion, such as those performed by Vaughan et al. (2016), Formiga et al. (2010) and Femia et al. (1997).

Functional loss hierarchy

Available research on the order of functional loss are scarce and have mostly involved participants from younger age categories. In the study of Yeh et al. (2012), home-dwelling adults aged 50+ with no initial disability were followed up for approximately 11 years. Eight activities representing balance, endurance, and mobility skills were included in the study, such as running, carrying heavy weight, climbing up 2–3 floors, walking 200–300 m, and grasping with the fingers. The median ages of incident disability were ranked to identify the most frequent ordering of disability among the eight assessed activities. Their results suggest that with age, the activities that are the hardest to perform are more likely to decline first, for example, disability in running occurred at median age 69 and carrying heavy weight at median age 73, while those that are the easiest are more likely to deteriorate last, for instance, grasping with the fingers at median age > 76.

Likewise, in the work of Wloch et al. (2016), a British birth cohort was investigated at ages 43, 53 and 60-64. They noticed that people who reported difficulty in at least one task at the top of the hierarchy at age 43 (i.e. gripping, walking 400 meters, and/or climbing stairs) were more likely to report difficulty in at least one task at the bottom of the hierarchy at age 60-64 (i.e. feeding, washing and/or toileting). This finding suggests that disability in ADL possibly lies ahead for those who already have disability in mobility tasks and/or IADL. Furthermore, walking 400 meters and taking stairs were among the activities that were selected to assess the long-term change. The results showed that at each age, the prevalence of reported difficulty increased for both activities. However, between age 43 and 60-64, the prevalence increase was greater for taking stairs than it was for walking, indicating that the ability to climb stairs tends to decline sooner than the ability to walk. Bendayan and colleagues (2017), too, have reported that there

was a variation in the rate of decline in individual activities among the English and U.S. subjects aged 50 and more. After roughly eight years, they found that any of the six ADLs declined at a slower pace than the mobility tasks. Among the ADLs, the slowest decline was seen in eating, and among the mobility tasks, the fastest decline was in climbing several flights of stairs. The hierarchy was constructed by ranking the mean rates of decline of each activity.

While most studies have created the hierarchy by examining disability in separate activities, Ferrucci et al. (1998) had a different approach. They randomly selected a panel of 10 health professionals to group together a number of activities with similar underlying physical impairments into several domains of disability. There were 15 activities comprised of ADL, IADL and mobility that needed to be grouped into the domain. For example, walking 400 meters and bathing demand the same physical skills, such as lower extremity strength, therefore they were placed together. After an extensive discussion, the experts proposed four domains of disability which were defined as: 1) a combination of manual dexterity and balance in unstable position, 2) balance and lower extremity strength, 3) good indoor mobility, gait, and upper extremities, and 4) upper extremities in a seated position. They also postulated that disability in domain 1 preceded that in domain 2, which preceded that in domain 3 and so on. Therefore, the order of functional loss was predetermined by the professionals. Ferrucci and colleagues then measured seven 60+ populations across five European countries for their performance in the physical skills mentioned in the hypothesized domains of disability. The results indicate that the proportion of persons classified in each domain is similar in all country, except in Italy, with the majority of the participants being in a state of healthy (no disability in all assessed physical skills) and a great proportion of them having difficulty in domain 1. The fact that the hierarchic domains of disability were replicated in four of the five countries suggest that the domains are a valid model to determine the stages of the disablement process.

Although the method used by Ferrucci et al. (1998) differs from that of Yeh et al. (2012), Wloch et al. (2016) and Bendayan et al. (2017), all these findings convey a similar message, that is the ability to complete activities with a more challenging physical skills is likely to disappear first, and is likely to continue to deteriorate in those with a moderate and low degree of physical challenges.

Nevertheless, the order of functional loss in the very old population has remained unexplored. The Newcastle 85+ Study is among the few studies who have investigated it (Kingston et al., 2012). They revealed that cutting toe nails, shopping, using stairs and walking 400 yards were among the first activities with which participants had difficulty, suggesting that they are located at the top of the hierarchy (lost first). Conversely, the activities with which the participants reported the least difficulty were bed transferring, washing face and hand, and feeding, indicating that they belong to the bottom of the hierarchy (lost last). Furthermore, they found that certain activities tended to be clustered together in terms of difficulty. Four clusters of area of difficulty were obtained, resembling Ferrucci and colleagues' four domains of disability, only this time the number of activities was 17, including ADL, IADL and mobility.

Based on the limited, existing literature, it can be inferred that the order of functional loss among the oldest old population seems to be the same as in the younger population, despite the higher prevalence of disability in the older group. In this study, the hierarchy of functional loss will refer to the activities in which the participants have deteriorated the most.

3. FACTORS ASSOCIATED WITH CHANGES IN DISABILITY AMONG THE OLDEST OLD

There are multiple risk factors for disability in older populations (Ferrucci et al., 2008). If the condition of the risk factors changes, a person's status of functioning can also change, which is why functioning is a dynamic process. It has been studied that age, gender and educational level are among the most well-known predictors of disability progression (Jacobs et al., 2012; Kingston et al., 2014; Kingston et al., 2015).

3.1 Age

Age is the greatest predictor of functional disability. It is well established from a variety of studies that disability increases with age, and that the occurrence extends to the age of 90 years or more (Berlau et al., 2012; Ferrer et al., 2008). Guay et al. (2014) reported in their study that the association between age and the prevalence of disability in performing self-care activities is exponential rather than linear. Indeed, people in the 95+ age group have nearly a three-fold ADL disability in comparison to the 85–89 age group. Furthermore, Gu & Zeng (2004) have stated that increasing age raises the chance of transitioning from healthy to disabled status, and reduces the chance that the disabled individuals will return to healthy status. Therefore, age profoundly influences the dynamics of disability. Previous research have illustrated the increases in disability with age using various disability outcomes, namely disability score, number of disability activities and occasionally, specific disability activities (Cohen-Mansfield et al., 2013; Finlayson & Havens, 2001; Sjölund et al., 2015).

Although the process of the disability development may vary between individuals, at the population level, health decline with age is marked by general losses of physiological functions such as declining muscle mass and muscle strength (Crimmins, E. M., 2004; Ferrucci et al., 2008). These two physical skills, which are required to perform many activities of life, reach their peak typically in the third decade of life and gradually decline onwards (Ferrucci et al., 2016). Such changes contribute to increased vulnerability to diseases, both physical and mental, which in turn may cause further loss of physical functioning and disability (Crimmins, E. M., 2004). For instance, decreased physical

activity due to weakening leg muscles may escalate the risk for osteoarthritis, a disease that is known to have a disabling effect.

3.2 Gender

It is clear that men and women are distinct with regards to their functioning. Research articles have shown that the incidence of disability is greater among women than men, which may account for women's increased prevalence of disability (Auais et al., 2019; Jacobs et al., 2012). Women have higher disability in midlife and the gender differences have been shown to continue until the oldest age groups (Gu & Xu, 2007; Sjölund et al., 2015; Wloch et al., 2016). Additionally, many studies have also suggested that the differences in functioning between genders seem to become more prominent with advancing age since the gap widens beyond the age of 80+, 85+ and 90+ (Berlau et al., 2009; Lybecker Scheel-Hincke et al., 2020; Oksuzyan et al., 2010). In general, women are known to have higher risk of progressing from healthy to disability and lower likelihood of maintaining the same level of functional ability over time than men (Harris, Kovar, Suzman, Kleinman, & Feldman, 1989; Kingston et al., 2014; van Houwelingen et al., 2014).

