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NADIA AFRIN

Health-related predictors and outcomes of falls in postmenopausal women

HEALTH-RELATED PREDICTORS AND OUTCOMES OF FALLS IN POSTMENOPAUSAL WOMEN

AUTHOR: NADIA AFRIN

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ABSTRACT

In global terms, falls among older adults are common and a serious public health concern. Approximately every third individual aged 65 and over will fall at least once a year, with fall rates being higher in women than in men. About 10% to 20% of these falls cause serious injuries such as fractures requiring hospitalization. Falling is also associated with considerable disability, e.g. decreased functioning, loss of independence leading to reduced quality of life and institutionalization. Falls are multifactorial in terms of mechanism, locations and comorbidities. Slips and trips are the most common mechanisms of falls reported by community dwelling older people living in countries with cold climates. There are also several health-related factors, e.g. multiple chronic medical conditions (multimorbidity), especially musculoskeletal disorders are a common important risk factor of falls in the older population. Many studies have been conducted investigating various risk factors for falls among older adults. In contrast, there are few longitudinal studies which have examined the health–related risk factors for falls among postmenopausal women and almost none of these studies have differentiated between the type of falls (slip vs nonslip). By identifying risk factors, it may be possible to target preventive measures to reduce the risk of falling. Thus, it is important to determine the incidence, causes, mechanism, severity and consequences (i.e. patterns) of falls as well as changing patterns with age so that preventive measures can be implemented already among postmenopausal women. This present thesis is based on a large population–based sample (N=14220) of the OSTPRE study (Kuopio Osteoporosis Risk Factor and Prevention Study) which began in Kuopio, Finland in 1989. The main objective of the present study was to assess the risks of falling as related to morbidity, with special references to musculoskeletal disorders and if risk predictions differ by type (slip/nonslip) or severity (non-injurious/injurious) of falls in postmenopausal women. In addition, the prediction of future fractures according to previous falling history was also evaluated.

The association between morbidity and falling risk according to different type of falls (slip/nonslip) in postmenopausal women was examined in this thesis. The risk of fall increased by 1.41 fold (95% CI, 1.24–1.60) with ≥3 chronic medical conditions (multimorbidity) compared to healthy individuals. With respect to the type of falls, multimorbidity strongly predicted frequent nonslip falls (OR = 2.57; 95% CI 2.01–3.29) but was only weakly linked with frequent slip falls (OR = 1.46; 95% CI 1.17–1.80). The role of (specific) chronic medical conditions as risk factors for falls was also examined. The prevalence of musculoskeletal disorders (MSDs) was 53% and excess number of women who

fell due to MSDs was 10.3% more than that to any other disease main class. MSDs predicted falls (OR=1.38; 95% CI 1.26–1.50) and the association was stronger for nonslip (OR=1.56; 95% CI 1.39–1.75) than slip falls (OR 1.22; 95% CI 1.08–1.38) when compared to the women without MSDs. These predictions increased significantly along with the increasing number (1,2, ≥3) of MSDs. There were no significant differences between different musculoskeletal disorders and the fall risk. In addition, the relationship between a history of falling and the risk of future fractures was investigated. A history of injurious falls increased the risk of other fractures (n= 431, OR = 1.86, 95% CI 1.24–2.80) more than the respective risk of major osteoporotic fractures (n= 380, OR = 1.37, 95% CI 0.89–2.10).

In conclusion, multimorbidity and musculoskeletal disorders are important risk factors for falls, especially for nonslip falls among postmenopausal women. A history of injurious falls is a stronger predictor for other fractures than for typical major osteoporotic fractures. The early identification of these risk factors (before old age) could be a relevant aspect of screening and prevention strategies when striving to minimize the health care burden related to falls among the geriatric population.

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TIIVISTELMÄ

Vanhempien naisten kaatumiset ovat globaalisti yleinen ja vakava kansanterveysongelma. Noin joka kolmas yli 64-vuotias nainen kaatuu ainakin kerran vuodessa ja nämä kaatumiset ovat naisilla yleisempiä kuin miehillä. Noin (10–20)% näistä kaatumisista johtaa vakavaan vammaan, kuten sairaalahoitoa vaativiin luunmurtumiin. Kaatumisiin liittyy myös huomattavaa toimintakyvyttömyyttä, liikuntakyvyttömyyttä ja riippuvuutta johtaen elämänlaadun heikkenemiseen ja laitoshoitoon. Kaatumiset ovat monen tekijän aiheuttamia. Liukastumiset ja kompastumiset ovat kotona asuvien vanhempien ihmisten tavallisimmat kaatumismekanismit kylmemmän ilmaston maissa. Terveyteen liittyvistä tekijöistä monisairastavuus ja erityisesti tuki- ja liikuntaelin (TULE) -sairaudet ovat yleinen ja tärkeä kaatumisten vaaratekijä vanhemmilla ihmisillä. On tehty useita tutkimuksia erilaisista kaatumisten vaaratekijöistä. Kuitenkin pitkittäiset tutkimukset vaihdevuodet ohittaneiden naisten terveystekijöistä ovat harvinaisia, eikä yksikään niistä ole verrannut liukastumisesta johtuvia ja muita kaatumisia keskenään. Tunnistamalla vaaratekijät voidaan ennaltaehkäisevät toimenpiteet kohdentaa ja näin vähentää kaatumisvaaraa. Siksi on tärkeä saada riittävä kuva kaatumisten yleisyydestä, syistä, mekanismeista, vakavuusasteesta ja seurauksista sekä iän vaikutuksista näihin niin että ehkäisytyö voitaisiin aloittaa jo pian vaihdevuosien jälkeen.

Tämä väitöskirja pohjautuu Kuopion Osteoporoosin vaaratekijät ja ehkäisy (OSTPRE)-tutkimuskohorttiin (n=14220), joka on väestöpohjaan suhteutettu vuonna 1989 aloitettu kaikille v. 1932–41 syntyneille Kuopion läänin naisille tarkoitettu prospektiivinen kohorttitutkimus. Väitöskirja käyttää hyväkseen v. 1989, 1994, 1999 ja 2004 kerättyjä OSTPRE-kyselyiden tietoja. Väitöskirjan päätarkoitus oli arvioida sairastavuuden ja erityisesti TULE-sairauksien roolia kaatumisissa sekä vaihteleeko kaatumisvaara kaatumisen tyypin (liukastuminen/muu) tai vaikeusasteen (vamma -/+) mukaan. Myös arvioitiin, lisääkö kaatumishistoria tulevia murtumia.

Tämä väitöskirja tutki, lisääkö sairastavuus kaatumisvaaraa vaihdevuodet sivuuttaneilla naisilla ja vaihteleeko tämä vaara kaatumistyypin ((liukastuminen/muu) mukaan. Jos naisella oli kolme tai useampia kroonisia sairauksia, kaatumisvaara lisääntyi terveisiin verrattuna seuraavasti: OR=1.41 (95% CI 1.24–1.60). Edellä mainittu monisairastavuus lisäsi paljon enemmän muiden kuin liukastumisten vaaraa, jos mukaan luettiin vain useammin kuin kerran kaatuneet: OR=2.57 (95% CI 2.01–3.29), mutta vastaavien liukastumisesta johtuvien kaatumisten vaara ei sanottavasti lisääntynyt: OR=1.46 (95% CI 1.17–1.80). Myös tiettyjen sairauksien/sairausryhmien aiheuttamaa

kaatumisvaaraa tutkittiin. TULE-sairauksien yleisyys oli suuri: 53 % naisista ilmoitti sairastavansa niitä ja niiden syyosuudeksi arvioitiin 10.3 % kaikista kaatumisista, mikä oli saman suuruinen kuin muista sairauksista johtuvien syyosuuksien summa. TULE-sairaudet ennustivat kaatumisia yleensä (OR=1.38 (95 % CI1.26–1.50) ja muiden kuin liukastumisesta johtuvien kaatumisten vaara oli suurempi (OR=1.56, CI 1.39–1.75) kuin liukastumisesta johtuvien kaatumisten vaara (OR=1.22 (95% CI 1.08–1.38). Myös yksittäiset TULE-sairaudet lisäsivät kaatumisvaaraa, mutta se ei vaihdellut eri sairauksien välillä. Tutkittiin myös, miten kaatumishistoria ennustaa tulevia murtumia: vammoihin johtaneet kaatumiset eivät lisänneeet tyypillisten luukatoon liittyvien (lonkka, nikama, ranne, olka) murtumien (n=431) vaaraa (OR=1.37, 95% CI 0.89–2.10), mutta lisäsivät muiden murtumien (n=380) vaaraa (OR 1.86, 95% CI 1.24–2.80).

