THE EFFECTS OF INTELLIGENT TECHNOLOGY ASSISTED EXERCISE INTERVENTION ON FUNCTIONAL CAPACITY IN OLDER COMMUNITY-DWELLING WOMEN AND MEN

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Väestön ikääntyessä yksilön toimintakyvyn ja itsenäisen arjessa selviytymisen merkitys korostuu. Mahdollisimman hyvä toimintakyky on merkittävä niin yksilön elämänlaadun, kuin kansantaloudenkin näkökulmasta. Yksi tärkeistä yksilön toimintakyvyn osa-alueista on kyky liikkua turvallisesti omassa elinympäristössään. Tämän tutkimuksen tarkoituksena oli selvittää kansainvälisten suositusten mukaisen progressiivisen voima- ja tasapainoharjoitteluintervention vaikutusta iäkkäiden fyysiseen suorituskykyyn. Tutkimushypoteesina oli, että älyteknologian avulla toteutettu kahden kuukauden mittainen liikuntainterventio parantaa toimintakykyä erityisesti kävelyvaikeuksia kokevilla ikääntyneillä.

Tässä kahden kuukauden interventiossa tutkimusaineisto koostui kahdestakymmenestä vapaaehtoisesta, kotona asuvasta ikääntyneestä miehestä ja naisesta (ikä 73 ±7 vuotta, BMI 29±5 kg/m2). Tutkittavat suorittivat älykuntosalilla (HUR Oy, Kokkola, Suomi) voima- (yhdeksän lihasryhmää) ja tasapainoharjoittelua kahdesti viikossa. Harjoittelukonsepti oli automatisoitu ja yksilöllistetty harjoittelun vastuksen, progression ja määrän osalta. Yhden toiston maksimia (1RM) jalkaprässin ja rintaprässin osalta käytettiin maksimaalisen voiman arvioimiseen ylä- ja alaraajojen osalta. Lyhyttä fyysisen suorituskyvyn testistöä (SPPB) käytettiin toiminnallisen kapasiteetin muutosten kartoitukseen. Aineistoa analysoitiin tilastollisin menetelmin t-testin, yleisen lineaarisen mallin (GLM), yksisuuntaisen varianssianalyysin (ANOVA) ja ristiintaulukoinnin avulla.

Kaikki yksilöt osallistuivat koko 16 harjoittelukertaan (keskimääräinen yksittäisen harjoituksen kesto 49 ±7min). Jalkaprässin 1RM lisääntyi 15% (alku 66±15 ja loppu 73±14 kg, $p<0.0001$) ja rintaprässin 12% (alku 20±7 ja loppu 22±9 kg, $p<0.0001$). SPPB osoitti 5% parannuksen toimintakyvyssä (alku 10.4±1.3 ja loppu 10.9±1.2, $p=0.016$). Yksilöt, jotka kokivat kävelyvaikeuksia alkutilanteessa raportoitiin erikseen (GD, n=7), samoin kuin ne jotka eivät kokeneet kävelyvaikeuksia (NGD, n=13). Kävelyvaikeuksia kokevat olivat vanhempia kuin ryhmä, jolla kävelyvaikeuksia ei ilmennyt (77±6 vs. 69±6 vuotta, $p=0.011$). Jalkaprässin 1RM kasvoi 25% kävelyvaikeuksia kokevalla ryhmällä ja 10% heillä, joilla kävelyvaikeuksia ei ollut. Rintaprässin 1RM muuttui 15% GD- ryhmällä ja 11% NGD- ryhmälle. SPPB parani 12% GD- ryhmälle ja 1% NGD:lle (yhteisvaikutus $p=0.001$). Ryhmät erosivat lähtötilanteessa toisistaan SPPB:n osalta (GD 9.4±1.2 vs. 11.2±0.5, $p<0.0001$), mutta eivät enää kahden kuukauden intervention jälkeen (GD 10.6±1.5 vs. 11.2±0.6, $p=0.199$) eli GD- ryhmä oli saavuttanut saman tason kuin NGD- ryhmä.

Älyteknologiaa hyödyntävä ja suosituksia noudattava liikuntainterventio on tehokas ikääntyneiden toimintakyvyn edistäjä lyhyen fyysisen suorituskyvyn testistöllä mitattuna. Erityisesti hyötyvät ne ikääntyneet henkilöt, joilla on kävelyvaikeuksia. Uudet fyysistä aktiivisuutta edistävät, modernia teknologiaa käyttävät konseptit voivat olla potentiaalisia väyliä ikääntyneille turvallisen kävelyn ja tätä kautta myös paremman elämänlaadun edistämiseksi.

Asiasanat: toimintakyky, ikääntyneet, voima- ja tasapainoharjoittelu, kävely, teknologia

ABSTRACT

Saikkonen, N. 2020. The effects of intelligent technology assisted exercise intervention on functional capacity in older community-dwelling women and men. Faculty of Sport and Health Sciences, University of Jyväskylä, (health education) Master's Thesis, 59pp, 3 appendices.

The significance of functionality and independency is emphasized for aging adults. The best possible functional capacity is as crucial for the aspects of individual quality of life and for the national economy as well. One important division of individual functionality is the ability to safely move within one's own environment. The purpose of this study was to find out whether a two-month progressive strength and balance training intervention guided according to international guidelines has a positive effect on the physical performance of aged, community- dwelling men and women. Since gait ability is one of major determinant of functional capacity, we hypothesized that an exercise training intervention using developed new intelligent technology concept will increase functional capacity especially among those aged individuals who report gait difficulties at baseline.

In a two months intervention, volunteer individuals (14 females and 6 males, aged 73±7 years, BMI 29±5 kg/m2) completed strength (nine major muscle groups) and balance training sessions two times weekly by using intelligent gym (HUR Oy, Kokkola, Finland). The developed exercise training concept was computerized and automated to individualize outcome measures, training loads and volumes, and progression of training. One repetition maximum (1 RM) for leg and chest press were used to assess changes in maximal muscle strength for lower and upper body, and short physical performance battery (SPPB) was performed as a measure for changes in functional capacity. The data was statistically analysed using t-test, general linear model (GLM), one-way ANOVA and chi-square test.

All individuals completed all 16 training sessions (average duration of single session was 49±7 min). 1 RM in leg press improved 15% (from 66±15 to 73±14 kg, $p<0.0001$) and in chest press 12% (from 20±7 to 22±9 kg, $p<0.0001$). SPPB showed 5% improvement in functional capacity (from 10.4±1.3 to 10.9±1.2, $p=0.016$). We analysed separately individuals who reported gait difficulties at baseline (GD, n=7) and those without reported gait difficulties (NGD, n=13). The GD was older than the NGD (77±6 vs. 69±6 years, $p=0.011$). 1 RM in leg press increased 25% for the GD and 10% for the NGD ($p=0.054$ for main effect). Accordingly, 1 RM in chest press changed 15% for the GD and 11% for the NGD ($p=0.517$ for main effect). SPPB improved 12% for the GD and 1% for the NGD ($p=0.001$ for main effect). The groups differed at baseline in SPPB (GD 9.4±1.2 vs. 11.2±0.5, $p<0.0001$), but no longer after the two months physical training intervention (GD 10.6±1.5 vs. 11.2±0.6, $p=0.199$) i.e. the GD was at same SPPB level than the NGD at the end of intervention.

Guideline based physical training intervention using automated intelligent technology is effective to increase physical performance expressed as short physical performance battery especially in aged individuals who report gait difficulties at baseline. New physical activity promoting solutions using modern technology may be potential pathways for promoting safe walking, improving functionality and this way also increased quality of life among aging adults.

Key words: functional capacity, aging adults, strength and balance training, gait, technology

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1 INTRODUCTION

The well-being of the growing number of aging individuals sets several global challenges for our societies. In the perspective of health, we need to further develop solutions that tackle these issues in the meantime of placing the quality of life as a priority outcome (Katz et a. 2014). Health, capability, and the ability to independently function in everyday life are fundamental parts of life quality. The World Health Organization (2019) states that every individual should have the opportunity to live a healthy and long life. Healthy aging is defined "as the process of developing and maintaining the functional ability that enables well-being in older age" (WHO 2019). Physical activity plays a crucial role in this process (Daskalopoulou et al. 2017). One cannot emphasize enough that identifying the pathways of improving the independent and active life are key elements in minimizing the burden on the economy and healthcare caused by aging population (Morgan et al. 2019). Active aging – the common goal that also Ab HUR Oy is working for, is defined as "the process of optimizing opportunities for health, participation and security in order to enhance quality of life as people age" (WHO 2015). From this viewpoint we can see how active aging, health, quality of life and aging process merge together.

Aging is associated with many biological changes and eventually leads to general decline in the capacity of the individual (WHO 2015). Safe and independent walking is one of most important abilities for an individual but on the other hand limitations in physical functioning and mobility are fairly common in the elderly population (THL 2018). Difficulties climbing stairs and walking a distance of 500 meters starts to be more clearly present within the Finnish population 60 years old and above (THL 2018). For example, one fifth of the aged 80 or above are not able to stand up from the chair without help (THL 2018). This highlights the fact that adequate level of muscle strength is crucial for maintaining the important functionality of an individual (Papa et al. 2017).

A growing body of scientific evidence supports the idea that even a habitual physical activity started in the later life can prevent or at least postpone the appearance of age-related functional limitations (Miller et al. 2000; Hamer et al. 2014). Previous research also clearly shows that progressive resistance training is effective for improving physical functioning (Liu & Latham

2009) and activities of daily living, even at high age of over 90 years old (Papa et al. 2017). But not only muscle strength is important. Also preserving and improving balance is one key factor to be considered in terms of functionality at old age as approximately one third of community-dwelling over 65 years old fall each year (Tinetti et al. 1988; Gillespie et al. 2012).

The purpose of this study is to find out whether a two-month progressive strength and balance training intervention is effective for improving functional capacity and has a positive impact on the physical performance of the aged community-dwelling men and women. We hypothesize that an exercise training intervention using new intelligent technology concept will increase the functional capacity especially among those aged individuals who report gait difficulties at the baseline. The exercise intervention was conducted with pneumatic based strength training machines, balance product and software from Oy HUR Ab. An intelligent technology concept, HUR Medical Concept, was used to deliver the individually designed training program and collect the data of realized training. The HUR Medical concepts are collected evidence-based treatment guidelines and customized training protocols for treatment, management, and prevention for some of the common chronic conditions and diseases (HUR 2019). The aim is to help professionals to provide the best practices for exercise as medicine with the advantage of technology that allows individualization in terms of training loads, volume, and progression. The technology additionally enables comprehensive individual data collection and follow up of the actual training realization and progression.

2 AGING AND FUNCTIONAL CAPACITY

The World Health Organization (2019) states that every individual should have the opportunity to live a healthy and long life. As described earlier, healthy aging is defined "as the process of developing and maintaining the functional ability that enables well-being in older age" (WHO 2019). Functional ability in turn, is defined by WHO (2015) as the combination of individual and environmental factors – intrinsic capacity (physical and mental) of the individual and characteristics of their environment. Functional ability consists of all the capabilities that a person needs to have to be able to live a fulfilling life: the ability to meet the basic needs, to be mobile, to be socially active and contribute to the society (WHO 2019). In this thesis we use the term "functional capacity" to assess individual well-being and overall ability to physically function. In this study functional capacity is measured by maximal strength (one repetition max, 1RM) and functional test (Short Physical Performance Battery, SPPB). Generally functional ability is seen as more wide description of a person's functionality and this thesis will adhere to this interpretation. In relation to "functional ability" by WHO, functional capacity focuses on the intrinsic capacity of an individual and especially on the physical dimension of it.

The usage of term functional capacity described above is relatively inconsistent in literature as there are several other similar terms used in parallel. In the International Classification of Functioning, Disability and Health (ICF), definition "functioning" refers to all body functions, activities and participation (WHO 2002). When narrowed down, physical functioning (Finnish: fyysinen toimintakyky) can be described as the ability to move and defined as the ability to perform daily activities in life (THL 2018). Here we use the definition of WHO ICF (WHO 2002).

2.1 Age related physiological changes in human body

Aging is associated with multiple physiological changes and this process eventually leads to a general decline in the capacity of the individual (WHO 2015). To prevent this decline, it is important to maintain adequate functional capacity, which enables independency and participation in social aspects of the society (Satariano et al. 2012). One of the most relevant components of independency and quality of life is the ability to walk safely (Satariano et al. 2012).

The age- related physiological changes can be considered to have specific general features that can be described with decreased maximal functional capacity (WHO 2015; Tilvis 2016a), increased vulnerability, universality and chronicity (Tilvis 2016a). Usually the physical activity levels drop within aging and the effect unfortunately concerns all domains of functionality; strength, balance, flexibility and endurance (Milanovic et al. 2013). One of the significant age-related changes in human body is the loss of skeletal muscle mass that may lead to a decrease of strength and functionality (Cruz-Jentoft et al. 2010; WHO 2015). Generally, this skeletal muscle and strength loss appears as difficulties in daily activities and loosing of independency. The amount of lost muscle strength within aging has reported to be around 2-4 % annually (Forrest et al. 2007; Wilson et al. 2017).

Aging is additionally associated with general changes in joints and bones (WHO 2015). The well-established age- related decreases in bone mass lead to increased risk of fractures and osteoporosis (WHO 2015; Tilvis 2016) which again are notable implications for mortality, disability and decreased quality of life (WHO 2015). Also articular cartilage and connective tissue undergo a biological process that exposes tissue to degeneration (WHO 2015) and joints to fragility, pain and stiffness (Tilvis 2016b). These age-related deficits result in more broad declines in musculoskeletal function (WHO 2015).