Several reasons have been proposed to explain the gender differences in functioning. Biological, social and behavioral risks are among the most frequently suggested explanations (Oksuzyan, Juel, Vaupel, & Christensen, 2008). In terms of biology, many sex hormones, such as estrogen and androgen, are known to stimulate the development of muscle mass and strength, which is fundamental for physical function (Horstman, Dillon, Urban, & Sheffield-Moore, 2012). However, during menopause, women exhibit an accelerated decline in muscle mass and strength due to rapid loss of estrogen, while the pace of sex hormone loss for andropause men is more gradual (Horstman et al., 2012; Klein & Flanagan, 2016). Therefore, as described by Jones et al. (2021), men have greater reserve in physical strength which protects them from functional decline with age. Other biological risks such as immune system response and genetic can also play a role in determining men and women's functional ability. Many genes on the X chromosome regulate immune function and have an important part in modulating gender differences in the progression of immune-related diseases (Klein & Flanagan, 2016). Since women have double (XX) the amount of X chromosome than men (XY), they are more

susceptible to autoimmune diseases, such as rheumatoid arthritis, multiple sclerosis, and type 1 diabetes, all of which has a detrimental impact on physical function (Klein & Flanagan, 2016; Oksuzyan et al., 2008). On the contrary, men's Y chromosome increases their vulnerability to infectious and cancer diseases which are known to be less disabling, yet are higher in mortality rates (Crimmins et al., 2019; Klein & Flanagan, 2016).

Furthermore, gender differences in functioning can partly be attributed to social roles and expectations. Traditionally, women had more responsibilities in taking care of the health of the family, therefore, it was culturally more acceptable for them to be sick, use health care services and report more health problems (Oksuzyan et al., 2008). These practices can be reflected in the Finnish population as well. A population-based study involving Finns aged 18-65 years old have shown that women appeared to be more engaged and attentive in seeking health information than men (Ek, 2015). It is likely that these habits persist until much older ages (65+) since the oldest age group (51–65 years) in his study had the greatest tendency to be care about health information. This kind of gender bias in social responsibilities has a potential to contribute in the earlier detection and higher reporting of disability among women than men. Besides biological and social factors, there is also behavioral risk. It has been widely recognized that smoking cigarette, drinking alcohol, using psychoactive substances, and consuming sugar-sweetened beverages as well as high protein food are more prevalent among men than women (Carmel, 2019; Vari et al., 2016). These habits are not only closely linked to higher risk of contracting heart disease and lung cancer in men, but also higher risk of mortality and lower risk of disability among them.

3.3 Level of education

In addition to age and gender, educational disparities in functional ability are also a well-documented finding in all ages, including in very old age (Enroth, Raitanen, Hervonen, & Jylhä, 2013; Stringhini et al., 2018). Education plays a significant role in determining the level of functional ability in later life as well as its progression over time (Fors & Thorslund, 2015; Harris et al., 1989; Kingston et al., 2015; Spalter et al., 2014). A number of studies conducted among adults with a variety of age groups (50+, 70-79, 90+) has shown that individuals with higher education tend to have better functioning than those with lower education, and that those with higher education may have greater likelihood

to reverse the decline in functioning than those with lower education (Enroth et al., 2016; Enroth et al., 2019; Gregory et al., 2011; Kollia et al., 2018).

There are several proposed mechanisms that may explain educational differences in functioning. First, education is one indicator of socioeconomic positions, which is usually completed in young adulthood and is likely to determine future employment and earning (Galobardes et al., 2006). Consequently, higher job and income opportunities could mean better access to, and utilization of health care services (Solé-Auró & Alcañiz, 2016). Second, people with higher education generally have greater incentives or motivations, a more effective mean and a more supportive social group to adopt healthy lifestyles such as physical activity, healthy diet, and smoking cessation (Pampel, Krueger, & Denney, 2010). In addition to that, education has been reported to be among the strongest predictors of health literacy in older adults (Cutilli, Simko, Colbert, & Bennett, 2018). As Galobardes et al. (2006) and Kawachi et al. (2014) state, the knowledge and skills gained through education may increase a person's emotional or cognitive ability to make health-promoting decisions throughout life. Owing to these factors, individuals whose educational attainment are high are more likely to have smaller rates of diseases and/or develop less severity of diseases compared to those whose educational attainment are low, including diseases that are detrimental to functional ability (Kiadaliri, Petersson, & Englund, 2019). Third, it has been suggested that higher level of education increases one's chance of having well-educated spouse and friends, through which one's long-term health is likely to improve as well (Kawachi et al., 2014). Furthermore, Montez et al. (2019) have proposed that the causal relationship between education and health can be explained by health selection and indirect selection. In the former, healthy individuals are more likely to obtain higher education, and in the latter, the effect of education on health is confounded by certain traits, such as IQ and personality, which lead to both better health and higher education.

Because of the interlinkages between education, occupation and income, and health, it is possible that people with fewer years of education can have fewer resources to compensate or forestall the loss of function during old age (Gregory et al., 2011). Therefore, when disability is clinically present, they are more likely to continue to deteriorate in their functioning rather than to improve or maintain an adequate level of

functioning. The accumulation of life-time exposures to risk factors associated with low education is expected to aggravate the functional loss processes in old age, thus, creating disparities in functioning between older adults with higher and lower education in a population level (Kollia et al., 2018; O'Rand, 2002).

4. SUMMARY OF THE STATE OF ART

A considerable amount of literature has been published on disability and functioning among older adults. These studies have contributed to the findings of the dynamics and the hierarchy of functional loss. However, current knowledge of the hierarchy of functional loss is mostly based on studies which are carried out in younger age groups (40-85) (Ferrucci et al., 1998; Katz, Sidney et al., 1970; Kingston et al., 2012; Wloch et al., 2016; Yeh et al., 2012). The impressive growth of persons aged 90 years and older has not been accompanied with extensive data on the order of functional loss of this population (Checci et al., 2020). In addition to that, there are relatively few studies that concentrate on the long-term progression of disability of the nonagenarians (Bravell, Berg, & Malmberg, 2007; Odden et al., 2019). When such longitudinal or follow-up studies do become available, not all of them address disability changes in individual activities (Finlayson & Havens, 2001). Although practical for identifying whether a person has passed a threshold, aggregate measures of disability cannot reveal the order with which specific activity loss appears (Gore et al., 2018). Thus, a great number of questions remains unanswered on how functional decline unfolds and changes over time for nonagenarians in the population.

The absence of longitudinal data on functioning as well as the order of functional loss of the 90+ population may lead to misidentification and misestimation of their needs. From the public health perspective, understanding these two aspects (the pace and the order of decline in functioning) will create a possibility for planning the need for care services and introducing disability prevention measures. These efforts can influence the quality of life of nonagenarians and expose their need for a more comprehensive health care and social services in the long run.

5. AIMS

The general aim of this study was to examine changes in the ability to perform daily living (ADL) and mobility activities among individuals aged 90 and over, as well as to explore the order of their functional loss. The specific objectives were as stated below.

1. To examine changes in the disability score from 2014 to 2018.
2. To examine changes in the number of disabilities from 2014 to 2018.
3. To examine changes in the ability to perform individual activities of daily living and mobility activities from 2014 to 2018.
4. To examine the associations between age, gender, and level of education with changes in disability from 2014 to 2018.

6. MATERIALS AND METHODS

6.1 The Vitality 90+ Study

This study utilized data from the Vitality 90+ Study. The Vitality 90+ is an ongoing population-based study of older adults aged 90 and above in Tampere, the third largest city of Finland, collecting various types of health and wellbeing information. Data in the Vitality 90+ Study are gathered by mailed surveys for the whole target population, and the other types of data, which comprised of face-to-face interviews, blood and performance tests, and qualitative life story interviews, have been collected for subsamples. The first round of the Vitality 90+ survey was conducted in 1995, and the subsequent rounds in 1996, 1998, 2001, 2003, 2007, 2010, 2014, and 2018. Mailed surveys were sent to the 90 years and older people living in the community in the study years 1996 and 1998. From 2001 onwards, mailed surveys were sent to all individuals in the city of Tampere aged 90+ regardless of their health status and place of residence, including those living in institutions (nursing homes or hospitals). Names, addresses, and personal identity codes, as well as the date of birth were obtained from the Tampere City Population Register. National register data on health and social care use and mortality have been linked with the survey data.

The same questions were asked in every study round. If a person did not return the questionnaire, a reminder was sent within a month after the initial mailing. If the respondents were not able to fill out the questionnaire by themselves, somebody else could help while the respondent himself or herself picked the answer. If the respondents were unable to answer, a caregiver or a family member was instructed to answer the questions as a proxy respondent. When studying people aged 90 and older it is important to involve proxies so that information on all participants can be collected (Berlau et al., 2009), especially those with memory disorders, poor health, etc.