Yhteenveto: monisairastavuus ja TULE-sairaudet ovat vanhempien naisten kaatumisten – erityisesti muiden kuin liukastumisesta johtuvien kaatumisen – tärkeitä vaaratekijöitä. Vammoihin johtanut kaatumishistoria ennustaa vahvasti muita kuin luukatoon liittyviä murtumia. Näiden vaaratekijöiden toteaminen ennen vanhuutta on oleellista, jos halutaan kehittää kaatumisten ja murtumien ehkäisyn strategioita ja näin vähentää taakkaa, joka liittyy geriatristen potilaiden kaatumistapaturmiin.

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Nadia Afrin

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I. Afrin N, Honkanen R, Koivumaa-Honkanen H, Lukkala P, Rikkonen T, Sirola J, Williams LJ, Kröger H. Morbidity predicts falls differentially according to the type of fall in postmenopausal women. Maturitas. 2016, 91:19–24.

II. Afrin, N., Honkanen, R., Koivumaa-Honkanen, H, Sund, R, Rikkonen T, Williams LJ, Kröger H. Role of Musculoskeletal disorders in falls of postmenopausal women. Osteoporosis Int. 2018;29(11): 2419–2426.

III. Afrin, N., Sund, R., Honkanen, R., Koivumaa-Honkanen, H., Rikkonen, T., Williams, L. and Kröger, H. A fall in the previous 12 months predicts fracture in the subsequent 5 years in postmenopausal women. Osteoporosis Int. 2019:1-9.

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Contents

ABBREVIATIONS

ADL	Activities of daily living
BMD	Bone mineral density
FOF	Fear of falling
ICD	The International Classification of Diseases
MDD	Major depressive disorder
MSDs	Musculoskeletal disorders
OA	Osteoarthritis
OH	Orthostatic hypotension
OR	Odds ratio
OSTPRE study	Kuopio Osteoporosis Risk Factor and Prevention study
PAF	Population attributable fraction
RA	Rheumatoid arthritis
SD	Standard deviation
SPSS	Statistical Package for Social Science
TBI	Traumatic brain injury
THL	Terveyden ja hyvinvoinnin laitos
WHO	World Health Organization
YLDs	Years Lived with Disability
95% CI	95% confidence interval

1 INTRODUCTION

Falls are common among the older population. At least one in every three of home-dwelling older adults aged 65 and over will fall once a year, with approximately half of them experiencing multiple falls (Tinetti et al. 1988, Nevitt et al. 1989, Campbell et al. 1990). The incidence of falls rises with age and is higher in women than in men (Prudham and Evans 1981, Ryynänen et al. 1993, Luukinen et al. 1995, Deandrea et al. 2010). The incidence rates of falls in nursing homes and hospitals are almost three times the rates for community dwelling older adults aged 65 and older (Dunn et al. 1992, Rubenstein and Josephson 2002).

Fall-related injuries are the third leading cause of years lived with disability among the older population according to the WHO (World Health Organization) report, Global burden of disease (Murray et al. 1996). In global terms, unintentional injuries are the leading cause of injury-related death in older adults and falls are responsible for two-thirds of the deaths resulting from unintentional injuries (WHO, 2007). In addition to the actual physical injuries, there are significant psychological and social consequences associated with falls; these include fear of falling, restricted mobility, loss of self-confidence, reduced quality of life and early institutionalization (Kong et al. 2002, Murphy et al. 2003). Thus, fall-induced injuries result in a substantial health care burden worldwide (Stevens et al. 2006). According to National Institute for Health and Welfare, falls are the leading cause (80%) of unintentional injuries, and they are the fourth leading cause of death in the older population in Finland. Falls are the leading cause of unintentional injury-related deaths as well as injuries requiring inpatient care in individuals aged 65 and over (THL, 2018). In Finland, falls are the number one cause of injury, limiting the functional ability of the victim either temporarily or permanently with ultimate health and socioeconomic consequences (Korhonen et al. 2013, Statistic Finland, 2018).

Falls can be viewed as multifactorial phenomena; risk factors for falls can be extrinsic (those related to environmental factors) or intrinsic (those related to individual human factors) (Tinetti and Speechley 1991). Falls are generally a result from the interaction between multiple risk factors and situations. This interaction may be modified by age, chronic disease, and the presence of hazards in the environment (Campbell et al. 1989, Tinetti and Speechley 1991, Hornbrook et al. 1994, Bath et al. 2000, Bueno-Cavanillas et al. 2000). According to the literature, common extrinsic risk factors contributing to a high incidence of falls include environmental hazards, e.g. slippery conditions, darkness, loose mats, and hazardous activities whereas intrinsic factors include age, chronic diseases, muscle weakness, gait and balance disorders, as well as visual and cognitive impairments (Bueno-Cavanillas et al. 2000, Deandrea et al. 2010). It is known that the risk of falling increases dramatically as the number of risk factors increases (Tinetti et al. 1988, Nevitt et al. 1989, Robbins et al. 1989, Nevitt et al. 1991, Speechley and Tinetti 1991, Faulkner et al. 2009). A fall can result from several mechanisms; the most common circumstances leading to falls among the older people are slips and trips (Lord et al. 1993, Berg et al. 1997). Slipping is the most common adult fall mechanism in cold climate countries (Honkanen 1982). There is a continuum from slips and trips where balance is regained (i.e. near fall) to completed falls, when balance is lost (Van Beurden et al. 1998). With advancing age, a variety of physiological changes occur which may interfere with balance and gait, placing older individuals at a higher risk not only for trips or nonslips but even for fatal injuries (Rubenstein 2006). It has been suggested that different types of falls are related with different risk factors (Cummings and Nevitt 1994).

Chronic medical conditions are one of the most common of the intrinsic risk factors for falling (Lawlor et al. 2003). The prevalence of chronic medical conditions is high among the older population (Paliwal et al. 2017); in these individuals, it is increasingly common that they have two or more chronic medical conditions (multimorbidity) (van den Akker et al. 1996, Immonen et al. 2020). Approximately 92% of older adults have at least one chronic disease (Hung et al. 2011) and 65–85% have multimorbidity (Marengoni et al. 2011). In particular, in community dwelling older women aged 60–90 years, a linear relationship has been observed between the occurrence of falling and the number of simultaneously present chronic medical conditions (Lawlor et al. 2003). The most common chronic medical conditions that independently contribute to the risk of falling are impaired muscle strength (Horlings et al. 2008), mobility impairments (Moreland et al. 2004), functional and cognitive impairments (Muir et al. 2012), balance disorders (Lord et al. 2007), visual deficits (Lord and Dayhew 2001), depressive symptoms (Kamińska et al. 2015). It has been claimed that the risk of falling increases along with the number of chronic medical conditions i.e. the extent of multimorbidity (Lee et al. 2009, Shumway-Cook et al. 2009). To date, the association between multimorbidity and risk of different types of falls (slip/nonslip) has rarely been studied longitudinally (Lee et al. 2009, Shumway-Cook et al. 2009).