Finally aging process affects the brain and nervous system. Age- related changes in the nervous system and brain lead to multiple changes in cognitive function, included weakened memory, observation ability and overall slower functions (Tilvis & Viitanen 2016). In addition of the cognitive transformations, the function of autonomic nervous systems declines. Age-related psychosocial effects include possible negative changes in emotional stage, like isolation, loneliness and depression (Tilvis & Viitanen 2016).

2.2 Mobility

Mobility can be considered as one of the basic rights and needs of an individual. The ability to move is necessary for functioning in everyday: accessing services and participating in activities at multiple domains of life (Rantanen 2013; Satariano et al. 2012). As mobility is a vital part of healthy aging it is especially unfortunate that mobility tasks like walking and running are usually first affected in the aging process (Rantanen 2013). Mobility disabilities are unfortunately common, especially among elderly and further increase within the age (Rantanen 2013). For instance, 13,7% of the American adult population have a mobility disability which correspond to a considerable prevalence of individual tragedy (CDC 2019). Mobility restrictions are affected by many factors on social and environmental level (Satariano et al. 2012), but the mobility improving interventions are mainly designed to create positive effects on the individual capacity. Mobility disability can for instance be ameliorated through interventions that increase muscle strength (Rantanen 2013). A systematic review from Peel et al. (2012) additionally underlines the importance of subjective experience in rehabilitation of mobility limitations. It seems that these individual beliefs are in fact important considering the entirety of influencing the mobility. It makes sense that individual walking ability is connected to the beliefs of being able to move and that also walking related self-efficacy is positively associated with better lower extremity function (Mullen et al. 2012).

2.3 Gait as a measure of functional capacity and overall health

What it takes to walk safely? From physiological perspective appropriate muscle strength and power addition to postural balance and endurance (Rantanen et al. 2001; Studenski et al. 2011). Not to undermine movement control and support for the required upright position (Rantanen 2001). Walking also comprehensively strains the neural system and is hardly any more described as “automated motor function”, but “an activity that requires executive function and attention as well as judgment of external and internal cues” (Yogev et al. 2008; Amboni et al. 2013). As muscle strength plays an important role in this process, it has been stated that progressive resistance and balance training may be effective in maintaining and improving gait ability among older population and those at risk of mobility decline (Liu & Latham 2011;

Rantanen 2013). In this thesis we use the two terms, “gait” and “walking”, whereas gait refers to the pattern of how an individual walks.

Gait speed is an important measurement in assessing geriatric people (Cesari et al. 2005; Studenski et al. 2011; Cesari 2011) with mobility limitations (Peel et al. 2012) and can even be seen as screening tool for geriatric approach to care (Cesari 2011) and as one of the most powerful indicators of future outcomes in old age (Abellan van Kan et al. 2009). Gait speed has been demonstrated to be an easily accessible indicator of the whole spectrum of functional performance that can predict survival (Studenski et al. 2011), hospitalization, mortality and severe mobility limitations (Guralnik et. al 1994; Cesari et al. 2005; Perera et al. 2016) and several clinical conditions. Perera et al. (2016) for example shows that gait speed is clinically independent risk factor of future disability in a large heterogenic population. Also, Abellan van Kan et al. (2009) had similar results in International Academy on Nutrition an Aging (IANA) task force study but in addition of other adverse outcomes they connected gait speed into future falls. Gait speed predicts for instance bathing and dressing dependency (Perera et al. 2016), all crucial abilities for individuals daily living. Miller et al. (2000) found in their study that older adults who walked a mile at least once a week had a lower risk of progressing further in their functional disability than their more sedentary counterparts.

Several studies have shown a link between gait abnormalities and significantly increased risk of developing dementia and cognitive decline (Verghese et al. 2007; Montero-Odasso et al. 2012; Beauchet et al. 2016) and this association seems to work in two ways. According to previous and still partial understanding, gait abnormalities would increase the risk of falling and cognitive impairments predicted dementia (Amboni et al. 2013) but the recent findings are suggesting that all the factors above are connected in a more complex way (Verghese et al. 2007; Montero-Odasso et al. 2012). Evidence implicates that gait abnormalities predict dementia or cognitive decline, and cognitive impairments increase risk of falling (Verghese et al. 2007; Montero-Odasso et al. 2012). For example, falls are twice as common among people with cognitive problems and dementia compared with people without cognitive issues (Montero-Odasso et al. 2012). This also highlights the role of executive function in this connection between gait variability and risk of cognitive decline. Consequently, gait decline, cognitive impairments and falls together are common among aging adults to cause significant health problems and disability. A substitute perspective could be improving attention and executive function as an alternative way of influencing mobility and the risk of falling (Montero-Odasso et al. 2012; Van het Reve & de Bruin 2014).

2.4 Other determinants of functional capacity needed in daily living

The definition functioning in the International Classification of Functioning, Disability and Health (ICF) refers to all body functions, activities and participation (WHO 2002). When narrowed down, physical functioning (Finnish: fyysinen toimintakyky) can be described as the ability to move and defined as the ability to perform daily activities in life (THL 2019). So, what other domains of physical capacity is needed in daily living to maintain optimal physical functioning? As it is well established, to be able to function and be mobile, enough muscle strength and cardiorespiratory fitness is needed. Mobility and the actions in daily life also require balance and sufficient flexibility. In this thesis we are concentrating on the aspect of muscular strength and balance.

2.4.1 The role of muscle strength

Muscle strength is associated with multiple domains of positive outcomes in human health and performance. As it is widely known, skeletal muscles are responsible for all the movements within human body and so their optimal performance is essential for functioning. Importance of muscle strength increases within the aging process as the strength levels and functional capacity keep naturally diminishing. Loss of strength that follows aging is associated with the loss of mobility, functioning and independence. Physiological changes in muscles like the loss of motor units, fibre type changes, muscle fibre atrophy and reduced neuromuscular activity are responsible for decline in muscle performance, force production and velocity (Tieland et al. 2018). Muscle weakness is also associated with other negative outcomes like increased risk of disability and falls. But, as luck would have, there is no reason why aged muscles could not still improve their capacity of force production. Previous research evidence demonstrates at that progressive resistance training at sufficient intensity improves muscle strength (Fiatarone et al.

1994), physical functioning (Liu & Latham 2009), functional mobility and activities of daily living, even at high age of 90 years old (Papa et al. 2017).

2.4.2 Biological changes in muscle related to aging

The degenerative process of aging equally affects the neuromuscular system. There are age-related changes in muscle size and fibre types and several contributors to the biophysiological changes in skeletal muscle during the aging process. The general conclusion is that aging muscles get smaller and weaker. With age, the muscle fascia gets thicker and infiltration of fat into skeletal muscle occurs (Tilvis 2016b; McCormick & Vasilaki 2018). The main changes in muscles include decrease in size of muscle fibres, loss of particularly type II fibres and resistance to anabolic signals from exercise and proteins (Wilson et al. 2017; Aagaard et al. 2010). Aging of the muscle tissue in fact decreases both the fast (type I) and slow (type II) muscle cells but the process is not equally paced for both muscle cell types. The full consensus regarding the diminishing of muscle fibres and especially specific muscle fibre types has still not been reached yet (Tieland et al. 2018). As the total number of muscle fibres have been reported to decrease, also non- differing muscle fibre numbers have been reported (Tieland et al. 2018). One of the main factors behind loss of muscle mass and strength is in addition neuron loss that causes decrease in motor units (Aagaard et al. 2010; Tilvis 2016b). Although, at all ages the thickness of individual muscle cells is dependent on the amount of muscle strain and usage (Tilvis 2016b).

Skeletal muscles have an important metabolic function by being essential in, for example, maintaining glucose homeostasis and providing a site for both fatty acid metabolism and glycogen synthesis (Tieland et al. 2018). Muscle tissue in addition produces myokines that have many auto-, para-, and endocrine effects, supporting the metabolic function of other tissues, like liver, pancreas and adipose tissue (Schnyder & Handschin 2015). Also, these hormonal changes and changes in other organ functions associate the dec,reasing muscle strength, endurance and speed (Tilvis 2016b). Other key explaining factors include sarcoplasm and calcium metabolism, lower production of ATP, weakened ability of mitochondria and decrease in myosin production

(Tivlis 2016b). As a result, loss of mobility, functioning and independence is closely related to decline in muscle function as people age.

All the changes in skeletal muscles eventually lead up to approximately 25 % decrease in muscle cross-sectional area between 2^{nd} and 70^{th} decade and the faster process, 2-4 % annual loss of muscle strength (Mitchell et al. 2012; Wilson et al. 2017). Mitchell et al. (2012) reported annual medial decline for muscle atrophy through life to be approximately 0.37% in women and 0.47 % in men in cross-sectional studies. Among over 75-year-old women and men the annual decline was reported to be 0.64-0.7% for women and 0.8-0.98 % for men in longitudinal studies (Mitchell et al. 2012). Decline in muscle power can be seen occurring earlier and more significantly compared to muscle strength (Reid & Fielding 2012).

Sarcopenia has been widely defined as the age-related syndrome that is characterized by progressive and generalized loss of skeletal muscle mass, quality and strength (Cruz-Jentoft et al. 2010; Wilson et al. 2017). For the last few years sarcopenia has been recognized as a disease and it also got its own ICD- 10 code in September 2016 (Anker, Moreley & von Haehling 2016). The European Working Group on Sarcopenia in Older People (EWGSOP) by Cruz-Jentoft et al. (2019) defines sarcopenia as "a progressive and generalised skeletal muscle disorder that is associated with increased likelihood of adverse outcomes including falls, fractures, physical disability and mortality." According to the newest scientific evidence the onset of sarcopenia can occur far earlier in life and there are many contributing causes beyond just the age (Cruz-Jentoft et al. 2019). Sarcopenia is proposed to be a multifactorial condition with changes in several mechanisms contributing to the structural and functional decline (McCormick & Vasilaki 2018) and other unwanted negative outcomes like higher fall rate, frailty, fractures and mortality (Cruz-Jentoft et al. 2019). The European Working Group on Sarcopenia in Older People (EWGSOP) states (2019) that the diagnosis of sarcopenia should include presence of low outcomes in three parameters: muscle strength, muscle quality/quantity and physical performance "as an indicator of severity". In the updated statement the working group uses low muscle strength as the primary diagnostic parameter and implicate that muscle strength would be the most reliable measure of muscle function (Cruz-Jentoft et al. 2019). Sarcopenia can be seen as a major socio-economic challenge of our time because of its effects on risk profiles of morbidities and mortality (McCormick & Vasilaki 2018).

Sarcopenia in turn, has been considered as a pre-stage (Wilson et al. 2017) and key element of frailty (Clegg et al. 2013). Frailty is defined as a state of increased vulnerability of an organism to stressors and is firmly associated to negative health outcomes. (Clegg et al. 2013; Cesari et al. 2017). The relationship between sarcopenia is not fully understood yet but these two conditions share many clinical outcomes, pathophysiology and defining criteria (Wilson et al. 2017). According to the current understanding regarding the connection between sarcopenia and frailty, it is proposed that they share common inflammatory drivers (Wilson et al. 2017). The current understanding regarding to sarcopenia and frailty is that they share common inflammatory determinants (Wilson et al. 2017).

2.4.3 The role of balance

Balance and adequate flexibility are needed in everyday life and are also crucial for maintaining independency towards the end of life. Balance problems are an inherent result of aging. Poor balance and flexibility are connected to many aspects of physical functioning but especially in restricted mobility, walking ability and increased risk of falling. Falls are common among aging adults and a considerable reason for disability, hospitalization, and death. Falls are also the second leading cause of accidental injury deaths worldwide, especially suffered by people aged over 65 years (WHO 2018). At least one third of community- dwelling population over 65 years of age fall annually (Tinetti et al. 1988; Sherrington et al. 2019). According to WHO (2018) annually 37,5 million falls are severe enough to cause medical attention and 646 000 falls result in death. In Finland the annual rate of fatal falls has more than doubled (from 500 to 1200) in the last forty years and most of the falls occur to over 75-year-old population (Tilastokeskus 2018). The globally growing amount of older population indicates that the number of falls will most likely grow in the future. Decrease of mobility and increased need of care make falling more likely for the elderly (THL 2012).

Moreover, falls are a major economic burden (Heinrich et al. 2009; Davis et al. 2010; WHO 2015). In Finland, the costs of falls leading to acute hospital care were approximately 39 million euros in year 2000 and 82 % of these were falls caused hip fractures (THL 2012). It would be crucial to provide systematic and effective falls prevention as a part of services for aged population to ensure their health, safety and to cut the growing expenses resulting from falls (THL 2012). Effective prevention requires multidisciplinary approach in which all the risk factors for falls are assessed and actions based on risk assessment individually planned (Tinetti & Kumar 2010; THL 2012). Exercise is shown to be effective in reducing falls in community-dwelling adults (Gillespie et al. 2012; Sherrington et al. 2019) but among residential care settings the evidence is yet unclear (Sherrington et al. 2016; Cameron et al. 2018). Although for example Hewitt et al. (2018) reduced the fall rate with 55 % in exercise group in their randomized controlled trial which included individuals in residential care.

3 IMPROVING FUNCTIONAL CAPACITY IN AGING ADULTS

It is clearly shown that physical activity is an important treatment in many diseases whereas sedentary lifestyle and physical inactivity are considerable risk factors for diseases. In other words, physical activity and exercise are the cornerstones in maintaining good health and improving physical function in older adults. Individual functional capacity can be enhanced by focusing on different dimensions of physical functioning like muscle strength and balance, which are also the focus areas in this thesis. Furthermore, physical inactivity and sedentary lifestyle are strongly connected to major global economic burden that could be partially contained by promoting active lifestyle. This chapter defines and describes the overall role of physical activity and exercise in improving functional capacity and introduces the global guidelines for physical activity, which exist as the foundation for the more specific exercise guidelines. Additionally, the economic impact of neglecting physical activity is highlighted.