This study used data from years 2014 and 2018. The baseline came from the 2014 survey and the follow-up was conducted among the subjects who continued to participate in 2018. This study year is chosen because it is the most recent and the largest survey carried out in the past decade. There were 2056 people who were born in 1924 or earlier (e.g. 1923, 1922, etc.) and resided in Tampere in 2014. Out of those who participated in 2014

(N=1637), 60.8% died before the next data collection on 23 March 2018 (N=996). The mortality follow-up ended in the given date because it was the day when the questionnaires were sent. Among the people who were alive after this date, 22.2% of them did not have complete data in both study years (N=142).

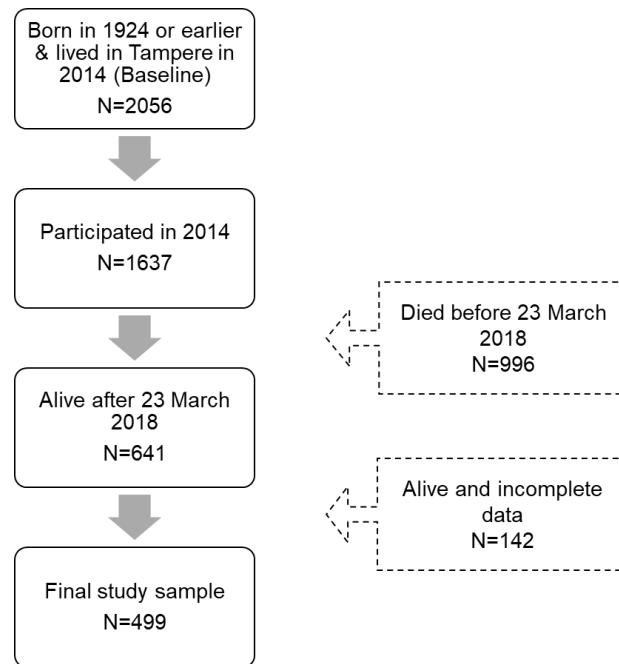


Figure 3. Study sample selection

6.2 Variables

Descriptive variables

The descriptive variables refer to the characteristics of the subjects which include the following information: age (treated as continuous variable); gender (female and male); marital status was divided into four groups: 1) unmarried, 2) married, 3) divorced, and 4) widowed. The Vitality 90+ Study had seven options for level of education: 1) elementary school, 2) lower secondary school, 3) vocational school, 4) folk high school, 5) upper secondary school, 6) college education, and 7) academic education. The subjects' level of education was considered 'low' if they selected option 1, 'middle' if they selected either option 2, 3 or 4, and 'high' for either option 5, 6 or 7.

To determine the place of residence, the subjects were asked "where do you stay at the moment when answering the questions?". For this question, six alternatives were given

in the Vitality 90+ Study: 1) private apartment, 2) service house (with staff available only in daytime), 3) service house with a 24-hour staff, 4) old people's home, 5) nursing home or dementia home, and 6) hospital. Of these alternatives, the first two was classified as 'home' and the rest was classified as 'long-term care'. To clarify the person who is answering the questions, the subjects were asked "who answered to these questions?" in the Vitality 90+ Study with five choice of answers provided: 1) the recipient him/herself (another person could help in writing), 2) family member, relative or friend helped in answering, 3) family member, relative or friend answered for the recipient, 4) home helper, health care worker or someone else helped in answering, 5) home helper, health care worker or someone else answered for the recipient. Of the five choices, options 2 and 4 were regarded as 'someone helped the recipient in answering (a family member, friend, or health care worker)' and options 3 and 5 were categorized as 'proxy', that is someone answered on behalf of the recipient (a family member, friend, or health care worker). Previous Vitality 90+ studies have also used similar coding for the variables of level of education, place of residence, and person answering the question (Enroth & Fors, 2021; Jylhä, Enroth, & Luukkaala, 2013).

Additionally, chronic diseases were inquired by asking the participants "has your doctor diagnosed (name of the disease) from you?". The choice of answer for this question is a yes/no. There are seven diseases which are repeatedly asked in 2014 and 2018, they include 1) high blood pressure, 2) coronary heart disease, arrhythmia, or infarction (heart condition), 3) stroke, 4) diabetes, 5) Alzheimer's disease, other dementia, or memory problems (dementia), 6) depression or depressiveness (depression), and 7) hip fracture or arthritis.

Explanatory variables

Age, gender, and educational level were set as explanatory variables.

Disability outcomes

This study used three mobility activities, which were walking 400 meters, moving around indoors and using stairs, and two activities of daily living (ADL), which were transferring from and to bed and getting dressed and undressed, to assess disability. The participants

were asked “are you able to...?” in the questionnaire. The response categories were 1) without difficulty, 2) with difficulty but without help, 3) only with help, 4) or unable to do. Disability in the present study was examined in three outcomes: disability score, number of disabilities, and degree of severity in individual activity.

1. Disability score

The score of disability was obtained by summing the score of each activity. The score was created for individual activities with the following code: 0 = not at all, 1 = only with help, 2 = yes, with difficulty, 3 = yes, without difficulty. A summary score of all five activities ranges from 0, unable to perform five activities, to 15, can perform five activities without difficulty. Changes in the disability score were assessed as: (a) unchanged, the disability score was the same in both years, (b) improved, the disability score increased at least by one point from 2014 to 2018, (c) deteriorated, the disability score decreased at least by one point 2014 to 2018.

2. Number of disabilities

To examine the number of disabilities all five activities were used. A person was classified as independent if they responded 1) without difficulty or 2) with difficulty but without help. Those whose response was 3) only with help or 4) unable to do was categorized as dependent. The number of activities where a participant was dependent were summed as follows: 1) completely independent (independent in all), 2) mostly independent (independent in 1 or 2 activities), 3) mostly dependent (dependent in 3 to 4 activities), 4) completely dependent (dependent in all). Changes in the number of disabilities were examined as: (a) unchanged, the category of the number of disabilities was the same in both years, (b) improved, the category of the number of disabilities decreased at least by one point from 2014 to 2018, (c) deteriorated, the category of the number of disabilities increased at least by one point from 2014 to 2018.

3. Degree of severity

The degree of severity refers to the participants’ ability to perform individual mobility and daily living activities. All five disability indicators were included in this assessment. The degree of severity was assessed separately for each indicator. The participants rated

their ability to perform each activity based on the given response category. A response category of (1) 'without difficulty' indicates no disability, (2) 'with difficulty but without help' implies a minor degree of severity, (3) 'only with help' shows a moderate degree of severity, and (4) 'unable to do' denotes a high degree of severity. Changes in the degree of severity were evaluated as: (a) unchanged, the ability to perform each activity was the same in both years, (b) improved, the ability to perform each activity decreased at least by one point from 2014 to 2018, (c) deteriorated, the ability to perform each activity increased at least by one point from 2014 to 2018.

6.3 Statistical methods

General characteristics of the study samples were described with frequencies and per cents separately for 2014 and 2018. Age, disability score, number of disabilities, and degree of severity in individual activities were described with medians and interquartile ranges separately for 2014 and 2018. Changes in each disability outcome from 2014 to 2018 were described with frequencies and per cents. The order of functional loss was formed by ranking the activities from those that declined the most (highest proportion of deterioration) to those that declined the least (lowest proportion of deterioration) between 2014 and 2018.

Multinomial regression was used to examine the association between the explanatory variables (age, gender, educational level) and each of the outcome variables (disability score, number of disabilities, degree of severity). Multinomial regression can be used with nominal dependent variable given one or more independent variables. In multinomial regression, the dependent variable can have more than two categories, while the independent variable can be a nominal and/or continuous variable (Lærd Statistics, 2020). In model 1, age, gender, and level of education was entered into the model one at a time and in model 2, the three of them were examined at the same time. The reference group was 'deteriorated', which means that those whose changes in disability were categorized as 'unchanged' or 'improved' were compared with those whose changes were categorized as 'deteriorated'. The analysis in both models were adjusted for baseline scores, that is the participants' disability score, number of disabilities, and degree of severity to perform individual activities in 2014. Given that the baseline scores can have a strong or moderate association with the outcome variables (disability score, number of disabilities, degree of

severity), and therefore acting as a covariate in this analysis, they can obscure the true relationship between the explanatory variables (age, gender, educational level) and the outcome variables. Therefore, adjustment of such covariate can increase the efficiency of the analysis and hence produces stronger precision of the estimated effect (smaller probability values (*P* values) and narrower confidence intervals) (The European Agency for the Evaluation of Medicinal Products, 2003). Results in models 1 and 2 were presented as relative risk ratios (RRR) with 95% confidence intervals (95% CI) and *P* values. *P* values below 0.05 were considered statistically significant. The data were analyzed using IBM SPSS Statistics 20 Software.