Musculoskeletal disorders (MSDs) are one of the most common chronic medical conditions experienced by individuals as they grow older (Woolf and Akesson 2001). Global burden of disease estimates rank MSDs as the most common (Global Burden of Disease Study 2013 Collaborators 2015) or the second most common major disease class resulting in years lived with disability. In Finland, after mental disorders, MSDs represented the second most common cause of permanent work disability in 2014 (KELA 2018). The most common forms of MSDs considered as an important risk factor for falls are osteoarthritis (Ng and Tan 2013), rheumatoid arthritis (Stanmore et al. 2013) and musculoskeletal pain (Stubbs et al. 2014). In global terms, out of all chronic diseases, low back pain was the number one cause of years lived with disability (YLDs). In addition, the consequences of MSDs such as muscle weakness, gait and balance instability which may also be due to aging have been shown to be associated with slipping and stumbling among older adults (Hausdorff et al. 1997, Bhatt et al. 2005). Nonetheless, the published studies have failed to explore the associations between MSDs and the risks of different type of falls among older adults.

In general, 40% to 60% of the falls lead to injuries: 30–50% result in minor injuries, 5–6% in major injuries other than fractures and 5% in fractures resulting in hospitalization (Tinetti et al. 1988, Alexander et al. 1992, Bergland and Wyller 2004). It is recognized that the probability of future falls and subsequent fractures increase if the individual has a history of falls. Thus, an overall history of falls (according to frequency, mechanism, and severity) could be a useful predictor of future fractures in an older population.

There has been very little longitudinal research conducted on the role of multimorbidity as a risk factor for falls subdivided by type of falls (slip/nonslip) among postmenopausal older women (Zhao et al. 2020). Very few studies have compared the effect of MSDs and different type of falls in conjunction with aging (Sibley et al. 2020). Thus far, no longitudinal studies have determined how the history of falls predicts future falls/fractures according to frequency, mechanism (slip/nonslip) or severity (injurious/non-injurious) of the falls. The long winters in countries with cold climates may change the slip /nonslip ratio and be associated with different risk factors for different types of falls (Ryynänen et al. 1991). Therefore, it is reasonable to identity risk factors for falls by type of fall (both indoors and outdoors). By differentiating between these types of falls, this might allow us to develop more specific measures for the prevention of falls in older populations. The main objectives of this present thesis are to evaluate the association between (multi)morbidity and risk of different type of falls (slip/nonslip) among postmenopausal Finnish women living in the community. In addition, the role of MSDs vs. other disease classes as risk factors for slip and nonslip falls is assessed. Furthermore, the prediction of future fractures according to a history of falls by frequency, mechanism and severity of falls has been evaluated.

2 REVIEW OF THE LITERATURE

2.1 CONCEPTS

2.1.1 Falls

The meaning of “a fall” seems intuitive. Nonetheless, older people, health professionals and researchers can interpret a fall in different ways. For epidemiological studies, a standardized definition is necessary if one wishes to make a comparison of outcome measures; for example, the literature contains diverse definitions of falls in (Zecevic et al. 2006). In 1988, Tinetti defined a fall as an event which results in a person coming to rest unintentionally on the ground or other level, not because of a major intrinsic event (such as a stroke) or an overwhelming hazard (Tinetti et al. 1988). Nevitt´s definition involved a person “falling all the way down to the floor or ground or falling and hitting an object like a chair or stair” (Nevitt et al. 1991). A fall has also been defined as an unintentional contact with the ground (Campbell et al. 1989, Robbins et al. 1989) or as a loss of balance such that hands, arms, knees, bottom or body touch or hit the ground or floor (Hornbrook et al. 1994). In a study of an institutionalized older population (Myers et al. 1991) a fall was defined as an event in which the staff had filed an incident report citing a “fall” which included falls out of a bed, out of a chair, or while walking or being transported. In the Finnish language there are two different words for falls; one for a fall on the same level (‘kaatua’) and the other for a fall from a height (‘pudota’). In an attempt to standardize clinical and research efforts, The Prevention of Falls network Europe (ProFANE) group and The Frailty and Injuries: Co-operative Studies of Intervention Techniques (FICSIT) studies defined a fall as “unintentionally coming to rest on the ground, floor or other lower level” (Ory et al. 1993, Lamb et al. 2005). They also suggested that ascertainment should consider a lay perspective so that participants (i.e. a general population of older people) can be asked about falls, including slips, trips, causing a loss of balance to land on the ground, floor, or a lower level (Lamb et al. 2005). The definition which is consistent with The International Classification of Diseases (ICD-10) states that a fall is an unexpected event where a person falls to the ground from an upper level or on the same level. In the ICD-10, falls are coded as W00-W19. These codes include a wide range of fall types, including falls without specifications but exclude an intentional change in position to rest on furniture, or against a wall or some other structure (WHO, 2007). ICD-10 does not consider falls while bicycling, skiing, or skating as falls.

2.1.2 Fallers

A faller is usually defined as someone who has fallen at least once over a defined period, usually one year or 6 months. A person who has fallen “only once” is often defined as an occasional faller whereas an individual who has fallen twice, or more is designated as a frequent faller (Masud and Morris 2001). However, some evidence suggests that people who have fallen “only once” (occasional fallers) are characteristically more closely related to non-fallers (Lord et al. 1994). Therefore, some researchers have defined a faller as someone who has had 2 or more falls and a frequent faller as those with 3 or more falls in one year (KOSK et al. 1996).

2.1.3 Place of occurrence

Investigators have found that approximately every second fall among adults aged 65 or more occurs in outdoor environments even though most older people spend most of their time indoors (Bergland et al. 2003). Outdoor falls are heavily influenced by the characteristics of the outdoor environment and are linked with risk exposure (Bergland 2012). Footpaths, curbs, and streets have been identified as the most common location of outdoor falls among middle aged and older adults (Li, Keegan et al. 2006). Commonly reported environmental causes of outdoor falls include an uneven surface, wet surface, tripping or slipping on some object or particularly in locations where ice and snow may contribute to slipping (Bulajic-Kopjar 2000, Li et al. 2006, Van Kamp et al. 2014). A high proportion of indoor falls occurs on steps and stairs (Bergland et al. 2003). Other locations of indoor falls reported by older people are bedrooms, living areas, or kitchens where they spend most of their time (Skelton et al. 2004). The risk factors for outdoor falls are different from indoor falls (Kelsey et al. 2010). Indoor falls tend to occur in frail people with compromised health (Kelsey et al. 2012). In contrast, those who fall outdoors are more likely to be younger, more physically active, healthier and more independent in activities of daily living (Nyman et al. 2013). There are evidence of sex differences in fall rates by circumstance, with outdoor falls being more common in men (Duckham et al. 2013).

2.1.4 Time of falls

Most falls among home-dwelling older adults occur during the active hours of the day; mainly in the afternoon followed by the morning, evening and night while older individuals are involved in their basic daily activities of living (Luukinen et al. 1994, Bergland et al. 2003). In institutions, most falls also occur in the patient's room during the basic activities of living, often from the bed, while sitting, or during transfers and they are evenly distributed throughout the day (Tinetti 1987, Masud and Morris 2001). There is a seasonal variation in the fall rate among community dwelling older adults (Saari et al. 2007) with the largest number of falls occurring during winter (December, January, and February) as compared to other seasons. It has been suggested that the winter climate (freezing temperatures, snow, and ice, etc.) and its potential for making outdoor surfaces slippery or otherwise hazardous may account for the increased incidence of falls during winter (Grønskag et al. 2010, Bird et al. 2013).