3.1 The role of physical activity

Physical activity is defined as “any bodily movement produced by skeletal muscles that results in energy expenditure” (Caspersen et al. 1985; WHO 2019). It is well established that physical activity throughout life has multiple benefits, including prolonged life expectancy (Chodzko-Zajko et al. 2009; WHO 2015; PAGAC 2018; Ekelund et al. 2019) by maintaining and enhancing functional capacity and reducing the impact of age-related biological changes on health and well-being (Chodzko-Zajko et al. 2009; PAGAC 2018). For example, Arem et al. (2015) found that people who met the minimum of weekly physical activity had 31% lower mortality risk. On average the estimation is 33% for lower risk of mortality for those people who are active for 150 minutes a week compared to those who are not physically active (PAGAC 2018).

Physical activity in older age has several other gains for the individuals. In addition of the improved physical capacity and longer life expectancy, the benefits of physical activity include positive impact on the mental health and quality of life by for example maintaining cognitive function, reducing anxiety and depression, improving social outcomes and sleep (Chodzko-Zajko et al. 2009; WHO 2015; PAGAC 2018). Higher levels of physical activity and cardiovascular fitness reduce risk of dementia and cognitive decline (Chodzko-Zajko et al. 2009; PAGAC 2018). Importantly, there is also moderate quality evidence for exercise being the only intervention for sarcopenia to improve muscle function and physical performance (Cruz-Jentoft et al. 2014). This is important to consider when examining the functional ability in old age.

Exercise is furthermore a vital part in the management, rehabilitation, and prevention of most of the chronic diseases. Exercise training can improve functional capacity, several risk factors and reduce disability among individuals with chronic diseases (Pasanen et al. 2017; Kujala et al. 2009. There is strong evidence that regular physical activity lowers risk of the following conditions and events; early death, coronary heart disease, stroke, type 2 diabetes (Chodzko-Zajko et al. 2009; WHO 2015; PAGAC 2018), insulin resistance, hypertension and high blood pressure, lipid profile, features of metabolic syndrome, weight gain, low cardiorespiratory fitness (PAGAC 2018). Physical activity is also shown to lower the risks of cancer on multiple sites; bladder, breast, colon, endometrium, oesophagus, kidney, lung, and stomach (PAGAC 2018). In addition, there is moderate to strong evidence of lowered risk of bone loss and weight gain after losing weight (PAGAC 2018). Physical activity is, moreover, shown to positively affect risk of falls or injuries resulting from falls, for example hip fractures (PAGAC 2018).

3.1.1 Effects of strength training

Strength, or resistance training can reduce age- related deficits in muscle function (Peterson et al. 2010) by increasing muscle strength, endurance (Williams et al. 2007; Chodzko-Zajko et al. 2009) and power in older adults but the improvements in muscle quality are although consistent despite the age of an individual (Wojtek et al. 2009). These improvements consist of adaptations in muscular and neuromuscular systems, for example changes in muscle mass and motor unit recruitment discharge rates (Chodzko-Zajko et al. 2009).

Beyond improvements in musculoskeletal system, resistance training causes numerous other advantages for older individuals. According to a meta-analysis from Liu & Latham (2011), progressive strength training appears to reduce physical disability and improve physical functioning (Liu & Latham 2009). Strength training causes additionally improvements in independence and quality of life and functional capacity (Williams et al. 2007; Aagaard et al. 2010) even at very old age (Aagaard et al. 2010). Strength training can positively affect important independency related activities like walking, stair climbimg (Papa et al. 2017; Fiatarone et al. 1994) and gait speed (Fiatarone et al. 1994; Chou et al. 2012; Papa et al. 2017). There is body of evidence that progressive strength training demonstrates positive effects on functional mobility, stability limits, balance (Chou et al. 2012; Howe et al. 2011; Papa et al. 2017) and falls prevention (Gillespie et al. 2012; Papa et al. 2017). Although according to Orr and Fiatarone Singh (2008) it is not clearly shown that solely progressive resistance training improves balance.

Resistance or strength training improves cardiovascular function, metabolism and coronary risk factors (Williams et al. 2007). Strength training is an effective way of improving overall metabolic health in individuals with type II diabetes (Colberg et al. 2010; Pesta et al. 2017). Moderate to high intensity resistance training does furthermore improve body composition by increasing fat free mass and decreasing fat mass in older adults and additionally preserving or improving bone mineral density (Chodzko-Zajko et al. 2009).

There has been a discussion about the significance of muscle power in terms of functionality and aging. Despite that various studies have shown that muscle strength is an immediate determinant of functional limitations, muscle power seems to decline earlier and faster than muscle strength (Aagaard et al. 2010). Reid and Fielding (2012) highlight muscle power as more distinguish feature in predicting of functional performance in older adults. Bean et al. (2010) found power to be related to more clinically significant improvements in mobility than leg strength alone in their randomized controlled trial. Be as it may, it seems to be safe to state that improving and preserving muscle power is crucial among older population. According to a 3-year longitudinal study from Trombetti et al. (2016) muscle power, mass, strength and physical performance are independently associated to increased fear of falling. Decline in muscle mass and physical performance were in turn connected to progressively reduced quality of life (Trombetti et al. 2016). The researchers underpin the role of promoting muscle health when growing older.

3.1.2 Physical activity recommendations for aging adults

It is well established that all areas of physical fitness – aerobic, strength and balance are important for aging adults. This chapter introduces the WHO International strength, balance, and aerobic training recommendations for aging adults (WHO 2010). Although the aerobic exercise recommendations are equally essential, in this thesis we mainly concentrate on strength and balance training, as the importance of muscle strength especially increases within the aging process and is well justified in the literature. The general guidelines for physical activity yet remain as a scientific foundation in the background.

1. ”Older adults should do at least 150 minutes of moderate-intensity aerobic physical activity throughout the week or do at least 75 minutes of vigorous-intensity aerobic physical activity throughout the week or an equivalent combination of moderate- and vigorous-intensity activity.

2. Aerobic activity should be performed in bouts of at least 10 minutes duration.

3. For additional health benefits, older adults should increase their moderate-intensity aerobic physical activity to 300 minutes per week, or engage in 150 minutes of vigorous-intensity aerobic physical activity per week, or an equivalent combination of moderate-and vigorous-intensity activity.

4. Older adults, with poor mobility, should perform physical activity to enhance balance and prevent falls on 3 or more days per week.

5. Muscle-strengthening activities, involving major muscle groups, should be done on 2 or more days a week.

6. When older adults cannot do the recommended amounts of physical activity due to health conditions, they should be as physically active as their abilities and conditions allow.”

3.1.3 Strength and balance training to improve gait and prevent falls

Exercise is proven to be an excellent way of reducing falls (Gillespie et al. 2010; Sherrington et al. 2016; Hewitt et al. 2018; Sherrington et al. 2019). Exercise programmes that include balance and functional exercises prevents falls among community-dwelling aged people (Sherrington et al. 2019). Sherrington et al. (2019) also state in their Cochrane Review that fall reducing interventions are multiple exercise category programmes, usually combined balance, functional and resistance exercise. Additionally, the international and national physical activity guidelines recommend without exceptions both strength and balance training for older adults (WHO 2019; UKK Institute 2019). A recent randomized control trial among long-term residential aged care facility members in Australia (The Sunbeam program) reported 55% decrease in falls rate due to combined high-level balance and moderate intensity progressive strength training protocol (Hewitt et al. 2018). The training was individually prescribed and performed twice a week for one hour, in total of 50 hours (Hewitt et al. 2018). This time period was followed by a maintenance program of six months (Hewitt et al. 2018). These findings are in line with previous knowledge of the positive effect of progressive strength and balance training on mobility (Rantanen et al. 2003; Liu & Latham 2011).

Considering balance training, the weekly volume for exercise training should be relatively high. According to a Cochrane review by Howe et al. (2011) more effective balance- improving programs were those that had been conducted three times a week for three months. The research group also found some specific types of exercise; gait, balance, co-ordination and functional tasks and strengthening exercise that were moderately effective in improving balance in older people. Because of the complex nature of walking ability, it is no surprise that physical activity interventions that are diverse, include walking, strength, flexibility and balance training can additionally improve gait speed of the elderly (Espeland et al. 2017). Chou et al. (2012) found significant changes in walking speed and balance after exercise intervention among frail older adults but no recommendations regarding exercise type could be drawn from the study. Some of the interventions in their systematic review included for example strength training, balance training and practicing the daily activities. As a conclusion, all older adults at fall risk should engage in strength, balance and gait training with flexibility and endurance taken into notice (American Geriatrics Society/British Geriatrics Society 2011).

3.1.4 Prescribing strength training for aging adults

Resistance strength training is widely used training modality for improving muscle strength and composition in elderly population. Despite this, clear and detailed evidence- based prescriptions for resistance training among this target group are not as well demonstrated as for adult population. Although the recommendations are to a large extent the same, there are some differences. First, aged adults should take part into any physical activity, including resistance training, according to their abilities and a therapeutic approach should be applied when necessary (Nelson et al. 2007). Second, flexibility and balance should actively be included when designing a training regimen (Nelson et al. 2007; WHO 2010).

Several institutions have published guidelines for prescribing strength training for adult population. For instance, The American Heart Association has published recommendations for resistance exercise with and without cardiovascular disease (CVD) (Williams et al. 2007) and the American College of Sports Medicine has published a position stand "Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory, Musculoskeletal, and Neuromotor Fitness in Apparently Healthy Adults: Guidance for Prescribing Exercise" (Garber et al. 2011). The general guidelines regarding resistance training usually state that the training needs to be progressive (Williams et al. 2007; Garber et al. 2011) and should generally be performed controlled, with full range of motion and with proper breathing manner (Williams et al. 2007; Garber et al. 2011). The training should involve major muscle groups of the body (Nelson et al. 2007; Williams et al. 2007; PAGAC 2018; Garber et al. 2011). Evidence suggests that for safety reasons, progressive resistance training should even be considered to precede aerobic training for individuals with mobility decline (Howe et al. 2011; WHO 2015). This is because aerobic training as a single exercise type seems to have no effect on balance, but combined strength and balance training clearly has (Howe et al. 2011).

The general guidelines including progressivity and adequate intensity of the resistance training are also well demonstrated in the literature. Although the overall heterogeneity of the exercise interventions remains a challenge, especially in systematic reviews of the existing literature. But as it is known progressive resistance training with high intensity is effective for preventing muscular weakness related to aging (Fiatarone et al. 1994; Liu & Latham 2009; Peterson et al. 2010) and promotes positive outcomes, like improved activities of daily living. Strength training frequency is usually recommended to be at least two times a week and some references even promote a higher frequency from 2-3 times a week (Nelson et al. 2007; Liu & Latham 2009; Ratamess et al. 2009; Garber et al. 2011) to even five times a week for advanced individuals (Ratamess et al. 2009). To improve muscular strength the intensity of resistance is recommended to be moderate or high level– generally with one to three sets of 8-12 repetitions, whereas 2-3 sets may be more effective (PAGAC 2018) and 10-15 repetitions more suitable for older individuals (Nelson et al. 2007). The recommended number of sets for strength and hypertrophy gains mainly vary within 2-4 in the literature but depending on the individual fitness level, even one set can somewhat improve these outcomes (Garber et al. 2011). Similarly for individuals not familiar to resistance exercise or exercise overall, training loads are recommended to be approximately at the level of 8-12 repetition maximum (RM) or between 60%-70% of 1RM (Ratamess et al. 2009; Garber et al. 2011; PAGAC 2018) whereas more advanced individuals may train with varying loads between 80-100% of 1RM (Ratamess et al. 2009). Specifically, old and possibly frail adults may need to start with a slightly lighter training regimen. This means lower training loading and possibly higher repetition level. Loading levels between 50-70% of 1RM (Borde et al. 2015) or even 40%-50% of 1RM are recommended (Garber et al. 2011). After achieving the necessary muscular performance these older individuals can proceed to following the general recommendations (Garber et al. 2011). Progressivity is generally recommended to be equal to 2-10% of initial training load (Ratamess et al. 2009) and the rest time 2-3 minutes between sets (Ratamess et al. 2009; Garber et al. 2011; Borde et al. 2015).

3.2 Economic impact of physical inactivity and sedentary behaviour

Physical inactivity is a remarkable global economic burden and responsible for at least an estimated price tag of 53,8 billion dollars through health-care expenditure (Ding et al. 2016). The price tag becomes even higher when the productivity loss based on physical activity related deaths are added into the calculation (Ding et al. 2016). From another perspective, physical inactivity is additionally responsible for 0,3-4% of the total healthcare costs in industrial countries which also bear the higher economic burden (Ding et al. 2017). The International Sport and Culture Association (2015) have published a report of economic costs of physical inactivity in Europe. In this report they state that the price tag is estimated to be 80 billion euros every year for the European economy, mainly through four main non-communicable diseases and indirect costs of mental disorders related to insufficient physical activity (ISCA 2015). This report likewise sets a conservative estimation of annual costs of over €125 billion by 2030 (ISCA 2015).

Finland is a small member state in the EU, with approximately 5,5 million inhabitants and GDP of €50 534 per capita (OECD 2018) but still the estimations of the costs of insufficient physical activity vary between €300 and €595 million, which equals 3% of the health care expenses (Ministry of Social Affairs and Health 2010; Kolu et al. 2018). If the amount of inactive population decreased 25 per cent from the current level, estimated savings would be around €1,15 billion (Kolu et al. 2018). Promoting the active lifestyle among the elderly population would also be economically beneficial way of decreasing the expenses of home and institutional care. According to one estimation it could potentially save annual costs of €150 million. (Sievänen 2018). Physical inactivity creates direct costs for the healthcare systems but additionally creates productivity loss through lost labour input, by social exclusion and raised social security benefits (Vasankari & Kolu 2018).