6.4 Ethical review

The study protocol was approved by the Regional Ethics Committee of Tampere University Hospital. The study has a research permission obtained from the City of Tampere. All participants or their legal representatives gave written informed consent.

7. RESULTS

7.1 Characteristics of the study subjects

The characteristics of the study subjects separately for 2014 and 2018 are shown in Table 1. At baseline, the median age of the subjects was 91, the majority were female, widowed, had low level of education, lived in their own homes, and answered the questions by themselves. The most reported chronic diseases were high blood pressure, osteoarthritis, and heart problem. In 2018, the median age, the number of widows, and the number of subjects reporting a heart problem and osteoarthritis increased. While the number of subjects living in their own homes, answering the questions by themselves, and reporting a high blood pressure declined. In addition, the prevalence of subjects with dementia almost doubled from 2014 to 2018. Because the same people were followed, the distribution of gender and education was the same in 2014 and 2018.

Table 1. Characteristics of the study subjects in 2014 and in 2018 in the Vitality 90+ Study

Variable	Study year			
	2014		2018	
	Total (N=499)			
	n	%	n	%
Age = Md (IQR)	91 (3)		95 (3)	
Gender				
Female	381	76.4		
Male	118	23.6		
Marital status				
Unmarried	50	10.1	49	9.8
Married	80	16.1	57	11.4
Divorced	25	5.0	29	5.8
Widow	342	68.8	363	72.9
Education level				
Low	253	51.6		
Middle	147	30.0		
High	90	18.4		
Place of stay				
Home	407	82.3	323	65.2
Long-term care	87	17.5	173	34.8
Respondent				
The recipient him/herself	395	80.0	291	58.4
Someone helped the recipient	70	14.1	131	26.3
Proxy	29	5.9	76	15.3
Diseases (YES)				
High blood pressure	336	68.0	323	65.1
Heart problem	242	49.0	280	56.5
Alzheimer's or memory problem	121	24.5	207	41.7
Stroke	26	5.3	27	5.4
Diabetes	76	15.4	75	15.1
Osteoarthritis	252	51.0	259	52.2
Hip fracture	68	13.8	86	17.3
Depression	67	13.6	86	17.3

Md median, *IQR* interquartile range

7.2 Disability changes in disability score, number of disabilities, and degree of severity to perform individual activity from 2014 to 2018

Table 2 displays the disability changes in disability score, number of disabilities, and degree of severity to perform each activity between 2014 and 2018. The median score of disability was 13 and decreased over time by three points, showing higher disability in 2018 than 2014. For 72.2% of the participants, their disability score deteriorated. In terms of the number of disabilities, the majority (70.0%) was completely independent (able to perform all five activities) at baseline. At follow-up, a great segment of the participants (40.2%) was categorized as mostly independent (unable to perform 1 to 2 activities). The proportion of participants being in a state of mostly dependent (unable to perform 3 to 4 activities) and completely dependent (unable to perform all five activities) was four times higher in 2018 than it was in 2014. The first half of the participants (50.6%) did not change in their number of disabilities and for the second half (46.2%), it deteriorated, suggesting poorer functioning in 2018. With regards to degree of severity of disability, bed transferring, dressing, and moving indoors remained unchanged for most of the participants during the four years of follow-up. Walking 400 meters and using stairs deteriorated for more than 50% of the participants and for a small proportion, an improvement was found in all activities. In descending order, the activities with the largest proportion of deterioration from 2014 to 2018 were as follows: using stairs, walking 400 meters, moving indoors, dressing, and bed transferring.

Table 2. Disability changes in disability score, number of disabilities, and degree of severity in individual activities from 2014 to 2018 in the Vitality 90+ Study

Variable	Study year					
	2014		2018			
^a Disability score = Md (IQR)	13 (4)		10 (6)			
Changes in the disability score 2014 – 2018 [n (%)]						
Unchanged	84 (17.7)					
Improved	48 (10.1)					
Deteriorated	342 (72.2)					
Number of disabilities = Md (IQR)	0 (1)		1 (2)			
Categories	n	%	n	%		
Completely independent (0 disabilities)	338	70.0	179	36.5		
Mostly independent (1-2)	118	24.5	197	40.2		
Mostly dependent (3-4)	14	2.9	55	11.2		
Completely dependent (5)	13	2.7	59	12.0		
Changes in the number of disabilities 2014 – 2018 [n (%)]						
Unchanged	240 (50.6)					
Improved	15 (3.2)					
Deteriorated	219 (46.2)					
^b Degree of severity in individual activities = Md (IQR)						
Activity name						
Bed transferring	3 (0)		3 (1)			
Dressing	3 (1)		2 (2)			
Walking 400 m	3 (1)		1 (2)			
Moving indoors	3 (1)		2 (1)			
Using stairs	2 (1)		1 (2)			
Changes in the degree of severity in individual activities 2014 – 2018 [n (%)]						
Activity name	Unchanged		Improved		Deteriorated	
	n	%	n	%	n	%
Bed transferring	325	65.7	17	3.4	153	30.9
Dressing	287	58.3	14	2.8	191	38.8
Walking 400 m	207	42.4	30	6.1	251	51.4
Moving indoors	277	56.2	23	4.7	193	39.1
Using stairs	200	40.7	31	6.3	260	53.0

Md median, *IQR* interquartile range

^aDisability score: higher score indicates lower disability

^bDegree of severity in individual activities:

A median score of 3 in the table indicates response category (1) no disability

A median score of 2 in the table indicates response category (2) minor degree of severity

A median score of 1 in the table indicates response category (3) moderate degree of severity

A median score of 0 in the table indicates response category (4) high degree of severity.

7.3 Multinomial regression models for the disability changes in disability score, number of disabilities, and degree of severity to perform individual activity by age, gender, and educational level from 2014 to 2018

1. Disability changes and age

The regression results indicate that age was statistically significantly associated with disability changes. Model 1 (Table 3 and 4) showed that subjects with higher age compared to those with younger age were at higher risk of having increased disability as measured by the disability score (RRR 0.83, CI 0.73–0.95), increased number of disabilities (RRR 0.89, CI 0.82–0.97), and increased disability severity in walking 400 meters (RRR 0.89, CI 0.82–0.98), moving indoors (RRR 0.91, CI 0.83–0.98), and using stairs (RRR 0.90, CI 0.82–0.99) than maintaining functioning at the same levels as in 2014. In bed transferring, the risk of increased severity rather than decreased severity (improved) was higher among older than younger subjects (RRR 0.71, CI 0.52–0.96). When adjustments for gender, education and disability at baseline were made, as presented in model 2, these significant associations did not change in most of the cases except in moving indoors (Table 4). There was no association found between age and dressing in either models.

2. Disability changes and gender

Statistically significant associations were found between gender and disability changes. Displayed in model 1, women as opposed to men were at greater risk of having deteriorated functioning as shown by the disability score (RRR 0.54, CI 0.32–0.92), increased number of disabilities (RRR 0.38, CI 0.25–0.61) (Table 3), and increased severity of disability in walking 400 meters (RRR 0.42, CI 0.26–0.66) and moving indoors (RRR 0.54, CI 0.34–0.86) than having no changes in their functional ability between 2014 and 2018. The risk of increased degree of severity rather than declined degree of severity (improved) in bed transferring was higher among women compared to men (RRR 0.21, CI 0.05–0.80) (Table 4). The significant associations between gender and disability changes were consistently found after adjusting for age, educational level and baseline disability, as exhibited in model 2. Gender was not associated with dressing.