2.1.5 Mechanism of falls

As stated above falls are multifactorial phenomena. An individual can fall in many ways and the way in which a person falls often determines its consequences (Nevitt et al. 1993). If we are to prevent falls and their consequences, it is important to identify the mechanism causing the fall. In this respect, the mechanism of fall refers to the way of falling. There are extrinsic (slipping, tripping, stumbling) and intrinsic (e.g. dizziness) mechanisms of falls (Ryynänen et al. 1991, Lockhart et al. 2005). The most common mechanism of falls reported by older people are slips, trips or stumbles during walking (Waller 1978, Tinetti et al. 1988, Lord et al. 1993, Berg et al. 1997, yang et al. 2012). A slip occurs when the foot slides from underneath the person, whereas a trip involves a stumble when an object obstructs the pathway (Steinberg et al. 2000). Slipping often starts by a sudden heel glide forwards causing the individual to fall backwards, while tripping usually causes him/her to fall forward (McGorry et al. 2010). It has been proposed that there is a continuum ranging from near falls (i.e. sways where balance is regained), to complete falls (Van Beurden et al. 1998). The seasonal variation of falls requiring medical attention from the health care district of Helsinki (Honkanen 1982) or evidence from Kuopio where the fall has caused a distal forearm fracture (Rikkonen et al. 2010) suggest that slippery roads are an important cause of injurious falls. Further evidence has emerged about falls in early postmenopausal women from the OSTPRE enquiry in 1994 conducted in the Health care district of Kuopio Province, Finland which is situated within latitudes of 62-65; depending on the calculation method, this suggests that slipping was the mechanism of falls in 58-65 % of incidents (Randell et al 2001). In warm climate countries such as Australia, the proportion of slipping in falls suffered by older women has been about one third (Sanders et al. 2017). Thus, risk factors for falls should also be studied according to mechanism of the fall in cold climate countries, as causal triggers, and these different mechanisms pathways to be considered in the fall's consequences.

2.1.6 Severity of falls

There is considerable heterogeneity in defining injurious falls in the published fall prevention interventions. Abbreviated Injury Scale (AIS) and Injury Severity Score (ISS) are the most widely used Injury severity scales. AIS is anatomical and has 6 categories: 1=minor, 2=moderate, 3=serious, 4=severe, 5=critical and 6=unsurvivable and is used for a single injury (Greenspan et al. 1985). In multiple injuries, each of the three most severe injuries is first given an AIS code which are then summed up for an overall ISS. These have been applied for use in emergency stations with a register for injury diagnoses & AIS scale, but they have also been used in several fall prevention programs to define an injurious fall (Jensen et al. 2002, Stenvall et al. 2007). Some studies defined a fall injury as "serious" if the fall has resulted in a fracture or admission to hospital or if any wounds needed stitches and "moderate" is there is bruising, sprains, cuts, abrasions, or a reduction in physical function for at least three days, or if the participant sought medical help (Campbell et al. 1997, Hauer et al. 2006, Schwenk et al. 2012). Other studies used the definition of The Frailty and Injuries Cooperative Studies of Intervention Techniques (FICSIT) collaboration; fall injuries as fractures, head injuries requiring hospitalization, joint dislocations, sprains and lacerations requiring suturing (Schwenk et al. 2012). However, due to the difficulties in defining an injurious fall with these definitions, this has usually led to simple practical solutions such as "seeking for medical care or hospitalization due to injury" including hospital discharge registers (Schwenk et al. 2012). Previous studies have shown that older women have a higher risk of experiencing falls and injurious falls than older men (Kannus et al. 2005, Timsina et al. 2017).

2.1.7 Recording of falls

In epidemiological studies, fall data is mostly collected by *(a)* retrospective reporting systems using telephone interview, face-to-face interview, or postal questionnaire; *(b)* prospective reporting systems using postcards, calendars, or diaries; and *(c)* routine surveillance systems or abstraction from health care records (Hauer et al. 2006). In addition, there are fall detection devices (Noury et al. 2007) and wearable devices such as accelerometers which have been used to monitor falls in clinical settings (Culhane et al. 2005) although such methods are impractical for large-scale population monitoring. The most common methods of summarizing fall outcomes include *(a)* reporting data on the number of participants sustaining a fall or multiple falls (usually two or more); *(b)* the number of falls; *(c)* fall rates; and/or *(d)* time to first fall (Hauer et al. 2006). In addition, the focus may be on falls causing injury or requiring medical care. Several factors confront researchers when collecting falling data. For example, the accuracy of self-reporting and retrospective recall of previous falls (Peel, N. 2000, Ganz et al. 2005, Mackenzie et al. 2006), as well as differing perceptions of what constitutes a "fall" (Hauer et al. 2006, Zecevic et al. 2006). It has been suggested that depending on the length of the recall period, falls may be forgotten (Cummings et al. 1988, Wijlhuizen et al. 2006). Many falls are often unwitnessed, unreported and may go undetected until after an injury and disabilities have occurred. There may be even disincentives on the part of the older person for reporting falls, which include perceptions that a fall will be seen as a marker of aging, embarrassment, loss of independence and the risk of institutionalization (Allen 2004, Peel et al. 2008). The kinds of falls resulting in injury are more likely to be recorded in administrative data sets, such as hospital records and institutional incident reports. Fewer than half of fall events are reported to a health practitioner (Hauer et al. 2006, Shumway-Cook et al. 2009) and the percentage is likely to be much lower in cases where a fall occurs but does not require treatment (Allen 2004). Rather a lot is known about the relatively small number of fall-related deaths, less about hospital in-patient cases, and even less about cases resulting in neither death nor hospitalization. It has been stated that novel strategies are required to increase reporting of falls by older people e.g. increasing their awareness of the value of reporting falls (in order to permit the early detection of risk and implementing strategies to reduce future risk). In addition, initiatives aimed at health professional are needed to encourage them to ask all older people at least once each year whether they have had a fall (Society et al. 2001).

2.2 PROPORTION OF FALLERS IN THE HOME-DWELLING OLDER POPULATION

The proportion of the fallers in the home-dwelling older adults has been estimated in several prospective and retrospective studies; the data indicate that falls are a common problem among older adults. About 30–40% of home-dwelling older adults fall at least once each year (Tinetti et al. 1988) and that the proportion of fallers increases with age (Campbell et al. 1981, Prudham and Evans 1981, Blake et al. 1988, Tinetti et al. 1988, Graafmans et al. 1996, Iinattiniemi et al. 2009, Von Heideken Wågert, et al. 2009). The tendency to fall is more common in women than men among home dwelling older adults (Campbell et al. 1990, O'Loughlin et al. 1993, Luukinen et al. 1994, Lehtola et al. 2006). The proportion of injurious falls out of all falls among older adults has been estimated in several studies; the average proportion has been about 50% of all falls (Nevitt et al. 1991, Koski et al. 1998, Lawlor et al. 2003,). Women were found to be more prone to experience falls causing an injury (O'Loughlin et al. 1993, Malmivaara et al. 1993). Ryynänen et al. reported a significant gender difference (men 2.5%; women 4.4%) in the incidence of injurious falls requiring medical treatment (Ryynänen et al. 1991) among older adults. The incidence rate of injurious falls increased with advancing age among both sexes and in some studies only among men (Camp-bell et al. 1990, O'Loughlin et al. 1993). Below, table 1 presents the proportion of any, frequent and injurious fallers among the older population in population–based studies.

Table 1. Proportion of fallers among the home-dwelling older population.