Considering the whole population of Finland, approximately one quarter meet the physical activity guidelines for aerobic exercise when measured by both questionnaire and accelerometer-based studies (Mäkinen et al. 2012). Approximately half of the working aged population in Finland are not physically active enough in terms of their health. For example, among the 55-64-year-old population, only 7 % meets the strength training recommendations (Husu et al. 2011). Then again, as much as two thirds of the retired men and women are evidently too inactive and only a few percent meet the physical activity recommendations (Husu et al. 2011). Also the sedentary time should be taken into account in this equation, despite the amount of physical activity as it is shown to be an independent risk factor for mortality (Chau et al. 2013) especially when the daily sitting time exceeds six hours (Owen et al. 2010). Sedentary behaviour is also a risk for metabolic health. The risk for elevated blood pressure, abdominal obesity, and lower levels of good cholesterol (HDL) may already increase after four hours of sitting (Owen et al. 2010; Chau et al. 2013). The Finnish working aged population sits over three hours on average workday and when for example the average sitting time of approximately 2 hours at home is added (Borodulin et al. 2013) the total sitting time is already very significant.

4 PURPOSE OF STUDY

The purpose of this study is to find out whether a two-month progressive strength and balance training intervention guided according to international guidelines has a positive effect on the physical performance of aged, community- dwelling women and men. The aim of this study was also to investigate whether intelligent technology concept is suitable for chosen operational environment. The research aims to find answers to the following research questions:

1. Has a two-month progressive strength and balance training intervention conducted with intelligent technology concept a positive effect on functional capacity measured by SPPB and muscle strength among community- dwelling women and men?

2. Is there a difference between the results of individuals who do, and do not experience gait difficulties?

The research hypotheses are:

1. The exercise training intervention will increase functional capacity among this group of community- dwelling women and men.

2. The exercise training intervention will increase functional capacity more among those aged individuals who report gait difficulties at baseline.

5 MATERIAL AND METHODS

The effectiveness of exercise training concept named as falls prevention concept (HUR Medical Concept) on muscular strength, balance, functional capacity was studied in Oulunkylä Rehabilitation hospital (Helsinki, Finland). The length of the study in controlled intervention group was two months. Measurements and tests were conducted in the beginning of the intervention and after two months of exercise. The participants for this study were recruited through an online and local newspaper announcement. The study was carried out according to the Declaration of Helsinki, the local committee of research ethics of the Oulunkylä Rehabilitation Hospital approved the protocol, and all the subjects gave written informed consent.

The Oulunkylä Rehabilitation Hospital is a geriatric rehabilitation hospital providing rehabilitation, interval care, day rehabilitation and long-term care for senior citizens and war invalids (OKS 2018). Their mission according to OKS (2018) is to “support the senior citizens’ functional ability, and to produce cost-efficient services that contribute to both rehabilitation and functional ability in a way that senior citizens are able to live in their own homes for as long as possible”. Oulunkylä Rehabilitation Hospital have had a gym of HUR intelligent pneumatic strength training machines since January 2017. Before this, the facility has had analogue HUR pneumatic machines for several years. In their facility they utilize the gym for all of their customer groups, including veterans, hospital care groups and other senior citizens (OKS 2018). Additionally, groups outside of these mentioned scopes take part in training in Oulunkylä rehabilitation hospital gym. One example of this is would be private customers of which the study population was also constituted through the recruitment process.

5.1 Study design

The recruitment process started in early July 2018, when the local newspaper and internet announcement was published (Figure 1). The Oulunkylä rehabilitation hospital employees were trained in the middle of August (15.8.2018) in how to use the Medical concepts in practice by the HUR company. The baseline measurements were conducted during middle of August and beginning of September. The training intervention started gradually for each individual between the end of August and the beginning of September. All the final measurements were finished by the middle of November 2018.

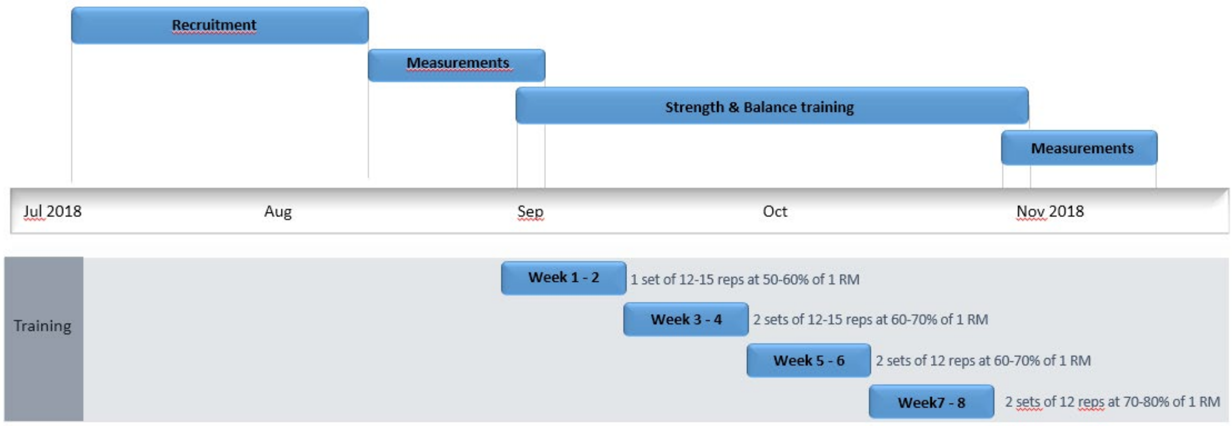

FIGURE 1. Timeline of the study

5.2 Participants

Study participants have been recruited through an announcement in local newspaper and online on the website of Oulunkylä Rehabilitation Hospital (https://www.okks.fi/huipputarjous-syksyn-kuntosaliryhmiin/). There was an open invitation to participate in the research and included information about the study design. Possible research participants were offered a reduced price for two months training package and measurements included in the study protocol. Those interested were then informed in detail about how and when to enrol into the measurements and take part in the exercise intervention. The screening, measurements and exercise intervention were conducted in Oulunkylä Rehabilitation Hospital. Inclusion criteria were over 65- year old men and women interested in a strength training protocol and its effect on functional capacity and balance. Exclusion criteria were severed dementia – Mini Mental State Examination (MMSE) < 15, (tested in case suspected within the assessment or medical history, CDR > 1.0); New York Heart Association Classification (NYHA) IV- all physical activity causes symptoms. Symptoms can occur also in rest heart failure – with symptoms like notable swelling/oedema and big changes in body weight (5kg) within the past two months. If the person has required hospital care within the last year for angina pectoris - chest pain on even land, or they have daily need of Dinit nitro spray. Also, atherosclerosis obliterans (ASO)- disease with intermitted claudication (walking distance under 50m), pain in rest, incurable wound, diabetic retinopathy (currently actively treated) or neuropathy (severe symptoms) were additional exclusion criteria.

Health status and functional ability of the study subjects were evaluated by 20-minute medical examination by a medical doctor, followed by an appointment with a physiotherapist. The medical examination followed the same principles as a routine medical examination for war veterans. The participants were asked to arrive approximately 30 minutes earlier to fill in the consent and background information form. This form was forwarded immediately to the medical doctor to familiarize with the information of the arriving participant. The final decision for the ability to participate in the study was made based on the two appointments with doctor and physiotherapist. In case the subjects met the inclusion criteria, they were given the data protection policy and further information about the study. Additionally, time for first physical training session was scheduled at this point. The initial study participants were twenty over 65- years old community dwelling elderly men and women who met the inclusion criteria. The group had a total of 14 females and 6 males, aged 73±7 years. Their BMI was 29±5 kg/m2. The reported diseases included musculoskeletal, metabolic, neurological, mental, lung, heart, and skin disorders with addition of cancer. There were two dropouts during the study due to health and personal reasons. The main baseline characteristics are illustrated in Table 1.

TABLE 1. The baseline characteristics.

Baseline characteristics (n = 20)	
Gender (M/F)	6/14
Age (yrs)	73±7
Resting systolic blood pressure (mmHG)	147±22
Resting heart rate (bpm)	70±9
Average reported number of diseases	6±2
Subjective gait difficulties	7±20

5.3 Methods

5.3.1 HUR SmartTouch Ecosystem

HUR manufactures pneumatic strength training machines and solutions for rehabilitation, active aging, and inclusive wellness (HUR 2019a) that were used in this study. The intelligent technology concept HUR Medical Concept for fall prevention was delivered by HUR strength training machines and SmartTouch software. The context of the development of this specific concept is in improving balance and eventually preventing falls, although falls were not studied in this intervention whereas the focus was on functionality and strength. HUR Smart Touch software is a computerized system for automated reporting, tracking, and training. The HUR strength training machines, Smart Touch software, HUR Balance platform and software, other testing equipment in addition of some cardio machines form an ecosystem called HUR SmartTouch ecosystem where all the information from each component can be stored, tracked and viewed.

5.3.2 HUR Medical Concepts and HUR Falls Prevention concept

The HUR Medical concepts are collected evidence-based treatment guidelines and customized training protocols for treatment, management and prevention of some the most common chronic conditions and diseases (HUR 2019). The aim is to help professionals to provide the best practices for exercise as medicine in terms of five different conditions; type II diabetes, hypertension, cardiac rehabilitation, hip, and knee rehabilitation and falls prevention (HUR 2019). The delivery of HUR Medical Concepts is done with the help of HUR solutions and products, mainly HUR machines and HUR SmartTouch System. In practice the five HUR Medical Concepts consist of evidence-based exercise and strength training protocols and are build up and used in the SmartTouch Software. The technology allows individuality in the training program design, progression and follow up, with addition of comprehensive data collection about the training realization. The evidence of each concept rises from a literature review and all the references are stated in the Medical Concept Book. For each concept there are two starting levels available and built, one for lighter program for beginner level users and one heavier for advanced level users. They key idea is to furthermore provide evidence of the actions and effects of the strength training intervention. Which equals that client assessment is a crucial component of the HUR Medical Concepts and is included in the protocols to be used. According to the concept flow, client assessment is done in the beginning and the end of the training intervention. (Figure 2).

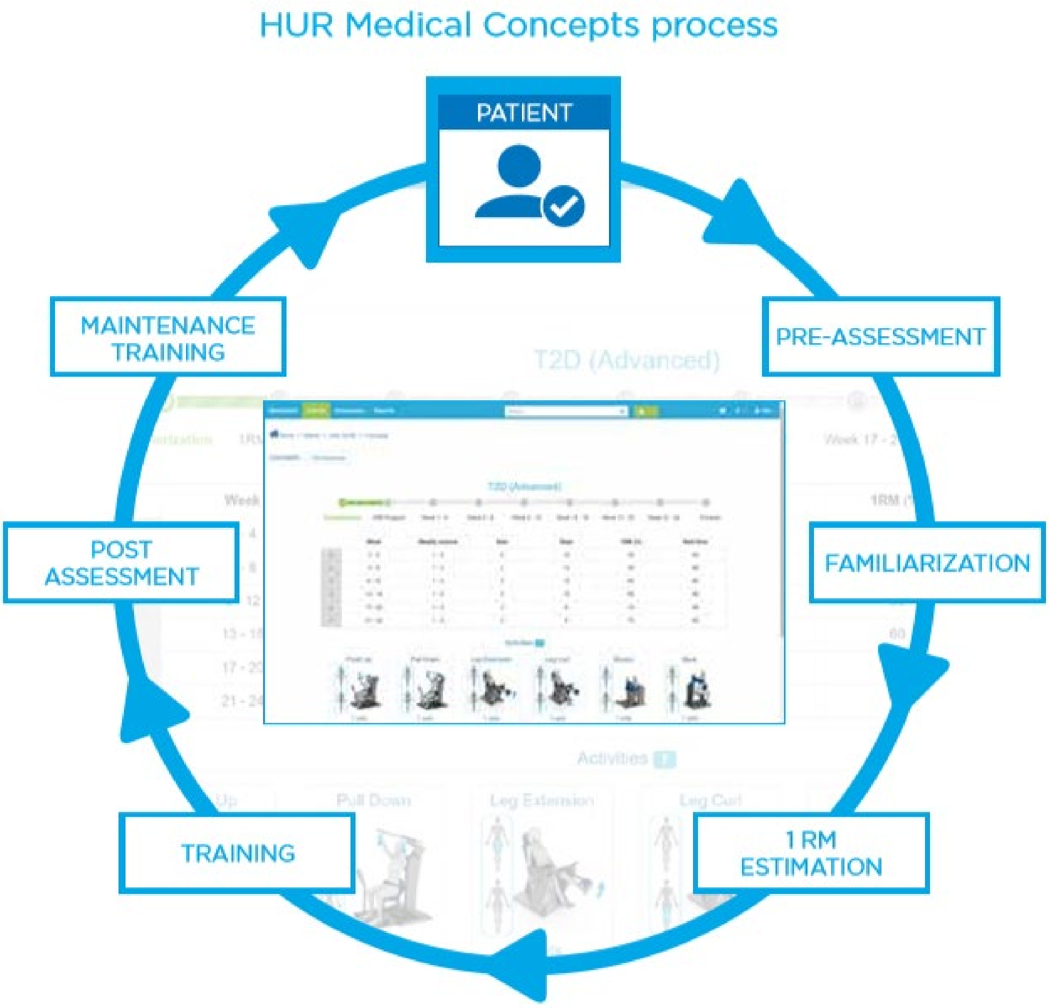

FIGURE 2. Description of HUR medical concepts and the process.