3. Disability changes and educational level

There were few statistically significant associations between level of education and disability changes. These associations were found in model 1. Subjects with low educational attainment in comparison to the ones with high educational attainment had greater risk of having increased number of disabilities (RRR 0.53, CI 0.31-0.89) and increased severity of disability in moving indoors (RRR 0.57, CI 0.34 – 0.96) than retaining the same functioning levels as in 2014. No significant associations between disability changes and educational level were discovered in model 2, which was adjusted for age, gender and disability at baseline.

Table 3. Relative risk ratios (RRR) and their confidence intervals (CI) for the participants’ changes in the disability score^a and number of disabilities^b by age, gender, and educational level from 2014 to 2018 by multinomial logistic regression in the Vitality 90+ Study

Variable	Model 1						Model 2					
	Unchanged			Improved			Unchanged			Improved		
	RRR	95% CI	P value	RRR	95% CI	P value	RRR	95% CI	P value	RRR	95% CI	P value
^aChanges in the disability score												
Age	0.83	0.73 – 0.95	0.01	0.96	0.83 – 1.10	0.54	0.85	0.74 – 0.97	0.01	0.95	0.83 – 1.10	0.56
Gender												
Female	0.54	0.32 – 0.92	0.02	1.10	0.46 – 2.66	0.83	0.58	0.34 – 0.99	0.05	1.10	0.45 – 2.67	0.83
Male	1.0			1.0			1.0			1.0		
Education												
Low	0.83	0.45 – 1.57	0.58	1.05	0.40 – 2.78	0.91	0.90	0.47 – 1.72	0.77	1.05	0.39 – 2.79	0.91
Middle	0.78	0.39 – 1.57	0.50	1.18	0.42 – 3.29	0.74	0.82	0.40 – 1.66	0.58	1.18	0.42 – 3.31	0.75
High	1.0			1.0			1.0			1.0		
^bChanges in the number of disabilities												
Age	0.89	0.82 – 0.97	0.01	0.83	0.64 – 1.09	0.18	0.90	0.82 – 0.98	0.02	0.83	0.62 – 1.11	0.83
Gender												
Female	0.38	0.25 – 0.61	<0.001	0.31	0.07 – 1.34	0.12	0.41	0.26 – 0.66	<0.001	0.34	0.07 – 1.47	0.34
Male	1.0			1.0			1.0			1.0		
Education												
Low	0.53	0.31 – 0.89	0.02	0.68	0.13 – 3.62	0.66	0.59	0.35 – 1.01	0.06	0.80	0.15 – 4.32	0.80
Middle	0.79	0.45 – 1.38	0.41	0.65	0.09 – 4.30	0.65	0.88	0.49 – 1.56	0.66	0.75	0.11 – 5.08	0.75
High	1.0			1.0			1.0			1.0		

RRR relative risk ratios, 95% CI 95% confidence intervals, P value probability value.

Deteriorated as reference group.

Bold numbers suggest statistically significant p values.

Model 1: age, gender and educational level was entered into the model separately

Model 2: age, gender and educational level were examined at the same time

^aChanges in the disability score:

(a) unchanged, the disability score was the same in both years

(b) improved, the disability score increased at least by one point from 2014 to 2018

(c) deteriorated, the disability score decreased at least by one point 2014 to 2018.

^bChanges in the number of disabilities:

(a) unchanged, the category of the number of disabilities was the same in both years

(b) improved, the category of the number of disabilities decreased at least by one point from 2014 to 2018

(c) deteriorated, the category of the number of disabilities increased at least by one point from 2014 to 2018.

Table 4. Relative risk ratios (RRR) and their confidence intervals (CI) for the participants’ changes in the degree of severity to perform individual activities^a by age, gender, and educational level from 2014 to 2018 by multinomial logistic regression in the Vitality 90+ Study

Variable	Model 1						Model 2					
	Unchanged			Improved			Unchanged			Improved		
	RRR	95% CI	<i>P</i> value	RRR	95% CI	<i>P</i> value	RRR	95% CI	<i>P</i> value	RRR	95% CI	<i>P</i> value
Bed transferring												
Age	0.94	0.82 – 1.03	0.22	0.71	0.52 – 0.96	0.03	0.93	0.85 – 1.01	0.11	0.68	0.48 – 0.96	0.03
Gender												
Female	0.66	0.41 – 1.07	0.09	0.21	0.05 – 0.80	0.02	0.70	0.43 – 1.15	0.16	0.19	0.04 – 0.78	0.02
Male	1.0			1.0			1.0			1.0		
Education												
Low	0.89	0.53 – 1.51	0.67	1.85	0.20 – 16.49	0.57	0.94	0.55 – 1.16	0.84	2.84	0.30 – 26.41	0.35
Middle	1.42	0.78 – 2.56	0.24	2.54	0.25 – 25.52	0.42	1.49	0.82 – 2.71	0.18	3.33	0.30 – 36.15	0.32
High	1.0			1.0			1.0			1.0		
Dressing												
Age	0.94	0.86 – 1.02	0.13	0.92	0.71 – 1.19	0.53	0.94	0.86 – 1.02	0.16	0.94	0.72 – 1.23	0.66
Gender												
Female	0.80	0.51 – 1.24	0.33	0.80	0.15 – 4.12	0.79	0.86	0.54 – 1.35	0.51	0.87	0.17 – 4.51	0.87
Male	1.0			1.0			1.0			1.0		
Education												
Low	0.62	0.37 – 1.03	0.06	1.18	0.12 – 11.00	0.88	0.63	0.37 – 1.06	0.08	1.22	0.12 – 11.53	0.86
Middle	1.13	0.63 – 2.00	0.67	3.35	0.34 – 32.19	0.29	1.15	0.64 – 2.04	0.63	3.43	0.35 – 33.27	0.28
High	1.0			1.0			1.0			1.0		
Walking 400 meters												
Age	0.89	0.82 – 0.98	0.02	0.88	0.74 – 1.06	0.18	0.90	0.82 – 0.99	0.03	0.89	0.74 – 1.06	0.21
Gender												
Female	0.42	0.26 – 0.66	<0.001	0.54	0.18 – 1.62	0.27	0.43	0.27 – 0.70	<0.005	0.57	0.19 – 1.71	0.31
Male	1.0			1.0			1.0			1.0		
Education												
Low	0.73	0.43 – 1.24	0.25	0.74	0.22 – 2.52	0.63	0.82	0.48 – 1.40	0.47	0.81	0.23 – 2.76	0.73
Middle	0.90	0.51 – 1.58	0.72	1.26	0.35 – 4.46	0.71	0.98	0.55 – 1.74	0.95	1.35	0.37 – 4.85	0.64
High	1.0						1.0			1.0		

Moving indoors												
Age	0.91	0.83 – 0.98	0.03	0.87	0.70 – 1.09	0.24	0.92	0.84 – 1.00	0.07	0.86	0.68 – 1.09	0.24
Gender												
Female	0.54	0.34 – 0.86	0.01	0.85	0.21 – 3.32	0.81	0.59	0.37 – 0.95	0.03	0.81	0.20 – 3.20	0.77
Male	1.0			1.0			1.0			1.0		
Education												
Low	0.57	0.34 – 0.96	0.04	1.53	0.30 – 7.88	0.60	0.61	0.36 – 1.04	0.07	1.58	0.30 – 8.33	0.58
Middle	0.87	0.49 – 1.54	0.65	1.49	0.24 – 8.98	0.66	0.93	0.52 – 1.65	0.81	1.54	0.25 – 9.46	0.63
High	1.0			1.0			1.0			1.0		
Using stairs												
Age	0.90	0.82 – 0.99	0.03	0.83	0.68 – 1.01	0.06	0.91	0.83 – 1.00	0.04	0.83	0.68 – 1.02	0.08
Gender												
Female	0.66	0.41 – 1.06	0.08	0.57	0.20 – 1.59	0.28	0.72	0.45 – 1.17	0.19	0.67	0.23 – 1.92	0.46
Male	1.0			1.0			1.0			1.0		
Education												
Low	0.69	0.40 – 1.17	0.17	0.63	0.20 – 1.95	0.42	0.71	0.41 – 1.22	0.22	0.67	0.21 – 2.15	0.51
Middle	0.66	0.37 – 1.18	0.16	0.59	0.17 – 2.04	0.41	0.67	0.37 – 1.21	0.19	0.62	0.18 – 2.17	0.46
High	1.0			1.0			1.0			1.0		

RRR relative risk ratios, *95% CI* 95% confidence intervals, *P value* probability value.