Authors[1]	Year	A	B	N	Age (years)	Falls (%) Any	Frequent	Injurious
Tromp	2001	Netherlands	P/12mh	629 (m) 656 (w)	65-70	25.3 (m) 36.5 (w)		
Randel	2001	Finland	P/12mh	9792 (w)	47-56	31		18.2% falls required medical treatment
Neutel	2001	Canada	P/12mh	227 196(w)	≥65	55.1 (m+w)		
Lawlor	2003	Great Britain	CS/12mh	4050 (w)	60-70	16.9	7	6.8% falls required medical treatment
Rozenfield	2003	Brazil	CS/12mh	634 (w)	≥60	37.4	14	
Morris	2004	Australia	P/12mh	467 (m) 533(w)	65-79	m=21 w=34	m=6 w=11	33% falls required medical treatment
Chu	2005	Hong Kong	P/12mh	15517 49.2% (w)	≥65	19.3 (m+w)	24.5 (m+w)	75.2 % fall-related minor injuries
Landi	2005	Italy	P/3mh	2854 1661(w)	≥65	37 (m+w)		
Koijima	2008	Japan	CS/12mh	m=436 w=413	65–74	m=27.2 w=33.9		
Shumay-Cook	2009	USA	CS/12mh	12,669 (m+w)	≥65	22.1	10	7.2 % fall-related serious injuries
Buatois	2010	France	P/ (18–36)mh	2735 1357 (w)	≥65	18 (m+w)		
Muraki	2011	Australia	P/12mh	587 (m) 1088 (w)	60-90	m=16.7 w=18.8		
Rouzi	2015	Saudi Arabia	P/12mh	707 (w)	≥50	23.2	10.3	
Chang	2015	Canada	CS/12mh	14,881 (m+w)	≥65	m=17.3 w=22.4		(0.9+2.4)% (m+w), fall-related fractures
Ouyang	2018	China	P/24mh	12,527 (w=5913)	60.5 (mean)		16 (m+w)	
Sotoudeh	2018	Iran	P/12mh	321 (m) 332 (w)	65-69		m=11.8 w=16.6	
Ilmonen	2020	Finland	P/3mh	269 (m) 503(w)	≥65	13.3 (m+w)		

A= Country, B= study type, P=prospective, CS= Cross-sectional, mh=month, N= study population, m=men, w=women, USA= United States of America, [1] Only first author mentioned.

2.3 RISK FACTORS FOR FALLS

Identifying risk factors is an important first step in maintaining optimal function and preventing falls as this will increase our understanding of falls among older populations, and thereby provide important information to health professionals to develop more specific measures to prevent falls. In the literature, a risk factor has been defined as an aspect of personal behavior or lifestyle, an environmental exposure or an inborn or inherited characteristic which on the basis of epidemiologic evidence, is known to be associated with a health-related condition and is considered important to prevent future falls (Last et al. 2001). Thus, a risk factor can be (1) an attribute or exposure which is associated with an increased probability of a specific outcome, such as the occurrence of a disease, which is not necessarily a causal factor but is a marker of increased probability; (2) an attribute or exposure that increases the probability of the occurrence of a disease (3) or some other specified outcome difference between 1 and 2 i.e. a determinant that can be modified by intervention, thereby reducing the probability of occurrence of disease or other specific outcome; this may also be referred to as a modifiable risk factor. In the case of the fall risk, it is important to realize that the risk is the probability that an individual will fall during a given activity or external insult (Harwood 2001). Much of the variation in the risk of falling is due to biological and functional variability within age groups, rather than to simple age-dependent differences (Radebaugh et al. 1985).

Many risk factors for falls have been identified in older populations although there is no consistent classification (Deandrea et al. 2010, De Almeida et al. 2012). The etiology of a fall is usually multifactorial, resulting from the interaction between extrinsic and intrinsic factors (Bath et al. 2000). *Extrinsic* factors are environmental factors; these generally include home hazards (such as poor lighting and loose mats) and environmental hazards (such as slippery surfaces and darkness). *Intrinsic* factors are individual-specific and include age, gender and race which are non-modifiable (Bueno-Cavanillas et al. 2000). Some of these factors (e.g. morbidity, medications, and behaviors) are often modifiable and are associated with changes due to ageing such as a decline in physical and cognitive capacities (World Health Organization, 2008). The interaction between extrinsic and intrinsic risk factors increases the risk of falling (Deandrea et al. 2010). For example, loss of muscle strength tends to cause a loss of function which may intensify the risk of falling due to environmental hazards (World Health Organization, 2008). Falls among people younger than 75 years are more likely to be associated with extrinsic factors whereas intrinsic factors are more important in the over 75s (Todd and Skelton 2004). *Health Behavioral factors* for falls are those that reflect choices of older individuals with respect to how they interact within their environments. Behavioral risk factors include *performing behaviors* that increase the fall risk (e.g. standing on unstable objects to reach items that are stored on high shelves); not performing behaviors that could reduce the fall risk (e.g. failing to turn on lights when using the bathroom at night); or selecting inappropriate clothing, footwear, or eyewear, excess use of alcohol, or sedentary behavior (Bergland 2012). The risk of falling increases dramatically as the number of risk factors increases (Faulkner et al. 2009). It has been suggested that persons who fall for intrinsic reasons (such as dizziness or low extremity weakness) may be exposed to different risk factors than those who fall for extrinsic reasons (tripping, uneven ground and slipping) (Fuller 2000, Ambrose et al. 2013). A list of different risk factors for falls among older adults are presented in table 2.

Table 2. List of risk factors for falls among the older population.

Extrinsic factors		
	Home hazards	Narrow steps Slippery surface of the stairs Loose mats Poor lighting
	Environmental hazards	Slippery floor Uneven sidewalks Poor lighting in public places Obstacles
	Footwear	
Intrinsic factors		
	Age	
	Sex	
	Genetic factors	
	Living alone	
	Clinical impairments	Orthostatic Hypotension
		Vertigo and dizziness
		Drop attack
		Previous stroke
		Visual impairment
		Vestibular dysfunction
		Loss of sensory function
		Poor abilities in active daily living
	Chronic medical conditions	Osteoarthritis
		Rheumatoid arthritis
		Musculoskeletal pain
		Muscle weakness
		Cognitive impairment
		Balance impairment
		Gait impairment
		Dementia
		Depression
	Medication use	Polypharmacy
		Psychotropic drugs
		Antihypertensive and Cardiovascular drugs
		Analgesics
	Previous falls and fractures	
Health behavioral factors		
	Physical activity Use of alcohol Smoking	

Modified from FULLER, G.F., 2000

2.3.1 Extrinsic factors

The environment has been implicated in from one third to one half of all falls or fall injury events (Speechley and Tinetti 1991). Poor lighting and objects around the home, such as loose rugs and defective floors may increase the risk of falls (Downton and Andrews 1991). Some investigators have suggested that light switch hazards, thresholds, extension cords, slippery surfaces, and other household products may increase the risk of falling (O'Loughlin et al. 1993). The architectural design of stairways and homes and visual patterns on flooring can cause missteps and increase the risk of falling (Lach et al. 1991). The fall risk related to extrinsic factors is not easy to assess, and the exact role of environmental factors is not known (Pynoos et al. 2010). However, some studies examining the seasonal variation of distal forearm fracture from Finland (Rikkonen et al. 2010) suggest that slippery roads are an important cause of injurious falls. Falls are often related to changes in how an individual uses the environment (for example, the faller was hurrying or inattentive) or to difficulties or discomfort experienced when using the environment (Bergland et al. 1998). It has been suggested that the role of the environment interacts with other (intrinsic and behavioral) risk factors (Bergland et al. 2003). Commonly reported environmental factors leading to falls in public places include pavement cracks and misalignments, gutters, steps, construction works, uneven ground and slippery surfaces (Nevitt et al. 1991). Some authors have reported that environmental hazards are more likely to contribute to falls in older adults in better health than in their frailer counterparts (Bath et al. 2000, Bergland et al. 2003). In a study of over 1,400 people living in the community, Weinberg and Strain found that those with better self-rated health were more likely to attribute the cause of a fall to the outdoor surroundings. Those with poorer self-rated health and those who reported having difficulties in dexterity (skill in performing tasks) were more likely to attribute their falls to their own limitations (Weinberg and Strain 1995). Studenski et al. found that those at a low risk of falling (immobile, or mobile and stable people) were either more able to withstand environmental challenges or were not as challenged by their environments as their high-risk (mobile and unstable) counterparts (Studenski et al. 1994).