HUR Falls Prevention Concept is designed to provide the exercise prescription in falls prevention; to help maintain and improve balance and functionality according to the latest international preventive and treatment guidelines. As earlier stated, it is well known that correctly designed exercise training can help to reduce the rate and the risk of falling. Although, falls are not under the scope in this study, the aim was still to apply the accurate exercise prescription for improving functionality and gait ability. Regular strength and balance training is recommended also in the perspective of falls prevention, and therefore the HUR Falls prevention concepts provides a program of progressive strength and balance training (HUR 2019). The duration of the protocols are six months by default, but all the components of exercise training can be modified for individual needs, for example the length of the training intervention in this study was two months and the necessary adjustments were made. In this study, volunteer individuals completed sessions of strength training for nine major muscle groups and balance training two times weekly by using an intelligent gym (HUR Oy, Kokkola, Finland). The intelligent exercise training concept was computerized and automated to individualize outcome measures, training loads and volumes, along with progression of training.

5.3.3 Assessing functional capacity and maximal strength of the individuals

Short Physical Performance Battery (SPPB) was used to assess functional capacity in this intervention. The functional test was performed and documented by a physiotherapist after the medical examination. SPPB is a widely used performance test for especially lower extremity function. It has the capacity of proving information of the human performance; predict risk of disability, mortality and institutionalization among different populations, also in community-dwelling population (Guralnik et al. 1994; Guralnik et al. 2000). What is noteworthy is that the predictive factor for the relative risk of disability onset can be significant even as long as six years after the performance (Guralnik et al. 2000). Both researches emphasize that from clinical viewpoint is essential to routinely examine gait speed for older persons (Guralnik et al. 1994; Guralnik et al. 2000). SPPB test protocol includes assessing 4m walking distance, chair stand (5 times) and balance (THL 2012). The balance testing section includes three different standing positions, feet together, semi tandem, and full tandem (THL 2012). The different sections are timed and scored, whereas the maximal score of this test is 12 points (Guralnik et al. 1994; THL 2012).

Maximal muscle strength assessment (1RM, one repetition maximum) was conducted in the gym facilities and time for the strength test was scheduled to occur during the first week of strength training program, after initial familiarization phase. Muscle strength was assessed through a maximal dynamic strength test, three to five repetition maximum test. Test was performed on HUR machines and done for each muscle groups separately. After warm up the goal was to find a loading so high that the individual is not able to perform more than approximately three to five repetitions. From this result, the HUR SmartTouch software calculates estimation of one repetition max value in client's individual profile using Brzycki formula (Brzycki 1993). If the individuals were unfamiliar with the specific strength training machines or strength training overall, a familiarization phase of one or two training sessions preceded the maximal strength testing process. This was to ensure that optimal results could be reached in the most safe and efficient way. After the strength assessment, the two-month training program could be added into the research subjects' individual profiles in SmartTouch software and used automatically on the HUR machines with RFID- cards. Chest press and leg press were chosen for the analysis to describe the possible change of individual strength levels in both upper and lower body.

5.3.4 Other outcome variables

In addition of SPPB test, other outcome variables and were measured during the appointment with the physiotherapist. The Falls Efficacy Scale (FES-I) was used to measure fear of falling in this study, although actual falls were not targeted. Nevertheless, there is evidence of fear of falling being linked to for example lowered quality of life, restricted independence, and depression (Yardley & Smith 2002; Delbaere 2010). It has also been suggested to be an independent risk factor for falls (Friedman et al. 2002). The participants filled in the survey during the appointment with the physiotherapist before and after the intervention. The Falls Efficacy Scale International (FES-I) is a survey that comprehensively measures fear of falling in both physical and social perspectives (Yardley et al. 2005). The scale assesses concerns related to falling with 16 items that cover daily activities and social functions, for example walking stairs or taking a shower. Each of the items have scores between 1-4 (Not at all concerned = 1 and Very concerned = 4) (Yardley et al. 2005). That makes the minimal point rate 16 (no concern about falling) and maximal 64 (severe concern about falling) (Yardley et al. 2005). FES-I have shown to have good reliability and validity and is suggested to be used in clinical settings (Delbaere et al. 2010).

These included basic anthropometry that was measured with a segmental body composition analyser (Tanita) that is based on Bioelectric Impedance Analysis (BIA) technology (Tanita Corporation 2018). In Oulunkylä Rehabilitation Hospital the Tanita body composition analyser (model BC-418MA) is connected into the SmartTouch software and delivers the results straight into the software.

To be able to separately investigate the effect of the intervention on individuals with and without gait difficulties, the participants were asked by medical doctor during the medical examination whether they perceived any gait difficulties in their daily life or not (Yes/No). The question was not specified aiming to find out medical or other reason for the gait difficulty. Instead it was asked to achieve individual subjective feeling of gait ability since it is an important component of independency and quality of life.

5.4 Intervention

The participants of study completed sessions of strength training for nine major muscle groups and balance training two times weekly by using the HUR gym. The exercise training concept was computerized and automated to individualize outcome measures, training loads and volumes, along with progression of training. 1 RM for leg and chest press were used to assess changes in maximal muscle strength for lower and upper body, and SPPB alongside with 1RM was utilized as a measure for changes in functional capacity.

The physical therapists working in Oulunkylä Rehabilitation hospital oversaw the use of SmartTouch, into which individual profiles for study subjects were added and training protocol automatically built according to the fall prevention concept. Any personalized changes to the training regimen were done by the physiotherapists and one of the two starting levels were applied, advanced or beginner level depending on the individual background of the research subjects. This phase occurred during and after the baseline tests before the training protocol started.

Study participants trained in supervised group sessions scheduled twice a week for two months in Oulunkylä Rehabilitation Hospital gym total of 16 times. The clients came independently to the training facility and trained in groups twice a week according to their individual, progressive strength and balance training programs. The sessions were always supervised by a physiotherapist. The realization of physical activity intervention was followed through HUR SmartTouch system that automatically logs every training session (length, training realization, lading, repetitions) into the program in clients own personal profile. All the study participants had their own personal RFID- cards that they used to identify themselves on the training machines during the training. The identification cards were delivered to the subjects by the physiotherapist during each session and were stored in the facility for safe keeping and inconvenience.

The training sessions included a warmup, strength training regimen and two balance exercises. The clients went independently through their progressive training program in a circuit type and required very little help during these sessions. The strength training was recommended to precede the balance exercises but as the group was relatively big, the order was in practice somewhat varying. The resistance training program involved all major big muscle groups (9), in total of six pneumatic machines of which four had two movement directions. The machines used in the intervention were leg press, abduction/ adduction, leg extension/ curl, twist, abdomen/back, chest press. The program included altogether ten activities and two balance exercises (Figure 3 and Figure 4). Average duration of one training session was 49 min. After the two-month strength and balance training program the baseline tests were performed once again in the same manner than in the beginning of the intervention. The training protocol described in Table 2.

TABLE 2. The two months progressive strength and balance training according to Falls Prevention Concept.

week 1-2:	**week 3-4:**	**week 5-6:**	**week 7-8:**	One Balance exercise in each exercise set on HUR SmartBalance platform
1 set of 12-15 reps at 50-60% of 1 RM	2 sets of 12-15 reps at 60-70% of 1 RM	2 sets of 12 reps at 60-70% of 1 RM	2 sets of 12 reps at 70-80% of 1 RM	

FIGURE 3. HUR strength training facility in the Oulunkylä Rehabilitation Hospital.

FIGURE 4. One balance training exercise in each exercise set on was performed with HUR SmartBalance platform.

5.5 Statistical analyses

The results are expressed as means (SD). The normal Gaussian data distribution was verified by the Kolmogorov-Smirnov goodness-of-fit test. The changes in measured parameters for the whole study group was analyzed by using paired-samples t-test. The differences within the with gait difficulties (GD) and without gait difficulties (NGD) groups after the training intervention were analyzed by general linear model (GLM) procedure for main effect. One-way ANOVA was used to compare the groups at baseline and after intervention if the main effect in GLM < 0.05. A chi-square test was also used to compare categorical parameters. Statistical analyses of the data were performed with SPSS software (SPSS 22, SPSS Inc., Chicago, Illinois, USA.). A P value of <0.05 was considered significant.

6 RESULTS

All individuals completed all 16 training sessions, and the average duration of a session was 49±7 min. The main results for the whole study group are shown in Table 3.

TABLE 3. The main results of the intervention for the whole group. Values are mean (SD).

	Pre	Post	p-value
Body mass index (kg/m2)	29±5	29±5	0.939
4 m gait speed test (s)	3.5±0.9	3.3±0.8	0.081
Repeated chair stand test x 5 (s)	13.2±3.3	12.0±2.7	0.001
Short Physical Performance Battery (0-12)	10.4±1.3	10.9±1.2	0.016
Leg Press (1 RM, kg)	66±15	73±14	<0.0001
Chest Press (1 RM, kg)	20±7	22±9	<0.0001
Falls Efficacy Scale (16-64)	24±7	24±7	0.792

When analysed separately the groups with (GD, n=7) and without (NGD, n=13) gait difficulties, the GD group was older than the NGD (77±6 vs. 69±6 years, p=0.011). The groups did not differ from each other according to other measured baseline characteristics.

6.1 Maximal strength

For the whole research subject group the 1 RM in leg press improved 15% (from 66±15 to 73±14 kg, p<0.0001) and in chest press 12% (from 20±7 to 22±9 kg, p<0.0001) after the exercise intervention. When results are viewed and compared between the GD and NGD- groups, the 1 RM in leg press increased 25% for the GD (from 56.7±17 to 65.2±13.4) and 10% for the NGD (from 71.7±9.7 to 78.8±11.9) (p=0.054 for main effect). Accordingly, 1 RM in chest press changed 15% for the GD (from 17.5±7 to 20.3±9.2) and 11% for the NGD (from 21.0±7.2 to 23.2±7.8) (p=0.517 for main effect). The difference in strength gain between the subgroups are illustrated in Figure 5 and 6.

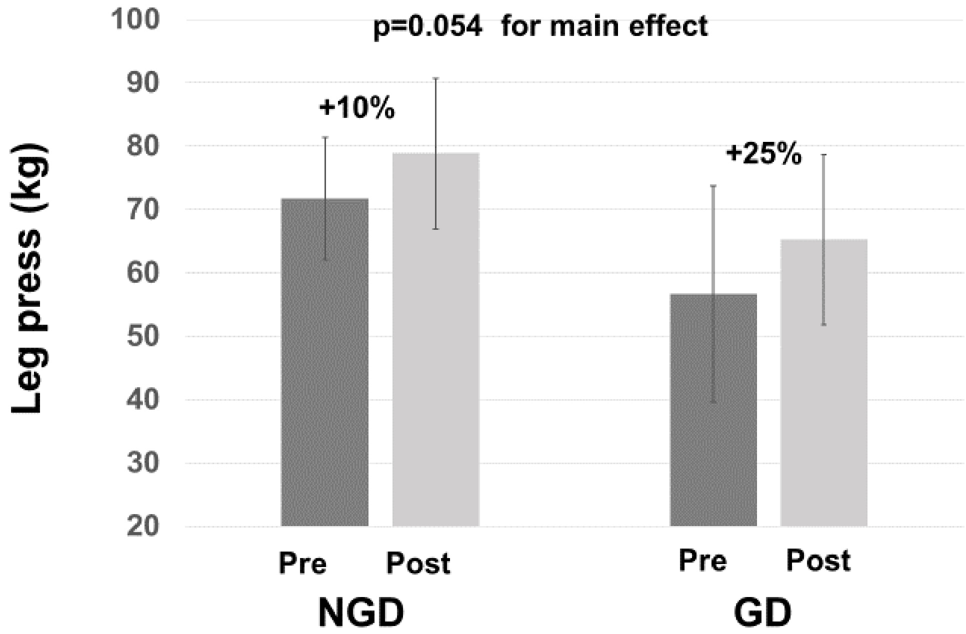

FIGURE 5. The changes for maximal leg press strength (1 RM) for non-gait difficulties group (NGD) and gait difficulties (GD) group.

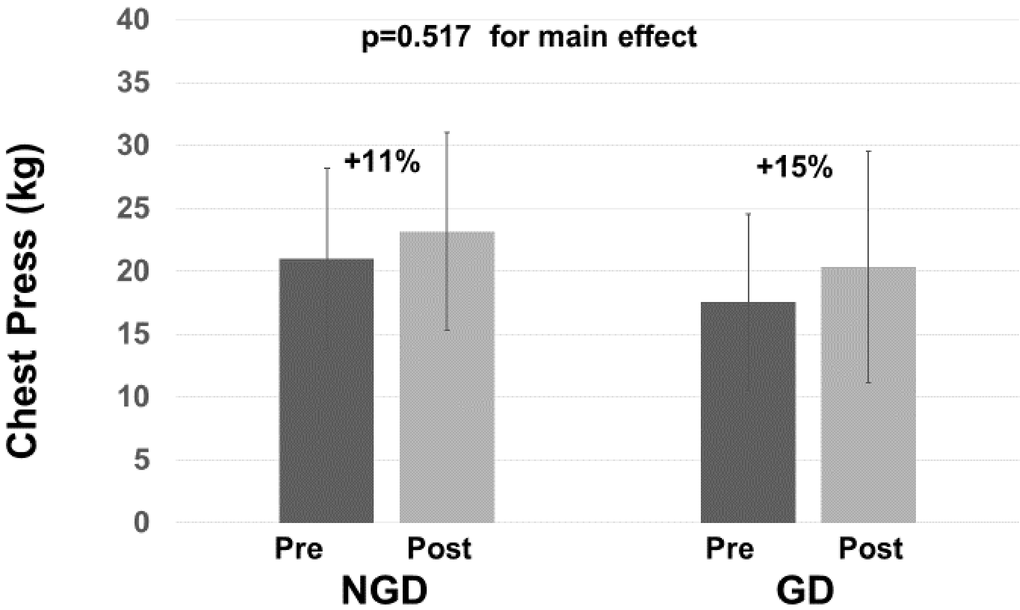

FIGURE 6. The changes for maximal chest press strength (1 RM) for non-gait difficulties group (NGD) and gait difficulties (GD) group.