Deteriorated as reference group.

Bold numbers suggest statistically significant p values.

Model 1: age, gender and educational level was entered into the model separately

Model 2: age, gender and educational level were examined at the same time

^aChanges in the degree of severity to perform individual activities:

(a) unchanged, the ability to perform each activity was the same in both years

(b) improved, the ability to perform each activity decreased at least by one point from 2014 to 2018

(c) deteriorated, the ability to perform each activity increased at least by one point from 2014 to 2018.

8. DISCUSSION

This study examined changes in disability from 2014 to 2018 as well as the order with which disability occurred among nonagenarians living in the city of Tampere, Finland. Disability was assessed as disability score, number of disabilities, and degree of severity in each activity. The analyses were conducted separately by age, gender, and level of education. The results of this study indicated that for most of the respondents, their disability increased as measured by the disability score (72.2%). As to the number of disabilities, the respondents were divided into two majorities, consisting of those who did not change (50.6%) and those who deteriorated (46.2%), that is their number of disabilities increased in 2018. During the four years of follow-up, between 2014 and 2018, 63.5% of the respondents were dependent in at least one activity. Specifically, there was a rapid increase in the proportion of respondents reporting dependence in 3 to 4 activities (from 2.9% to 11.2%) and in all five activities (from 2.7% to 12.0%). For the majority of the respondents, the ability to perform bed transferring, dressing, and moving indoors remained the same as in 2014, while walking 400 meters and using stairs became more difficult in 2018. Improvement was found in all five activities for a small fraction of the respondents. Functioning deteriorated the most in using stairs, walking 400 meters, moving indoors, dressing, and deteriorated the least in bed transferring. The regression analysis showed that older age and being women were significantly associated with increased disability as shown by the disability score, increased number of disabilities, and increased degree of severity in bed transferring and walking 400 meters. Additionally, there was an association found between older age and increased severity in using stairs, as well as between being women and increased severity in moving indoors.

8.1 The hierarchy of functional loss of the nonagenarians

This study discovered that there was a gradation in the proportion of deterioration in individual daily living and mobility activities among the 90 years and older people. The largest proportions of deterioration were found in activities that required balance, agility, and lower body muscles such as using stairs and walking 400 meters, whereas the fewest proportions were observed in those performed using upper body muscles and upper extremities such as dressing and bed transferring. The order of functional loss found in this study is in agreement with Verbrugge & Jette's (1994) Disablement Process where

functional limitation, encompassing mobility skills, appears prior to disability in self-care activities.

Direct comparison of the hierarchy of functional loss with other studies was difficult as they have mostly focused on younger age groups. In the work of Ferrucci et al. (1998), disability in mobility, basic and instrumental activities were categorized into four domains based on the underlying physical impairments. They defined activities in the first domain as the hardest to perform, which entailed activities requiring complex manual dexterity in unstable positions, such as cutting toenails and heavy housework. The second domain referred to activities requiring balance and the capacity to walk long distances with obstacles, for example, using stairs, moving outdoors, walking 400 meters, cooking, and bathing. Activities completed using a static balance and good upper limb control, such as walking indoors, toileting, dressing, and bed transferring, belonged to the third domain. The last domain, which was regarded as the easiest to perform, was related to good upper extremities in a seated position, for instance washing face and hands, and feeding.

The results of their study suggest that the progression of disability begins with a group of activities demanding the physical skills categorized in domain 1 and ends with those involved in domain 4. This hierarchical pattern was observed repeatedly in home-dwelling older adult populations aged 60 and over across five European countries. Activities included in the current study are equivalent to Ferrucci and colleague's classification of the second and third domains. After four years of follow-up, from 2014 to 2018, disability in activities that belong to domain 2 (walking 400 meters, using stairs, and moving indoors) seems to have developed earlier than those categorized in domain 3 (dressing and bed transferring). The fact that mobility declines faster than ADL has been supported by prior research as well. In Bendayan et al. (2017), English and U.S. subjects aged 50 and more were followed up for eight-years long. They reported that the rate of decline of any ADLs in their study was slower than the rate of decline for mobility tasks.

Furthermore, in the study of Wloch et al. (2016), the prevalence of reported difficulty in climbing stairs and walking increased at each age from age 43, 53, to 60-64. The increase in the prevalence, from age 43 to 60-64, was larger for climbing stairs than it was for walking. This indicates that disability manifests primarily in climbing stairs and later in

walking. Hence, it is in consonance with the present study where more people deteriorate in using stairs (53%) than in walking 400 meters (51.4%). In addition, Yeh et al. (2012), who studied a population of 50+ people with no initial disability over nearly 11 years of follow-up, have also found a similar occurrence. Their study used the median age at onset of disability to create the hierarchy, and they noticed that difficulty in taking stairs occurred at a relatively younger age compared to that in walking. This sequence is therefore in agreement with the one shown in the current study.

More importantly, the existing hierarchy of functional loss, which has often been attained from the younger age groups (40+, 50+, and 60+), appears to have remained the same in the oldest old population. In the Newcastle 85+ Study, they discovered that using stairs and walking 400 yards were among the first activities with which the participants had difficulty, while bed transferring was among the activities with the least reported difficulty. Although the method that Kingston et al. (2012) employed to obtain the hierarchy is distinguished from that in this study, both results indicate that activities with a more challenging physical skills are likely to be the first to deteriorate, followed by those with a moderate and low degrees of physical challenges.

Because disability does not occur in all domains of activity at the same time, it is possible for individuals to have more difficulties in a group of activities but to have less difficulties, or not at all, in some others (Ferrucci et al., 1998). Such sequence can be used to determine where individuals are in the disablement process (Hennessy et al., 2015; Stineman et al., 2012). Past research has explained that the more ADLs with which a person has difficulty, the more severe his or her disability (Guralnik et al., 1996). Difficulties in IADL and mobility related tasks are considered to be an early sign of functional decline (Bergland, Jørgensen, Emaus, & Strand, 2017; Forjaz et al., 2015; Mänty et al., 2007). More than 50% of the participants in this study reported deteriorations in mobility activities (using stairs and walking 400 meter) while less than 40% in daily living activities. According to Ferrucci and colleagues' classification, the skills required to perform mobility activities are categorized in domain 2, which means they are located at the top of the hierarchy. Hence, the current results imply that some of the nonagenarians in this study are at the initial stage of their disablement process. This can be supported further by the fact that the majority of the participants managed to live in their own home

during both study years, 82.3% in 2014 and 65.2% in 2018. On the other hand, some others might have already reached the intermediate or final stage of the process. The heterogeneity in functioning established here, so did in many other studies, has been widely known to increase with age, even at exceptionally old ages (Burns et al., 2019; Strozza et al., 2020).

However, the current result is in contrary to that of Wolinsky et al. (2011) on long-term (8 years on average) ADLs, IADLs, and mobility declines encompassing 70-year-old adults in the U.S. Survey on Assets and Health Dynamics among the Oldest Old (AHEAD). They reported that the respondents had more ADL (36.6%) than mobility (30.9%) declines. The difference can be explained by several reasons. First, Wolinsky et al. (2011) included more items of ADL in their research, covering five activities, namely moving between rooms, dressing, bathing or showering, eating, and bed transferring. By assessing more ADL items, it is possible to find more deteriorations in this measure as well. Second, they included moving indoors as an ADL, whereas that activity was regarded as a mobility activity in this study. Thus, difficulties or inability to move indoors might have increased the prevalence of ADL declines in their study. Third, their ADL items involved bathing. Based on the classification of Ferrucci et al. (1998), bathing is an activity of domain 2 which appears at the top of the hierarchy (lost first). Therefore, the higher rates of decline in ADL than in mobility might have resulted from the participants' declining ability in bathing as well.