Footwear effects postural stability and thus, it can influence the incidence of falls and fall related injuries (Koepsell et al. 2004). Older people tend to wear slippers while they are at home. Menant et al. reported that older people who wear slippers had a higher risk of falling compared to those who walk with fastened shoes or who are barefoot (Menant et al. 2008). In another study, it was claimed that walking barefoot or with socks can increase the risk of falling by up to 11 fold as compared to walking with canvas or athletic shoes (Tencer et al. 2004). The design of the shoes is another important factor of increasing the risk of falling. Shoes with heels are associated with a higher risk of a fall in comparison with canvas shoes (Tencer et al. 2004, Kelsey et al. 2010). Wearing well-fitting and low-heeled shoes has been recommended to reduce risk of falls (Davis et al. 2019). Anti-slipping devices (anti-slipping shoes, mats) along with home hazard managements have also been shown lead to a significant reduction in falls and fall induced injuries among the older population (Mohsen et al. 2019).

2.3.2 Intrinsic factors

Age

Several studies have found age to be a significant predictor of falling (Campbell et al. 1981, Tinetti et al. 1988, Nevitt et al. 1989, Campbell and Spears 1990, Ryynänen et al. 1993, Moylan and Binder 2007, Deandrea et al. 2010). The risk of falling increases after the age of 60 (Kerber et al. 1998, Deandrea et al. 2010). It is now well established that about one in three individuals aged 65 years and older living in the community, fall each year (Prudham and Evans 1981, Tinetti et al. 1988, Campbell et al. 1989, O'Loughlin et al. 1993, Graafmans et al. 1996). This proportion rises to over 40% in those over 75 years (Prudham and Evans 1981, Blake et al. 1988) and almost every second person more than 80 years old will fall at least once each year (Blake et al. 1988, Tinetti et al. 1988, O'Loughlin et al. 1993, Lindqvist et al. 2001). Fall-related injuries increase markedly with age (Luukinen et al. 1995, Bell et al. 2000,). It is evident that the chance of falling increases with age due to both physiological and pathological changes (Ambrose et al. 2013). Normal aging is associated with declines in several physiological systems including those devoted to musculoskeletal, cardiovascular, visual, vestibular and proprioception, coordination, and there are slowed postural responses and cognitive functions (Segev-Jacubovski et al. 2011). Thus, older people are stiffer, are less well coordinated, and have a more dangerous gait than their younger counterparts who are more able to avoid an actual fall after a trip or slip (Rubenstein 2006). In the LSOA study (Longitudinal Study of Aging), over 4000 home dwelling older adults were interviewed over a period of 6 years at 2 year intervals to monitor their decline in functional status (Dunlop et al. 2002). According to these results, age related conditions such as arthritis, prior cerebrovascular disease, diabetes, impaired vision and urinary incontinence were significant predictors of moderate functional limitation, which in turn increased the number of trips, stumbles, and falls among these older adults (Dunlop et al. 2002). Other studies have found that the recovery from a fall-related injury is often delayed among the older adults, which in turn increases the risk of subsequent falls (Rubenstein 2006).

Sex

The findings regarding the association between fall risk and sex have not always been consistent. Many studies have found that women are more likely to fall than men (Prudham and Evans 1981, Campbell et al. 1990, Downton and Andrews 1991, Luukinen et al. 1995, Deandrea et al. 2010, Kelsey et al. 2012, O, El Fakiri 2015), while others have detected no sex-related differences (Blake et al. 1988, Campbell and Spears 1990, Graafmans et al. 1996, Bergland et al. 1998). Dunlop et al. estimated that women would be 58% more likely than men to suffer a nonfatal injury. On the other hand, the death rate associated with falls was 46% higher for men than for women, after taking age into account (Dunlop et al. 2002).

Genetic factors

It has been suggested that genes may influence the risk of falling (Trajanoska et al. 2020). Twin studies from Finland have found that genetic factors can explain 35% of the variability in the likelihood of experiencing at least one and 45% of the variability in the risk of recurrent falls (Pajala et al. 2006). Genetic influences are known to contribute to fall-related factors such as muscle function, postural balance, cognitive abilities, and physical activity, all of which contribute to the fall risk (Reynolds et al. 2005). In other words, the falling risk can be heritable, at least to some extent. However, heritability may not be constant over the lifespan; there are studies indicating that heritability typically declines with increasing age as a consequence of accumulation of environmental influences as the individual ages (Steves et al. 2012).

Living alone

An older person who lives alone is 2–2.25 times more likely to experience a fall and has a higher risk of multiple falls (Stevens 2005). Falls are the primary cause of severe non-fatal injuries, and the most common reason for hospital admissions among adults who live alone (Fallon Jr et al. 2002). Single older women who lived alone had significantly more fall-related injuries and an increased risk of complications from falls than seniors who lived with a spouse or others (Leslie and St Pierre 1999). In addition, those living alone were more fearful of falling (FOF) (lives alone: 62.2%; lives with others: 48%) and restricted their activities more often than those living with others (lives alone: 44.5%; lives with others: 32.8%) (Zijlstra et al. 2007). Murphy, Williams, and Gill conducted a study with over 1,000 community-dwelling older adults and determined that while over half (57%) were unafraid of falling, a significant minority (24%) reported a FOF while no one else was at home, and 19% reported limiting their activities due to a FOF (Murphy et al. 2002). Social support may reduce the risk of falls and FOF among community-dwelling adults and lessen the likelihood of adults withdrawing from activities due to FOF (Howland et al. 1998).

Clinical impairments and diseases associated with falls

A number of chronic medical conditions are significantly associated with falls among older adults (Table 3). It has been demonstrated that the risk of falling increases along with the number of chronic medical conditions in older adults (Tinetti and Kumar 2010, Paliwal et al. 2017).

Previous studies reported that approximately 92% of older adults have at least one chronic disease (Hung et al. 2011) and 65–85% have two or more co-existing chronic medical conditions or multimorbidity (Marengoni et al. 2011). Multimorbidity is described as “the coexistence of two or more chronic medical conditions” in the same individual (Van den Akker et al. 1996). Some investigators have observed that older people with chronic medical conditions experience higher rates of falls than active healthy older people (Lawlor et al. 2003) and the risk of falling increased along with an increase in the number of chronic medical conditions or multimorbidity. In their studies, Lee et al. and Shumay–Cook et al. reported that the likelihood of having 1 or 2 or more falls in the previous year (relative to no falls) was significantly associated with multimorbidity (Lee et al. 2009, Shumway-Cook et al. 2009). Older adults with multimorbidity are likely to experience a loss of physical functioning, poorer quality of life, are more likely to suffer from depression and to be receiving multiple drugs and thus, multimorbidity might well significantly increase their falling risks (Sibley et al. 2014). There are several chronic conditions which have been implicated such as musculoskeletal disorders (e.g. rheumatoid arthritis, osteoarthritis, low back and neck pain, gout) are a common cause of an elevated falling risk in older adults (Global Burden of Disease Study 2013 Collaborators 2015).