6.2 Short Physical Performance Battery

SPPB (range 0-12) showed 5% improvement in functional capacity from 10.4± 1.3 to 10.9± 1.2 ($p=0.016$) for the whole group. When analysed separately the GD group and NGD, the GD group was older than the NGD, 77±6 vs. 69±6 years ($p=0.011$). SPPB improved 12% for the GD and 1% for the NGD ($p=0.001$ for main effect). The groups differed at baseline in SPPB (GD 9.4±1.2 vs. 11.2±0.5, $p<0.0001$), but no longer after the two months physical training intervention (GD 10.6±1.5 vs. 11.2±0.6, $p=0.199$) i.e. the GD was at same SPPB level than the NGD at the end of intervention. The differences in SPPB between the subgroups are illustrated in Figure 7.

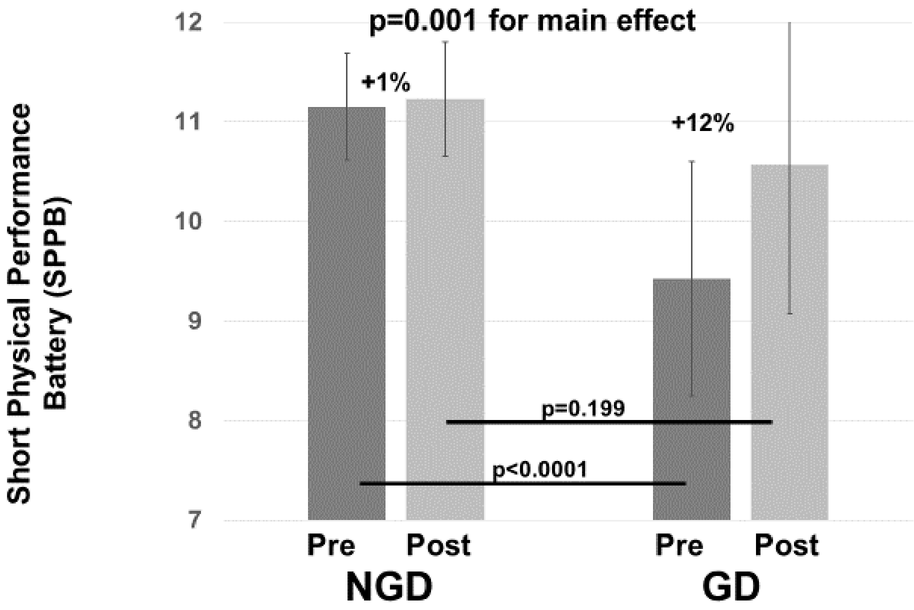

FIGURE 7. The changes for Short Physical Performance Battery for non-gait difficulties group (NGD) and gait difficulties (GD) group.

6.2.1 Gait speed

For the whole group, the change in gait speed was not statistically significant (from 3.5±0.9 to 3.3±0.8), p= 0.081. Gait speed time decreased 2% for the NGD group and 8% for the GD group but the result was not either statistically significant (p=0.351 for main effect). For the NGD group the intervention did not have much effect on 4m gait speed time but the level over all in this group was relatively good. In fact all except one individual from the whole research group scored full points (4) from the section according to SPPB point scale. The differences in gait speed between the subgroups are illustrated in Figure 8.

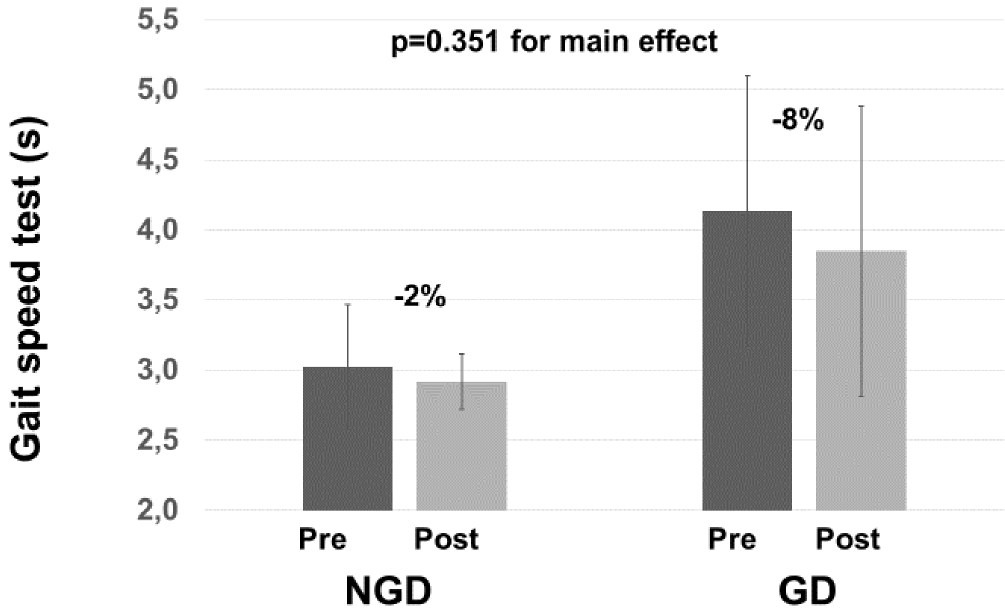

FIGURE 8 The changes for gait speed test time for non-gait difficulties group (NGD) and gait difficulties (GD) group.

6.2.2 Repeated chair stand test

For the whole group the change in repeated chair stand test time in seconds (from 13.2±3.3 to 12.0±2.7) was statistically significant (p= 0.001). Repeated chair stand test time improved 6% (from 11.8 ±1.7 to 11.1±1.7) for the NGD group and 13% (from 15.9±3.8 to 13.9±3.3) for the GD group (p= 0.040 for main effect). The groups differed more at the baseline (p=0.006) than after the intervention (p= 0.027). The differences in repeated chair stand test between the sub-groups are illustrated in Figure 9.

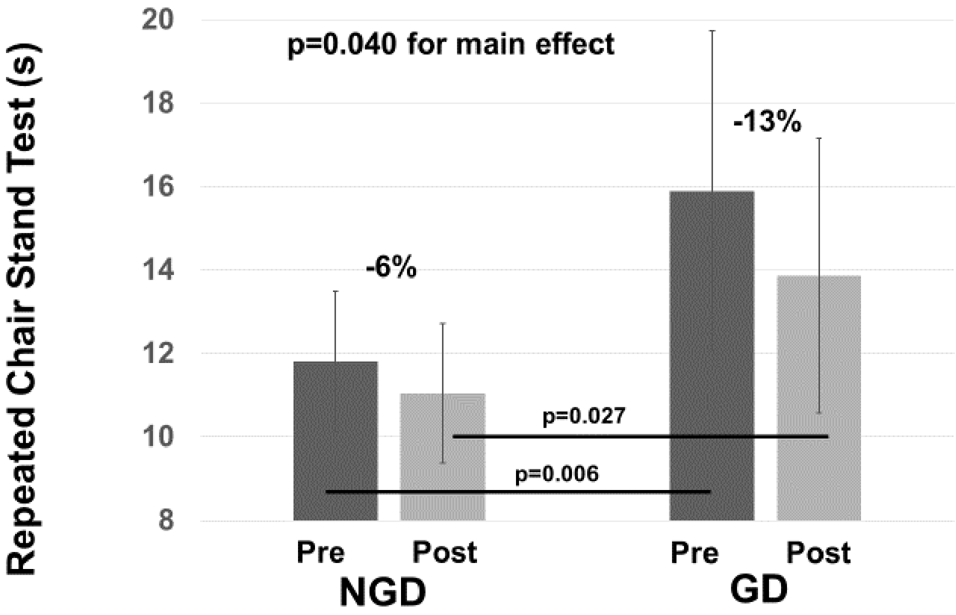

FIGURE 9 The changes for repeated chair stand test for non-gait difficulties group (NGD) and gait difficulties (GD) group.

6.3 Falls Efficacy Scale (FES- I)

The results in FES-I scale (range 16 - 64) for the whole group remained unchanged, 24±7 on average in pre and post measurements. The intervention had no statistically significant effect on FES-I scale (p= 0.792) for the whole group. When comparing the results in NGD (20.2±2.7 to 19.7±2.5) and GD (26.4±6.6 to 28±7.1) groups, no statistically significant effect was found (p= 0.312). The differences in FES-I between the subgroups are illustrated in Figure 10.

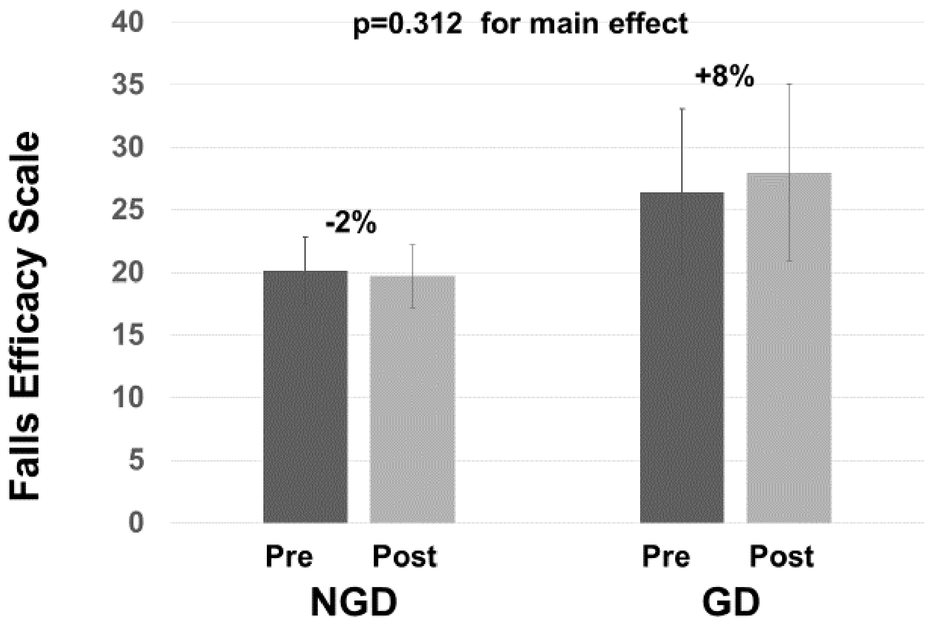

FIGURE 10. The changes for Falls Efficacy Scale for non-gait difficulties group (NGD) and gait difficulties (GD) group.

7 DISCUSSION AND CONCLUSIONS

The aim of this study was to investigate the effectiveness of an exercise training intervention using automated intelligent technology in increasing functional capacity in community-dwelling aging adults. The results of this study showed that progressive strength and balance training intervention of two months, according to current exercise guidelines for seniors, delivered with smart technology is effective for increasing functional capacity and maximal upper and lower body strength. Especially, the intervention was most beneficial among aged individuals who reported gait difficulties at baseline. This appeared as increased functional capacity that consequently reached the same level with individuals without gait difficulties. The exercise related use of modern intelligent technology applications and machines that allow features like individual training implementation, training, automated progression and follow up, may be potential pathways of promoting safe walking and improved quality of life in aging adults.

In this section, the different dimensions of the study results are discussed and additionally considered in the light of existing research. Furthermore, the validity and reliability of this study are addressed, followed by brief insight into study ethics and technology aspects.

7.1 Short Physical Performance Battery

The results of SPPB showed relatively small 5% increasement for the whole group but when analysed separately individuals who reported gait difficulties at baseline and those without reported gait difficulties, SPPB improved 12% for the GD and 1% for the NGD. The groups differed at baseline in SPPB but no longer after the two months physical training intervention. In other words, at this point in the end of the intervention the group with GD was at same level than the NGD group. This seems to implicate that the intervention was more effective among individuals who experience gait difficulties. In this light, subjective gait difficulties could possibly indicate or predict issues in functionality even though the functional ability level would be relatively high.

The group (n=20) scored overall relatively high on SPPB which would place them in the well-functioning end of this specific functional scale, a fact that is important also in the light of the results overall in this study. Although SPPB is shown to demonstrate the functioning and future adverse outcomes also for the individuals who score in the highest end of SPPB points spectrum (Guralnik et al. 1994). One-point change has been shown to have a clear effect on predicted unwanted outcomes risks like mortality and institutionalization (Guralnik et al. 1994: Perera et al. 2006). Perera et al. (2006) suggest a recommendation based on their research for a meaningful change in SPPB to be 0.5 for small meaningful and 1 point for substantial meaningful change. In this study the improvement for GD group was over one point, from 9.4±1.2 to 10.6±1.5 while for NGD group it was basically non-existent (11.2±0.5 to11.2±0.6). In conclusion, the exercise intervention had a substantial meaningful effect on those individuals who experienced gait difficulties.

7.1.1 Gait speed

When the different sections of Short Physical Performance Battery are viewed in more detail, gait speed increased moderately, and so did repeated chair stand test time. The gait speed increased 2% for the NGD and 8% for the GD, when the mean change on 4m gait speed time is converted into gait speed, it is 0.05m/s for the whole group, 0.03m/s for NGD and 0.09m/s improvements for GD group. As gait speed is widely associated and has predictive value with multiple negatively associated health outcomes like disability, institutionalization, cognitive decline and even mortality (Abellan et al. 2009) it has associations with increasing survival with only 0.1 m/s increments (Studenski et al. 2011). Likewise, Perera et al. (2006) have earlier suggested 0.1. m/s improvement in 4m gait speed to be substantial meaningful change and 0.05m/s small meaningful change. Although their recommendation for sample size is notably bigger (n=130+) (Perera et al. 2006). Also, in our study the group mean score for SPPB was higher (10.6/11.2) than in the study Perera et al. (2006) present (8.3) but the mean age of 74 was quite similar. This could additionally implicate that the group in this study was relatively physically well performing even though they might have experienced walking difficulties. For example Studenski et al. (2003) defined individuals who walked 1.0m/s or faster as fast walkers, and 0.6-1.0m/s as intermediate walkers, whereas they stated that these two groups had a clearly smaller risk of hospitalization within the next 36 months than the slow (<0.6 m/s) walking group. All individuals in our study belonged either into intermediate or fast walkers. Noteworthily the GD was older than the NGD, 77±6 vs. 69±6 years that could explain the prevalence of walking difficulties and differences in gait overall.