8.2 Nonagenarians with no changes in functional ability

This study noticed a considerable proportion of nonagenarians having unchanged functional ability from 2014 to 2018. While in terms of the disability score the majority deteriorated (increased disability), in other measures, such as number of disabilities and severity of disability in individual activities, approximately 40% to 60% of them managed to preserve their level of functional ability. In addition, the supplementary analysis showed that among the nonagenarians whose functioning level was the same as in 2014, in general, their daily activities performance was high (able to do with or without difficulty). The proportion of older adults with 'good' unchanged functioning discovered in this study is comparable to the one in the Women's Health Initiative (WHI). Vaughan et al. (2016) explained in their research that maintained independence was seen in more

than one third of women above 80 years old for over 15 years. However, their study differs from this study in several aspects, such as the study design, which is a retrospective cohort design; gender selection, which involves only community-dwelling women; and types of measure as well as number of items included in each measure, which consist of 4 ADLs and 2 IADLs.

Likewise, in each of the two follow-up periods (1986 – 1990 and 1990 – 1995), around half of the participants in a Danish study reported having no changes in their functional ability (Holstein et al., 2007). Their ‘no change’ definition was similar to the one applied in this study but the samples were limited to non-institutionalized persons aged 70 to 95 years old. Unlike the present finding, after three years of follow-up, the proportion in the NonaSantfeliu Study was fairly lower as maintained functioning was found among 23.8% of nonagenarians (Formiga et al., 2010). Such discrepancy can be attributed to their smaller sample size (N = 63). Reflecting on the studies mentioned above, therefore it can be argued that maintaining a desirable level of functioning for four years is possible at age 90 and beyond. However, as the sample size of the present study was small, this finding should be interpreted with caution.

8.3 Nonagenarians with improved functional ability

The nonagenarians whose functional ability improved from 2014 to 2018 were a minority in this study. The proportions did not differ greatly from one activity to another, suggesting that it would be somewhat difficult to say with certainty in which activities the participants had progressed better. However, there are some characteristics that are worth mentioning about the improvers. Those whose functioning improved had worse disability score and greater number of disabilities at baseline as opposed to the counterparts with deteriorated and unchanged functioning. The aforementioned findings signify that functioning is not a static situation but it changes throughout the life of an individual. As explained in many prior research, it is common for older adults to shift from being independent to dependent, and vice versa (van Houwelingen et al., 2014; Vochteloo et al., 2013). There has been numerous studies suggesting that recoveries from being disabled in ADL, IADL, and mobility were attainable after engaging in physical training programs (Carral, Rodríguez, Cardalda, & Bezerra, José Pedro Arieiro Gonçalves, 2019; Courtney et al., 2012). Conversely, deteriorations were applicable only for participants

with the best disability scores at baseline. There were 169 subjects (35%) holding the highest disability score (score 15) at baseline, therefore they did not improve.

8.4 The associations between age, gender, level of education and disability changes

Previous studies on changes in disability as well as its predisposing factors are scarce, particularly among the 90-year-olds. In the current study, higher age and being women were associated with increased disability shown by the disability score, increased number of disabilities, and increased degree of severity to perform most of the individual activities. Further elaborations on each of these associations will be discussed in the subsequent paragraphs.

Age

Disability score

In this 90+ population, from 2014 to 2018, the increase in disability was higher for older subjects compared to the younger ones as shown by the disability score. Similarly, The Cross-Sectional and Longitudinal Aging Study (CALAS) followed-up a number of participants who was 75-84 years old in the first wave of data collection and survived until the third wave (age 87-98) (Cohen-Mansfield et al., 2013). Their 10-year analysis showed an accelerated decline in ADL score, however, the rate of decline was small. On the contrary, the earlier findings from the Vitality 90+ Study, using data from 2001, 2003, 2007 and 2010 (9 years follow-up), found higher mobility disability for older participants at baseline, yet the pace of change in disability did not differ statistically significantly by age over time (Tiainen, Raitanen, Vaara, Hervonen, & Jylhä, 2015). The differences in the findings may be related to the different time period; different methods; and different measure of disability, which involved only mobility.

Number of disabilities

This study showed that older age was associated with an increase in the number of disabilities. The 90+ study, which followed 216 residents of a U.S. retirement community (between 2003-2007), demonstrated that the annual incidence rate of disability was 8.3% and 25.7% for age groups 90-94 and 95+ years, respectively (Berlau et al., 2012). Such a

three-fold difference indicates an accelerated disability rate that commences from the age of 90. Despite the methodological differences between the study of Berlau et al. (2012) and this study, both investigations presented a higher increase in the number of disabilities among older people than younger people over time.

Degree of severity

Increased severity of disabilities was seen among the nonagenarians for bed transferring, walking 400 meters, moving indoors and using stairs. The descriptive analysis also showed that the majority of the subjects had no disabilities at baseline but progressed to a minor and moderate degree of severity in 2018. Investigations on changes in disability in individual activities among the oldest old are scarce. However, a one-year follow-up research conducted in Utrecht, the Netherlands, has reported a similar occurrence among 60+-year-old adults (Bleijenberg et al., 2017). They found that the risk of disability in walking nearly tripled from age 65 to 85, implying that disability in walking becomes more severe with advancing age. Thus, it can be assumed that both studies support for the notion that the progression of disability severity is more prompt with age and is likely to continue beyond the ninth decade of life.

Gender

Disability score

This study showed that between 2014 and 2018, disability increased more for women than men when measured with the disability score. In the Newcastle 85+ Study, women showed greater disability than men in respect to median disability score at both baseline and the subsequent follow-up waves, at 18, 36, and 60 months (Kingston et al., 2014). However, the increase in the median score, either from baseline to the last wave (60th month) or from one wave to another, did not vary between genders. These conflicting results can be influenced by several factors. First, in Kingston et al. (2014), performing an activity with difficulty, performing independently with an aid or appliance, and unable to do an activity were all scored as 1. It may be that their manner of scoring is less sensitive to changes in disability. Second, the activities assessed by Kingston and colleagues consisted of mainly IADL, such as managing medications and preparing a

meal, and the article has suggested that men tend to decline sooner than women in these activities (Bleijenberg et al., 2017). Therefore, these factors are likely to contribute to the similar pace of decline in functioning between men and women in the findings of Kingston et al. (2014).

Number of disabilities

In the current 90+ population, the increase in the number of disabilities was higher for women compared to men. Likewise, Sjölund et al. (2015) have found that the incidence rate of ADL disability increased with age and that the increase was higher for women than men. The incidence rate for men at age 84+ was almost similar to when they were 78-81 years old. However, during the same period (78-81 to 84+), women's incidence rate of needing assistance in ≥ 1 ADL grew five times higher and in ≥ 2 ADLs, it was 10 times higher.

Degree of severity

This study discovered that being women was associated with increased severity in walking 400 meters, moving indoors and bed transferring. Although there are no recent studies on changes in disability in individual activities among very old people, the results shown here are similar to those reported among adults aged 50 and over by Bendayan et al. (2017). In their study, women were found to have a higher mean rate of decline than men in each of the 10 mobility tasks, such as climbing stairs and stooping, after eight years of follow-up. This indicates that the severity increases more rapidly for women than men over time. Furthermore, when different age groups were analyzed separately (i.e., 50-65, 65-70, 70-75, 75+), the rates of decline were bigger in older groups compared to the younger ones. Taken together, the findings from both studies can be used as a preliminary indication that the progression of disability severity in individual activities becomes more rapid with age, and is faster among women.

The gender differences in functioning that are presented in this study can be attributed to several factors. According to Oksuzyan et al. (2008), men and women are exposed to a distinctive set of biological, social and behavioral risks. From the point of view of biology, for example, the rate of decline in sex hormones with age has been found to be

more progressive in women than men (Horstman et al., 2012; Klein & Flanagan, 2016). The growth and loss of some sex hormones are known to be related to the increase and decrease of muscle mass. Furthermore, there are some gender-bias responsibilities and roles in the society which incline to support women accessing health care services (Ek, 2015). Thus, diagnosis of disability is more likely to occur in women than men. Finally, behavioral pattern also plays a role in which men generally are more interested in health-deteriorating lifestyles, such as smoking (Carmel, 2019). Such habit has been associated with the presence of many heart diseases which are less disabling, but are more fatal (Crimmins et al., 2019). Even with the well-known gender differences in functional ability, some studies have found that the rate of change in functioning has been similar for both genders over time (Odden et al., 2019; Tiainen et al., 2015).