Cardiovascular problems e.g. orthostatic hypotension (OH), have been suggested as risk factors for falling among older adults (Carey and Potter 2001) although there is some variation in the results (Liu et al. 1995). OH is a common condition, defined as a reduction of over 20 mmHg of systolic blood pressure when standing up from a supine position. It can stem from several factors, including autonomic dysfunction (frequently related to age, diabetes, or brain damage), hypovolemia, low cardiac output, Parkinsonism, metabolic and endocrine disorders, and medications (particularly sedative, anti-angina and antihypertensive drugs as well as antidepressants) (Gangavati et al. 2011).

Drop attacks often are defined as sudden falls without any loss of consciousness or dizziness and patients typically experience abrupt leg weakness, sometimes precipitated by a sudden head movement (Parry and Kenny 2005). The weakness is usually transient but can persist for hours. This syndrome has been attributed to transient vertebrobasilar insufficiency, although it probably stems from diverse mechanisms, including leg weakness and knee instability (Rubenstein 2006). However, today drop attacks are being reported much less frequently than before.

Beninato et al. examined community dwelling older people with *stroke* and reported annual fall incidences ranging from 22% to 73% (Beninato et al. 2009). For comparison, a case-control study on older adults with (n=80) and without (n=90) stroke resulted in a 1.77 times higher fall rate for stroke patients (Simpson et al. 2011).

Vestibular dysfunction is common in older adults. This often results in impairments of posture and gait, placing older adults at an increased risk of falls and fractures (Baloh et al. 2001, Viljanen et al. 2009, Lin and Ferrucci 2012). An impaired peripheral vestibular system may impair balance and impede posture control and can increase the risk of falling (Whitney et al. 2000). Dizziness is also common in older adults and is a major cause of falls. However, it is a non-specific symptom and may reflect a variety of problems such as cardiovascular disorders, hyperventilation, unwanted effects of some drugs, anxiety, or depression (Lawson et al. 1999). Hearing provides acoustic information about the environment, enabling the individual to notice and avoid environmental hazards that may lead to a fall (Enrietto et al. 1999). There are rather few studies into the associations between hearing acuity and falls and the results have been contradictory. Some evidence exists that home accidents, most often falls, are more common among people with hearing problems (Evci et al. 2006). However, other studies have found only a minor or no association between hearing acuity and postural balance or falls (Purchase-Helzner et al. 2004).

Visual impairment is a verified risk factor for falls and frequent falls according to many studies (Lord et al 1991, Lord et al. 1996, Boptom et al. 1998, Lord and Dayhew 2001, Tromp et al. 2001, Lord et al. 2007). Impaired visual depth perception has been found to be one of the strongest visual risk factors for frequent falls in community dwelling older people (Nevitt et al. 1989, Lord and Dayhew 2001, Ambrose et al. 2013). In a systemic review of 19 prospective fall studies, Salonen et al. reported poor depth perception as a risk factor for frequent falls (Salonen and Kivelä 2012). Campbell et al. observed a significant association between a lack of visual acuity and falls in a large sample of older people living in the community, although this association disappeared when adjusting for age (Campbell et al. 1989). Contrast sensitivity has also been found to be useful in identifying those older people at risk of falling and may be more important than visual acuity in predicting falls (Lord et al 1991, Lord and Webster et al. 1994). A loss of edge contrast sensitivity may predispose older people to tripping over any obstacle such as steps, footpaths, and surface malalignments (Patino et al. 2010). The Salisbury Eye Evaluation study found that visual field loss was an independent risk factor for falls among older adults (Freeman et al. 2007). Many investigators have reported that the ability to judge the distance accurately is important for moving safely (De Boer et al. 2004). Older adults with age-related macular degeneration are found to have visuomotor and balance deficits resulting in clumsiness and an increased risk of falling (Szabo et al. 2008).

Loss of sensory function has been observed in the lower extremities among fallers (Vandervoort 1992). Anacker et al. reported that older fallers tend to be more dependent on somatosensory cues from the feet and ankles than nonfallers (Anacker and Di Fabio 1992). Reduced peripheral sensation or proprioception, for instance a loss of the sense of vibration and tactile insensitivity are known to be significantly associated with falls among the older adults (Sorock and Labiner 1992, Era et al. 1996, Lord et al. 1996, Hurley and Rees et al. 1998).

Osteoarthritis (OA) is one of the most common forms of musculoskeletal disorders and has been considered as an important risk factor for falls among the older adults (Nevitt et al. 1989, Leveille et al. 2002, Foley et al. 2006, Ng and Tan 2013, Prieto-Alhambra et al. 2013). It has been reported that individuals with self-reported OA on average experience 25% more falls than those without OA and the risk is about 50% higher for people with OA to experience a fall every year (Prieto-Alhambra et al. 2013). OA is a degenerative joint disease characterized by a progressive loss of articular cartilage, subchondral bone sclerosis, osteophyte formation, and synovial inflammation. OA may occur in any joint although the knee joint is the tissue most commonly affected in the lower extremity (Ng and Tan 2013). The symptoms of OA include knee, hip and back pain which appear to increase the risk of falls among older adults. Joint pain has also been associated with a reduced quality of life and depression which in turn elevate the risk of falling among older adults (Foley et al. 2006, Scott et al. 2012). Older adults with OA have been observed to exhibit poorer postural stability, reduced muscle strength and muscle mass resulting from muscle atrophy (Toda et al. 2000, Baker et al. 2004, Zhai et al. 2006). It is also evident that older patients with knee and hip OA adopt different compensatory biomechanical strategies while walking, resulting in instability (Prevention, Orthopaedic Surgeons Panel on Falls 2001, Arnold and Gyurcsik 2012). A reduction in joint flexion/extension due to pain, deformity or muscle weakness may occur because of worsening knee OA, which leads to an avoidance of movement of the affected joint, functional limitations, deficits in balance control, a reduction in physical activity; a kind of vicious cycle, increasing the risk of falling among older adults (Slemenda et al. 1998).

Rheumatoid arthritis (RA) is another common musculoskeletal disorder in older adults. Studies suggested that adults with rheumatoid arthritis (RA) have an increased risk of falls due to a variety of reasons (Stanmore et al. 2013). The risk factors for falls in patients with RA that have been identified from previous studies include pain in the lower extremities, tender joints, low levels of physical activity, impairment in walking, impaired balance, impaired general health, the number of medications and especially the use of antidepressant as well as the number of comorbidities, the Health Assessment Questionnaire (HAQ) disability score (Armstrong et al. 2005, Oswald et al. 2006, Smulders et al. 2009).

Musculoskeletal pain is very common in older adults and quite often associated with mobility deficits, impaired gait, and balance deficits (Campbell et al. 1989, Stubbs et al. 2014). In global terms, lower back pain was ranked as the greatest contributor to Years Lived with Disability (YLD) and the sixth in terms of overall burden (Hoy et al. 2014). Several studies have identified chronic musculoskeletal pain as an established risk factor for falls in community dwelling older adults (Leveille et al. 2002, Leveille et al. 2009).

Muscle weakness is an extremely common finding among older adults, mostly stemming from disease and inactivity (Horlings et al. 2008). Muscle strength has been postulated to have an important role in maintaining balance and in overcoming obstacles during daily living and moving (Ahmadiahangar et al. 2018) and a decline in muscle strength may increase the risk of falling in these individuals (Cebolla et al. 2015). Several studies have demonstrated a substantially increased risk of falls and fall related injuries among the older adults with a muscle dysfunction (Ding and Yang, 2016). In a systematic review, Moreland et al. reported that persons with a lower extremity weakness, usually measured by knee extension, ankle dorsiflexion and the test "chair stands", displayed a 1.8-fold increased risk of falling and 3-fold risk for recurrent falls (Moreland et al. 2004).