7.1.2 Repeated chair stand test

Repeated chair stand test time improved 6% for the NGD group and 13% for the GD group and the groups differed more at the baseline than after the intervention. The change for the whole group was statistically significant. Therefore, could it perhaps be presumed that the effect of this intervention was primarily functional with a shift on strength associations rather than gait improving. Additionally, the achieved strength gain discussed in the next chapter is likely to have some effect repeated chair stand test time as lower limb strength is an important factor in conducting this movement.

7.2 Maximal Strength

The improvements in maximal strength in leg press and chest press did apply to the whole group. The maximal strength in leg press improved 15% and in chest press 12% as a result of the two-month exercise intervention. When results are viewed and compared between the GD and NGD groups, the change in strength is more visible in GD group. Probably one outcome achieved on the side of the strength gain was a new way of conducting strength training, especially the higher intensity, concerned both the physiotherapists and the individuals doing the training. A lot of evidence also signify the importance of high intensity and this is often the key to better results of strength training (Liu & Latham 2009). There was still relatively big variation in the estimated 1RM results although this might be explained by the small study population; the different backgrounds of the individuals in strength training, the physical fitness overall and also the age of the individuals varying from 62 to 85 years old. The GD group had predictably generally lower strength levels to start with, that could furthermore explain the perceived walking difficulties and lower functionality level, but also the bigger strength gain.

The results from this study are consistent with previous studies implicating that progressive strength training would improve physical functioning (Liu & Latham 2009), functional capacity (Aagaard et al. 2010; Williams et al. 2007) and gait (Papa et al. 2017; Fiatarone et al. Chou et al. 2012; Fiatarone et al. 1994). Although the heterogeneity of existing strength training interventions (Liu & Latham 2009) makes the comparison more challenging. Described with Short Physical Performance Battery and strength gain, the results furthermore support the earlier findings of progressive strength training being related to favourable effects on functional mobility and balance (Chou et al. 2012; Howe et al. 2011; Papa et al. 2017). In the light of improvements in and the predictive value of SPPB, this kind intervention could perhaps have positive effects on also preventing falls (Gillespie et al. 2012; Papa et al. 2017) but based on this study it is not possible to draw conclusions on fall rates as we are not studying falls. This would require further research. Additionally, the study group was relative well-functioning and scored high on SPPB to begin with even though the whole group did still significantly increase their point rate from the statistical point of view. It is well established that functional difficulties like gait deficits could indicate future falls but in what scale, it is impossible to tell based on our research data. Although when designing purely falls prevention interventions, it would probably be more beneficial to pick the individuals who report gait difficulties and increased fear of falling to target the preventive actions meaningfully.

7.3 Fear of falling

The intervention had no difference in the participants concerns of falling measured with FES-I. When GD and NGD groups were analysed separately, there was a small decrease in fear of falling for NGD and increase for GD group. It is interesting how the small difference is distributed between these two groups and naturally there can be several reasons for this outcome. Fear of falling is generally affected for example by earlier falls, high age, female gender and declining muscle strength, power and physical performance (Sheffer et al. 2008; Trombetti et al. 2016), not just functional capacity level itself.

Sheffer et al. (2008) reported varying prevalence of fear of falling (FOF) in their systematic review of 28 studies, of which 21 reporting the prevalence of FOF, among community dwelling older adults, with results scaling from 3 to 85 %. Also, in our study we had a relatively big variation in existing fear of falling that could be based on the small population, especially among the group who experienced gait difficulties. Taken the positive changes in SPPB and strength among the whole group, the result might indicate that for some reason in this group fear of falling was not connected in the level of functional capacity. Obviously in a small sample like ours, big individual changes have relatively remarkable effect on the results than in a bigger group. For instance, one individual in our GD group reported the biggest increasement (56%) in fear of falling but simultaneously scored a better result (2p) in SPPB. Although the changes for this individual in strength gain were relatively modest, so one can only guess the reasons, perhaps greater increase in muscle strength would have correlated better with fear of falling in this case.

Naturally, there can be multiple other reasons in individual's life that have not been investigated in this study that could have affected fear of falling and below group- average strength gain. Especially due to the small study sample it brings a certain level of uncertainty. Although it is inevitable that individuals live their lives as desired, have different genes and end up in varying life situations, no matter how big or small the study sample is. Another reason for the unchanged fear of falling within the whole group could be the group had over all good physical level and were probably not in biggest risk of experience fear of falling or falls overall. It may be that before balance problems can be conceptualized as increased fear of falling, they might appear in form of other functional or structural issues like decreased muscle strength and gait difficulties. As gait deficits, balance problems, muscle strength and power are all connected, this would also be an important slot to address these issues before the decrease of functionality is accelerated.

7.4 Validity and reliability

The examination of research related quality is an important part of making and reporting a study. These quality factors can be investigated through validity and reliability, in other words to evaluate whether the study has examined it was meant to (validity) and are the measurement results are repeatable (reliability) (Metsämuuronen 2011, 65,74). The validity of the whole study is related to the accuracy and quality of the chosen measure (Metsämuuronen 2011, 74). Often a distribution between internal and external validity is used, where the internal refers to how well the study is operated the and the external to what extent it is generalizable (Metsämuuronen 2011, 65). Carefully chosen measures, study design, theory and sampling are central parts of validity (Metsämuuronen 2011, 65).

To justify the chosen measures, Short Physical Performance Battery and Falls Efficacy Scale, FES-I has proven to have good internal reliability and repeatability (Yardley et al. 2005) and is shown to relevant in measuring fear of falling with its 16 questions (Hill et al. 2014). SPPB has the capacity of delivering and predicting information of the human performance; and risk of disability, mortality and institutionalization also in community-dwelling population (Guralnik et al. 2000; Guralnik et al. 1994). The test has demonstrated to have an excellent predictive validity, average or good concurrent validity and good test-retest reliability (Freiberg et al. 2012). Furthermore, we chose two exercises, chest press and leg extension, to get a description of overall upper and lower body strength. The advantage of used 1RM- testing is that it is similar to natural functions like moving heavy loads but on the downside, it has generally been estimated to be less safe than isokinetic testing (Forman et al. 2017). Although with proper familiarization, instructions, and supervision the 1RM testing has been shown to be safe for also the elderly population (Fiatarone et al. 1994; Shaw et al. 1995). In this study we used a multiple RM test as it places even less stress on the musculoskeletal system. Certainly the specifics of different types of maximal strength estimations needs to be acknowledged before making assumptions, but maximal strength testing is always exposed to the daily change in human performance, despite of the measurement method.

The internal validity can be considered from different viewpoints whereas one of them is content validity (Metsämuuronen 2011, 74). It describes whether the chosen concepts of the study and the measures are right, accordant to the theory and correctly operationalized (Metsämuuronen 2011, 74). In this study, it naturally is an essential question how to conceptualize and measure physical functioning, physical performance or functional capacity. For example, Liu & Latham (2009) used the term physical function and primarily assessed it at the level of impairment, functional limitation, and disability. Then again Pasanen et al. (2017) used objective or subjective measures of performance, like gait speed or different patient report scales to measure functional capacity in their study. In our study we used the term “functional capacity” to assess individual well-being and overall ability to physically function, measured with trustful measures, maximal strength and SPPB, to describe functional capacity. It appears that in the light of research evidence there is not one and only, or even most common, way of defining and operationalizing functional capacity. As it is a broad term, the focus and chosen measures are also dependant on the interest of the research group but in our case we wanted to use comprehensive, validated and understandable measures that are strongly correlated to vital outcomes in the lives of older individuals.

External validity, the question how generalizable the results are and into which groups, we can affect with study design and sampling whereas threats to validity have been eliminated. The small study sample is a limitation in our study. In small samples, the results can be generalized into smaller extent than with bigger samples (Metsämuuronen 2011, 67). Moreover, with the recruitment process used in this study, selection could have occurred, as the enrolment was likely to be influenced by own overall interest in exercise. The selection wasn't truly random in any sense, but an individual choice, hence the skewness in the set of data is inevitable. Consequently, the sample might not be representative of the population intended to be analysed, in this case community dwelling older adults. The selection could also have affected the assumptively high motivation and further the good adherence and especially the good baseline physical functioning level in this study. If the baseline physical fitness would have been poorer, we might also have seen a greater increasement in physical functioning. The in- and exclusion criteria and study design additionally steered the sample heterogeneity in the extent that the individuals had to have the physical, cognitive and economical possibility to take part, in other words to, for example, independently transfer between home and Oulunkylä rehabilitation hospital. The subjects were besides more likely to be representing the same geographic area, as one of the announcement channels was the local newspaper. This decreases the possibilities to accurately generalize the results in for example the similar age population in Southern Finland. However, we managed to maintain good representability in the different backgrounds of strength training which could be more important in terms of the results than the portrayed geographic area. Nevertheless, the study sample had undeniably good overall physical fitness and functional capacity. Like stated, it is an interesting question whether the results for this study would have been better if the baseline functional capacity had been poorer.

To ensure the reliability in this study we have strived to carefully describe the different stages of the conducted research. Additionally, the staff in Oulunkylä rehabilitation hospital was trained to ensure there was no lack in the required knowledge and technology usage that could compromise the study flow and data collection. Consequently, the good technical and practical operability of the intelligent exercise concept can be seen as a strength in this study. The research data has also been collected and analysed by a different person which might increase the reliability. Furthermore, the structured form of used questionnaire FES-I favors the repeatability aspect.

7.5 Ethics of the study

The guidelines of Finnish Advisory Board on Research Integrity, "Responsible conduct of research and procedures for handling allegations and misconduct in Finland" from the year 2012 (TENK 2012) were followed in this research project. The participants were informed about the risks of physical activity intervention and the methods used in the study. All participants were voluntary and signed a written consent to take part in the study. The Oulunkylä data protection policy was followed in the process of handling, preserving, and analysing the research data. A privacy policy register (Finnish: rekisteriseloste) was created according to the procedure of Oulunkylä Rehabilitation Hospital. Only the researchers involved in this study were allowed to access the measurement results. The research group were also bound by the obligation to maintain confidentiality. All the analyses were made anonymously using identity codes so that the researchers were and are not able to identify the participants from the results. The participants have the right to interrupt the research and request the disposal of the results without any reasoning.

7.6 Aspects of technology and motivation in the promotion of physical activity among the elderly

Successful motivation and promotion of physical activity among the elderly are visible challenges of our time. Even though the importance of maintaining independency and functionality is acknowledged, we still struggle in finding the motivational ways of promoting active lifestyle among the elderly and the adherence yet remains low (Leikas 2008, 52; Foreman er al. 2017). The rapid development of technology, that also describes our current world, could at its best offer assistance to solving this problem and bring new ways of motivating and engaging the elderly. Even though the motivators of older individuals and exercise training were not studied in this thesis, according to the research new technology could promote the quality of life, health, and independency (Leikas 2008, 52) and increase the participation during the old age (Foreman et al. 2017). Noteworthy the adherence was extremely high in our study which could implicate that there are motivating and useful aspects of this intelligent technology concept. Gaming and technology have indeed been a standard for maintaining and improving cognitive functions (Leikas 2008,53) and many other areas of rehabilitation. However, concerning the matter of physical activity itself, full spectrum of technology could be better utilized (Leikas 2008, 53). Technology, especially for supporting physical activity might still be underused among elderly population and one cannot help the thought to cross that is partly because of prejudice or misperception that we have towards elderly and technology. That is, even though, the narrow experience rising from this study implicates that the elderly enjoyed the intelligence of the gym environment that brings them senses of safety, ease and additionally motivation through progression and tracking. When asked for voluntary user feedback the subjects were pleased with automation connected to the training and the ease of using personal RFID bracelets. Perhaps simple and forward usage of new technology and further research about the advantages among this population would also change the attitudes that the younger have towards technology and aged individuals. But also promoting and increasing awareness about the advantages and possibilities among elderly is important.

Despite of the scope been on the individual when conducting this study, we nevertheless also aim to find new ways to promote the health and independency of the older population. We also acknowledge that in the big picture promotion of physical activity among the elderly needs to occur on multiple levels (Bangsbo et al. 2019). Structural factors, for example social and structural inequality are remarkable determinants of physical activity, as are also senses of meaning and support on both social, cultural, and physical level (Bangsbo et al. 2019). Ecological models add even broader aspect into the determinant discussion. They include also the definition of social and physical environment, like industrialization, urbanisation and the economic situation

(Bauman et al. 2012). It is important to realize that the physical and social environments can at worst accelerate the decrease of functionality even though these are determinants that the society can influence (Rantanen 2013).

In this study many of the obstructive factors for physical activity were probably eliminated or they did not primitively exist. For example, the recruitment did perhaps reach mainly those who live nearby Oulunkylä Rehabilitation Hospital or those who did not have challenges with the transitions between home and the hospital. Social support and accurate, comprehensive information were perhaps provided from the group members and the physiotherapists in charge of the training. This might partly explain the good adherence in this study, since sometimes the crucial obstacle for physical activity can be for example the lack of information. Burton et al. (2017), who have examined the motivators and barriers for strength training, highlight the value of trained professionals and the spreading of right information. When promoting physical activity, the factors that the elderly themselves value and experience as motivating, like capability, decreased morbidity and prevention of falls should be highlighted (Burton et al. 2017). The right information in turn helps to prevent and correct misbeliefs or even fears about strength training or exercise over all (Burton et al. 2017).