Level of education

The educational disparities in disability are well established also among the oldest old (Enroth & Fors, 2021). Prior Vitality 90+ study with a cross-sectional approach in 2010 has found that lower level of education is associated with disability (Enroth et al., 2013). This association is further supported by the findings from scarcely available longitudinal studies. For example, in the Newcastle 85+ Study, men and women were analyzed separately to determine their pace of functional loss in 17 activities (IADL and ADL) according to the level of education (Kingston et al., 2015). A rather similar result for both genders was found. In general, from age 85 to 90 years old, those who have higher education are more likely to be free of disability (men) or to have increased difficulty in around four activities (women) than to develop severe disability in nearly all items compared to those with lower education. Gregory et al. (2011), using data from the Women's Health and Aging Study II (WHAS II), have also reported a statistically significant association between educational attainment and the incidence of preclinical disability over an 11-year period. However, in this study with a four-year follow-up, the number of disabilities as well as the severity of disability in moving indoors increased more for older adults with low education than for those with high education.

The fact that educational differences in the disability changes were found only in few outcomes may be related to several factors. First, the population was highly selected. Out of the baseline population, over 60% died before 2018 and of the eligible population,

77.8% (N=499) participated in 2018. Since people with lower educational level have in general worse health and higher mortality, which are also found among the oldest old (Enroth et al., 2013; Enroth et al., 2016; Enroth et al., 2019), it is possible that these selection processes weaken the effects of educational disparities in disability in this study. Second, it has been suggested that the study non-respondents are more likely to have poorer health than the study respondents and that poor health is associated with a lower educational level (Enroth et al., 2019). Considering that there were 142 non-respondents in the 2018 survey, it is possible that the educational disparities in disability are underestimated in this study. Furthermore, IADL items were not incorporated in the assessment. It has been found in many studies that difficulties with instrumental activities would appear prior to difficulties with basic care activities (Kingston et al., 2012; Yeh et al., 2012). Tasks in the IADL category are usually more complex and require challenging cognitive skills. The competencies demanded to perform IADL related tasks might be strengthened if one had obtained more years of education. However, it was not possible to examine a more fine graded association between educational attainment and disability since IADL items were not available in this study.

8.5 Strength and limitation of the study

The advantages of this study were the use of data from the Vitality 90+ Study, which consisted of a representative sample of the oldest old people in Tampere. The study did not have any exclusion criteria, meaning that people living in institutions were included and the use of proxy respondents were allowed. The same questions were asked in 2014 and 2018, and for each year, the response rate was high. The follow-up interval was four years, which is relatively long and with which this study was able to capture the heterogeneity in the patterns of change in disability. Furthermore, disability was assessed in three different outcomes (total score, number of disabilities, and degree of severity in individual activities). This approach has enabled this study to offer a broader view to the disability development in the very old population that has not been studied much before. Most of the earlier studies have used aggregate measures of ADL to determine the subjects' disability status and their transitions over time (Finlayson & Havens, 2001). Finally, since the analyses were completed using a regression model, it was possible to measure and adjust multiple explanatory variables at the same.

A number of limitations needs to be noted regarding the present study. Due to a high mortality, the large population-based sample of nonagenarians ($N = 2056$) reduced to 499 participants in the four-year follow-up. Thus, the sample was affected by mortality selection. A supplementary analysis was performed to compare the level of disability at baseline between those who died before the 2018 study and those who had information in both study years. The analysis showed that subjects who died sooner, on average, had worse disability score (poorer functional ability) at baseline (Md, IQR = 9, 7) compared to their peers who survived (alive in the 2018 study) (Md, IQR = 13, 5). Therefore, it is likely that the findings represent the healthier end of the population. Nevertheless, it should be borne in mind that the high mortality is beyond the control of the author.

A second limitation is that the limited number of participants has made this study unable to conduct a more detailed sub-group analysis and to assess the predictive effect of more covariates. Third, the ranking of the activities was built upon a descriptive analysis instead of a regression analysis. A more sophisticated analysis, such as the one performed by Ferrucci et al. (1998), was not possible to execute in this study because the number of activities was restricted to five. Therefore, the creation of the hierarchy of functional loss was not ideal. Despite the limitation, the functional loss sequence displayed in the present study is in line with preceding studies that have primarily dealt with younger age groups (Ferrucci et al., 1998; Kingston et al., 2012; Yeh et al., 2012).

Lastly, because proxies were allowed to provide information regarding the older adults' disability status (5.9% in 2014 and 15.3% in 2018), there could be a reporting bias or measurement error. Proxies are known to overestimate disability, particularly in the older adults (Todorov & Kirchner, 2000). However, the inclusion of proxies has allowed this study to assess functional status in participants who were unable to fill out a questionnaire themselves, for instance because of sensory or cognitive limitations. Proxies gave the answer to the questions for nearly 21% to 33% of the people who suffer from dementia. The prevalence of memory problems is high among nonagenarians (Cohen-Mansfield et al., 2013; Odden et al., 2019), and in this study, it ranged from roughly 25% to 42%. Still, according to Walker et al. (2004), older persons with early dementia, such as those with mild to moderate levels of cognitive impairment, can reliably and independently rate their functioning status. This suggests that self-reported functioning remains a valid measure

of health in this group. Therefore, it is not likely that their existence influences the findings in this study.

Disability in ADLs and mobility in this study was examined through a self-report measure, which is known for its reliability in reflecting objective measures of function (Bravell et al., 2011). Fried et al. (2001) also suggest that the self-reported function has a physiologic ground, thus providing criterion validity. In addition, the ADL items listed in this study, which were dressing and bed transferring, were adopted from the 5-item Katz Index. It has been reported that the validity, reliability as well as responsiveness of this index are reasonably good (Hopman-Rock et al., 2019). Although the number of ADLs in this study is fewer than that listed in the original Katz Index, it has been studied that reducing the number of ADL questions to a small subset of those in the complete ADL batteries will not substantially affect the psychometric properties of the instrument (Rodgers & Miller, 1997).

In the multinomial regression analyses, the test for the Goodness of Fit was not always statistically significant, suggesting that the model fit was not optimal. Despite the uncertainty in the model fit, the results from the regression analyses and cross-tabulations were in the same direction. Therefore, there is no reason to believe that the results would be affected by the quality of the model.

8.6 Suggestions for future work

To develop a full picture of disability changes among the oldest old, additional studies will be required. As it may be difficult to conduct a research with larger population in this age category, a study with shorter time period would make it possible for having more people being alive at follow-up and therefore, minimize the selection effects. Including IADL items, in addition to ADL, in the analysis would provide a more comprehensive depiction of disability progression over time as well. It has been suggested that ADL alone has a tendency to underestimate disability (Thomas, Rockwood, & McDowell, 1998). Subsequently, upcoming research could investigate more on the characteristics of people with maintained high functioning in the very old age for this will contribute to the better establishment of effective disability prevention programs. Moreover, since both medications use and disability tend to increase with age (Odden et al., 2019), future

investigation could explore the role of different medications to the disablement process. Consuming multiple drugs has been associated with adverse outcome and functional decline, and the research article indicates that people over the age of 80 are at higher risk of reporting such conditions (Burgess, Holman, & Satti, 2005; Peron, Gray, & Hanlon, 2011). Lastly, disabilities emerge as a result of one's incapability to meet the demand of their environment. Thus, future studies could evaluate the role of environmental factors on changes and maintenances in functional ability.

9. CONCLUSION

This study has provided insights into the changes in disability and the hierarchy of functional loss among the 90-year-olds. The conclusion that can be drawn is that generally disability increased between 2014 and 2018. The increase was particularly higher among people with older age and women. Although deteriorations were a common occurrence, specifically in terms of disability score and number of disabilities, this study did find some stabilities and improvements. This indicates that the nonagenarians in this study are a heterogeneous group of individuals as reflected in their functional abilities. In the present 90+ population, the order of functional loss was similar to that in the younger age groups (40-85). An implication of this is the opportunity to establish public health interventions and plan suitable services according to the given stage of disability. Functioning, especially in older adults, is a prerequisite for leading a satisfactory life. The efforts to forestall further declines in health and functioning will enable older adults to maintain a good quality of life for a longer time.

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