Hence when designing physical activity interventions for the elderly, more meaningful and concrete, individualized objectives outcomes ought to be used (Burton et al. 2017; Forman et al. 2017). Therefore, interventions should not necessarily only concentrate on increasing maximal functional capacity (Forman et al. 2017). Consequently, the representation and delivery of the outcomes should be thought through as the individuals after all are in charge of choosing their health-related habits. On the other hand, because functionality or functional capacity is widely connected into the ability to perform daily activities and the level independency, it is something that should be supported as long as possible. Especially as the quality of life is often more important driver to the elderly themselves than just being alive. That is why maintaining the functionality is important not only because of minimizing the risk of morbidity and mortality but that is also where the priorities and motivation of the individuals arise from. The challenge is how to learn how to wrap the outcomes in the right way to motivate the elderly. Through follow- up to our research subject group we could have studied that how many in fact did continue their physical activity habit and strength training after the intervention. This way we could have found some indication of how we succeeded in considering the motivational aspect, but it is hard to tell with the current data. Although some voluntary comments about the intervention that were captured from the subjects were very positive, the training had "cheered up the mood", "increased stamina in the daily living" and "increased walking ability". Anyhow, the evidence is getting clearer that at least on populational level we are struggling in increasing the physical activity levels of older adults because the lack of our approach of life quality related goals (Morgan et al. 2019).

7.7 Conclusions

Exercise training intervention using automated intelligent technology is effective to increase functional capacity expressed as short physical performance battery especially in aged individuals who report gait difficulties at baseline. New physical activity promoting concepts using modern technology may be potential individual motivators promoting safe walking, improved functional capacity and better quality of life in aging adults.

As an overview, the scientific evidence of the pathways of improving functionality and health of the elderly is well established but the gap between theory and practice is sometimes prominent. The issue how to motivate individuals and promote their physical activity levels in an enduring way often remains a challenge. Perhaps this kind of technology that provides useful, practical and theory related tools could be useful in decreasing the above-mentioned gap. Finally, it needs to be highlighted that hopefully the value of this study is not only seen as physical outcomes and numbers, but as something that enhances the positive attitudes towards the combination of aging, technology, and physical activity.

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ATTACHMENT 1: Content of the medical examination.

Significant illnesses, surgeries, hospital care intervals and prescribed medicines were mapped and documented. The information was collected from Navitas (Uudenmaan shp:n yhteinen sairauskertomusarkisto), Kanta, (electric recipe centre and preliminary information form). Dizziness, chest pain in rest and under strain (angina pectoris), claudication and short of breath were investigated through interview. Any hospital care periods within the last year, smoking history, earlier falls, sight, and hearing difficulties are also examined. Cognition orientation and co-operation was also evaluated during the examination; example wise the month, president, current topic of news was asked. Finger-nose tip- test was performed, also walking ability, toe and heel walking and squatting was assessed. A possible walking aid was reported. Joint function for shoulders, hips and knees was evaluated. Additionally, auscultation of heart and lungs and swelling was assessed. Blood pressure in a standing and sitting position, resting heartbeat and saturation from fingertip was measured. Current pain on VAS- scale and weight was examined.

ATTACHMENT 2: Preliminary information form.

OULUNKYLÄN KUNTOUTUSSAIRAALA **ESITIETOLOMAKE**
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Nimi	Henkilötunnus
Lähiosoite	Postinumero ja postitoimipaikka
Puhelin	ID (OKS täyttää)
Ammatti	Eläkkeellä ☐ kyllä ☐ ei

MITKÄ TAHOT AUTTAVAT KOTONA SELVIYTYMISTÄNNE?	**MITEN USEIN SAATTE APUA?**
☐ Kotisairaanhoito	
☐ Kotipalvelu	
☐ Päiväsairaala/päiväkeskus	
☐ Omainen/omaishoitaja	
☐ Ateriapalvelu	
☐ Turvapuhelin	
☐ Siivousapu	
☐ Pesuapu (saunotus, kylvetys yms.)	
☐ Pyykkipalvelu	
☐ Lääkkeiden annosjakelu	
☐ Muuta, mitä	

ASUMISMUOTO

☐ kerrostalo	☐ omakotitalo	☐ vanhainkoti
☐ rivitalo	☐ palvelutalo	☐ muu, mikä? ____________ ____________________
☐ talossa on hissi	☐ portaita sisällä	☐ portaita ulkona

Kanssanne asuvat:

Onko asunnossanne puutteellisuuksia tai esteitä, jotka vaikeuttavat kotona selviytymistä? Mitä?

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ESITIETOLOMAKE

TARVITSETTEKO TOISEN HENKILÖN APUA			
Ruokailussa	☐ en	☐ kyllä	mitä apua ______________
Peseytymisessä	☐ en	☐ kyllä	mitä apua ______________
Pukeutumisessa	☐ en	☐ kyllä	mitä apua ______________
Liikkumisessa	☐ en	☐ kyllä	mitä apua ______________
Lääkityksessä	☐ en	☐ kyllä	mitä apua ______________
WC-toiminnoissa	☐ en	☐ kyllä	mitä apua ______________
Kotitöissä	☐ en	☐ kyllä	mitä apua ______________
Asioinnissa	☐ en	☐ kyllä	mitä apua ______________

Käytössänne olevat liikkumisen tai muut apuvälineet		
Oletteko kaatunut viimeisen vuoden aikana?	☐ ei	☐ kyllä, kuinka usein?
Oletteko hakeutunut hoitoon kaatumisen takia?	☐ ei	☐ kyllä
Koetteko, että teillä on kävelyyn tai tasapainoon liittyviä vaikeuksia?	☐ ei	☐ kyllä, mitä?
Haittaako näkökyvyn heikentyminen liikkumista tai jokapäiväisiä toimia?	☐ ei	☐ kyllä, miten?
Pelkäättekö kaatumista?	☐ ei	☐ kyllä
Onko teillä sydämen rytmihäiriöitä tai rintakipua?	☐ ei	☐ kyllä
Joudutteko käymään WC:ssä tarpeettoman usein erityisesti öisin?	☐ ei	☐ kyllä
Onko Teillä muistihäiriöitä, jotka vaikeuttavat kotona selviytymistä?	☐ ei	☐ kyllä, millaisia?
Viimeaikaiset sairaudet/Sairaalahoidot		
Mikä sairauksistanne tai vaivoistanne haittaa tällä hetkellä eniten selviytymistänne kotona?		

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Arvioikaa millainen on mielestänne terveydentilanne (fyysinen) tällä hetkellä?	☐ Hyvä ☐ Melko hyvä ☐ Kohtalainen ☐ Melko huono ☐ Huono
Arvioikaa millainen on mielestänne toimintakykynne tällä hetkellä?	☐ Hyvä ☐ Melko hyvä ☐ Kohtalainen ☐ Melko huono ☐ Huono
Arvioikaa millainen on henkinen jaksamisenne/mielialanne tällä hetkellä?	☐ Hyvä ☐ Melko hyvä ☐ Kohtalainen ☐ Melko huono ☐ Huono
Mitä harrastatte?	

Minkälainen ruokavalionne on?	
Onko teillä allergioita?	
Käytättekö alkoholia?	☐ Ei ☐ Kyllä, miten usein?
Tupakoitteko?	☐ En ☐ Kyllä

Mitä odotatte tulevalta hoitojaksoltanne, omat tavoitteenne/toiveenne?

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ESITIETOLOMAKE

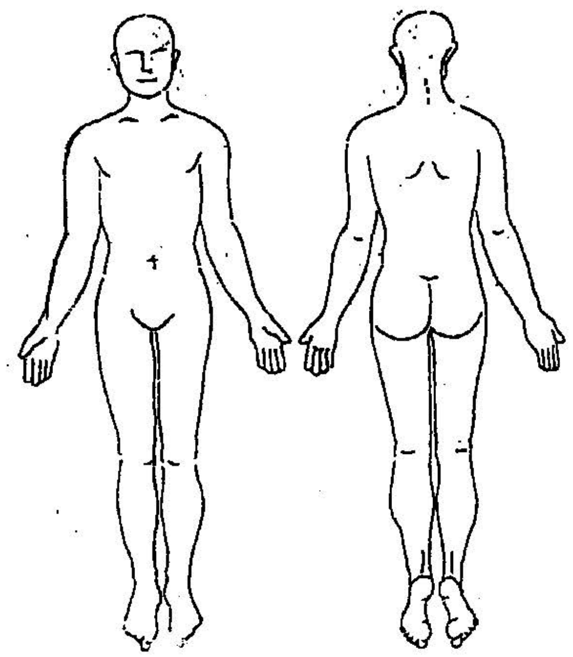
Mikäli tunnette kipua jollakin kehonne alueella, merkitkää se alla oleviin kuviin seuraavilla merkeillä:

Puutuneisuus, tunnottomuus XXXXXXXX

Särky, jomotus, tylppä kipu ///////////

Pistävä, terävä kipu OOOOOOO

Merkitkää tarkoin kaikki ne alueet, joissa tunnette kipua.



Esitiedot antoi

_________________________ _______________________________

Päivämäärä Allekirjoitus

Lomakkeen tiedot kävi läpi ja tarvittaessa täydensi

____

Lääkäri/sairaanhoitaja/lähihoitaja/fysioterapeutti

ATTACHMENT 3: Permission to conduct research

OULUNKYLÄN KUNTOUTUSSAIRAALA
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HUR Medical Concept: Kaatumisten ehkäisy
Älykkäässä kuntosaliympäristössä toteutetun liikuntaintervention vaikutus lihasvoimaan, tasapainoon ja toimintakykyyn

Suostumus

- **Tutkimukseen osallistumiseen**
- **Mittausten tekemiselle ennen kahden kuukauden (2 kk) kuntosaliharjoittelua ja uusintamittauksille harjoittelun jälkeen**
- **Lääkärintarkastukseen osallistumiseen ennen kahden kuukauden (2 kk) kuntosaliharjoittelua**
- **Laitteista saatavan harjoittelutiedon kerääminen ja käyttäminen; RFID-tunnisteen avulla tieto rekisteröityy HUR Smart Touch suljettuun pilvipalveluun**

Kotimainen yritys HUR valmistaa paineilmatekniikkaan perustuvia kuntoilulaitteita. He ovat kehittäneet myös älyteknologiaa hyödyntäen automatisoidun konseptin kaatumisten ehkäisyyn. Oulunkylän kuntoutussairaala on yli 25 vuoden aikana kehittynyt veteraanien kuntoutuksesta ikäihmisten kuntoutuksen edelläkävijäksi.

Tutkimuksen tarkoituksena on testata HUR Smart Touch-ohjelmistoon kehitetyn konseptin toimivuus ja arvioida ikääntyvien terveyshyötyjä ja konseptin vaikuttavuutta valituilla toimintakykymittareilla. Tutkimuksella pyritään näyttämään, että kahden kuukauden mittainen yksilöllinen kuntosaliharjoittelu on tehokasta ja vaikuttaa henkilön arjen liikunta-aktiivisuuteen ja toimintakykyyn lisäävästi.

Kuntosaliharjoitteluun tullessanne fysioterapeutti tekee Teille fyysisen toimintakyvyn mittauksia (kehonkoostumus, lyhyt fyysisen suorituskyvyn testistö, kaatumispelkokysely, tasapainon mittaus) ja lisäksi Teille tehdään lääkärintarkastus, jossa tutustutaan luvallanne myös aikaisempiin sairauskertomuksiinne. Kyselylomakkeen avulla kartoitetaan Teidän tämän hetkistä terveydentilaanne ja elämätilannettanne.

Kuntosaliharjoittelu sisältää kaksi kertaa viikossa kahden kuukauden ajan yksilöllisen voimaharjoittelun fysioterapeutin ohjauksessa. Lisäksi kuntosaliharjoitteluun kuuluu tasapainoharjoitusosio. Voitte itse seurata edistymistänne kerta kerralta kuntosalin tietokoneelta. Saatte myös mittaustulokset ja niissä tapahtuvat muutokset tietoonne.

Kuntosaliharjoittelun jälkeen tehdään samat mittaukset kuin tutkimuksen alussa. Lisäksi terveyshyötyä ja toimintakykyä arvioidaan harjoittelujakson jälkeen, ja mahdollisesti kolmen kuukauden (3 kk) kuluttua kirjekyselyllä.

Pyydämme lupaa käyttää antamianne/saamiamme tietoja tutkimuksessamme. Tietonne kirjataan Oksin omaan sairaskertomusrekisteriin. Kaikkia tietojanne käsitellään luottamuksellisesti. Tutkimuksen lopullisissa tuloksissa ei voida tunnistaa yksittäistä asiakasta. Tutkimusta tehdään elokuu 2018 – joulukuu 2018 välisenä aikana.

Sitoudumme noudattamaan tutkimuksessamme arkistolakia (831/1994), EU:n yleistä tietoturva-asetusta (2016/ 679), lakia sosiaali- ja terveydenhuollon asiakastietojen sähköisestä käsittelystä

(159/2007) sekä sosiaali- ja terveysministeriön asetusta potilasasiakirjoista (298/2009). Tietonne hävitetään kun niiden säilytys ei ole enää lakisääteisin perustein, henkilökohtaisen syyn tai tutkimukseen liittyen tarkoituksenmukaista.

Allekirjoittamalla tämän suostumuslomakkeen, annatte suostumuksenne tutkimukseen osallistumiselle ja tietojenne käyttämiselle tässä tutkimuksessa.

Teillä on oikeus keskeyttää tutkimus milloin tahansa ilman erityistä syytä suullisella/kirjallisella ilmoituksella ilman seuraamuksia.

Päivämäärä paikka | Allekirjoitus

Nimen selvennys

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