Foot problems are generally poorly defined and are often associated with falls among older people (Patil et al. 2015). It is reported that older people with a severe, toe deformity, ulcer and deformed nails have a two–fold increased risk of falling (Sharif et al. 2018). Menz and Lord studied foot problems and concluded that they are common in older people and may contribute to a functional impairment and falls (Menz and Lord 1999, Menz et al. 2018).

Balance and gait are important predictors of falling (Hausdorff et al. 2001, Fabre et al. 2010). The risk of falling increases when the individual undertakes more challenging stability tasks, suggesting that the more challenging the balance task, the stronger its association with falls (Scott et al. 2007, Montero-Odasso et al. 2012). Lord et al. summarized the results of various measures of postural stability and their relationship with falls. They concluded that reduced gait velocity, cadence and step length were strongly associated with the risk of falling (Lord et al. 2007). Gait problems can stem from simple age-related changes in gait and balance as well as from specific dysfunctions of the nervous, muscular, skeletal, circulatory, and respiratory systems or from simple deconditioning following a period of inactivity (Piirtola and Era 2006, Muir et al. 2012). Prospective studies have revealed that sway is a useful predictor of the risk of falling (Marsh and Geel 2000, Urrunaga-Pastor et al. 2018). Previous studies reported that more mobile older persons are exposed to greater environmental and other activity-related risks of falling. Less mobile people may be more cautious and less active, and thus limit their risk of falling (Kelsey et al. 2010, Vieira et al. 2016).

Cognitive impairments have been identified as risk factors for falls in several studies (Campbell et al. 1989, Nevitt et al. 1989, Maki et al. 1994, Muir et al. 2012). Wright et al. stated that cognitive factors were increasingly associated with an increased fall risk (Wright et al. 2011). Holtzer et al. reported associations between a reduction in cognitive functions and falls in community-dwelling older adults (Holtzer et al. 2007). Gleason et al. reported that the risk of fall increased by 20% for every single point decrease in the Mini Mental Status Exam (MMSE) (Gleason et al. 2009). Specific cognitive domains, such as executive function (EF) impairments, dual tasking, information processing and reaction time have been found to be associated with an increased risk of falling (Alexander and Hausdorff 2008, Herman et al. 2010). Cognitive impairment is associated with other factors such as neuropathy, musculoskeletal problems, impaired balance and gait and the total number of diseases, which in turn are risk factors for future falls (Muir et al. 2012). Dementia is associated with a high risk for any fall or recurrent falls in both community and institution–dwelling older adults (Bergland et al. 1998). In the meta-analysis conducted by Muir et al., a diagnosis of dementia, without specification of the dementia subtype or disease severity, was associated with a risk for falls in institution-dwelling older adults (Muir et al. 2012). There are reports of a significantly higher prevalence of falls in Alzheimer's disease (AD) patients than in age-matched normal elders. Similarly, patients with Parkinson's disease (PD) who had greater impairments in attention and executive function had a higher incidence of falls as compared to non-PD patients (Parry and Kenny 2005). There are also findings related to either a peripheral and/or a neurological deficiency as risk factors for falls among older adults (Richardson and Ashton-Miller 1996).

Depression has been associated with falls among older people (Nevitt et al. 1989, Biderman et al. 2002, Tanaka et al. 2012, Kamińska et al. 2015). It has been speculated that there are at least three different ways in which depression and falls may be related. Depression may precede a fall, or vice versa or both may be outcomes of a third factor that adversely affects health in older persons, with both conditions developing concurrently (Whooley et al. 1999, Wright et al. 2011). Tinetti et al. found that the relative risk of falls was 1.7 when comparing the rate of falls among depressed older people to those in non-depressed individuals (Tinetti et al. 1988). Falls often lead to the appearance of depressive reactions and fear of falling among community dwelling older people (Arfken et al. 1994). The combined evidence for depression because of falls is less compelling than the depression-falls causal direction (Tinetti et al. 1988). The third type of relationship between depression and falls postulates that both phenomena are the result of a third condition or set of factors (Biderman et al. 2002). Both depression and falls are known to be cross-sectionally related to the presence of chronic medical conditions such as a functional disability, and to prospectively predict a decline in physical functioning (Tinetti et al. 1995). Tinetti and colleagues found that high scores for depression and anxiety were one of four predisposing factors for falls, incontinence, and functional dependence (Tinetti et al. 1995). In a study examining the relationship between major depressive disorder (MDD), gait speed, dual tasking, and executive function, the MDD group had a significantly slower walking speed when performing tasks with the highest cognitive demand and also exhibited a greater impairment with dual tasks. Balance-impaired older adults with MDD demonstrate increased stepping time under cognitively demanding conditions, reflecting executive dysfunction and this may make an additional contribution to the increased risk of falling (Wright et al. 2011).

Table 3. Summary of studies on the association between chronic medical conditions and falls in the older population.

Author[1]	**Year**	**A**	**N**	**Age**	**Exposure Chronic medical condition**	**Outcome**
						Any fall OR (crude), 95% CI
Leveille	2002	P/36mh	940(w)	≥ 65	Musculoskeletal pain	1.27, (0.97–1.66)
Lopez	2011	P/12mh	2340 (m)	76–81	Vision Impairment	m=1.77, (1.35–2.32)
			3014 (w)			w=1.82, (1.44–2.30)
					Hearing impairment	m=1.44, (1.16–1.78)
						w=1.51, (1.15–1.97)
						Frequent falls OR (crude), 95% CI
Muraki	2011	P/12mh	587 (m), 1088 (w)	65.3 (mean)	Knee osteoarthritis	w=2.52, (1.58–4.02)
					Lower back pain	w=2.14, (1.30–3.46)
						Any fall OR (crude), 95% CI
Doi	2015	P/12mh	3400 (53% w)	71.5 (mean)	Mild cognitive impairment	1.69, (1.13–2.53)
					Slow gait	2.49, (1.53–4.08)
Paliwal	2017	P/12mh	159,336 (m+w)	≥ 65	Stroke	1.96, (1.81–2.11)
					Angina	1.49, (1.40–1.59)
					Heart attack	1.48, (1.39–1.58)
Smith	2018	P/12mh	4796 (m+w)	68.9 (mean)	Hip osteoarthritis	1.52, (1.26–1.84)
					Knee osteoarthritis	1.54, (1.35–1.77)
Quach	2018	P/24mh	7715 (62% w)	75 (mean)	Rheumatoid arthritis	1.39, (1.10–1.77)
					Osteoarthritis	1.41, (1.24–1.60)
Ouyang	2018	P/24mh	12,527 (w=5913)	60.5 (mean)	Depressive symptom	w=1.05, (1.04–1.07)
Immonen	2020	P/3mh	872 (w=503)	≥ 65	*Multimorbidity	2.92 (adjusted), (0.76–11.19)

A=study type, P=prospective, mh=month, N=study population, m=men, w=women, *multimorbidity=≥3 chronic medical conditions, OR=Odds ratio, 95%CI= 95%Confidence Interval, Author[1] =Only first author mentioned.

Medication use and falling risks

Several studies have investigated the effect of medication use on the risk of falls in older adults (Table 4). An increased risk of falling has been found with both increasing number of all prescription drugs and with specific classes of drugs (Hartikainen et al. 2007, Huang et al. 2012). The total number of medications, regardless of class, has been shown to be an independent risk factor for falls as well as for fractures. *Polypharmacy* (the use of five or more drugs) multiplies the risk for falling. Falls are one of the serious health problems that may be viewed as adverse drug consequences of polypharmacy. The reason for this might not be just the number but also the type of preparations included in the medications as well as the possible influences of underlying diseases (Hammond and Wilson 2013).

Several studies have suggested that the use of *antidepressants* significantly increases the risk of falling in older adults living the community (Campbell et al. 1981, Prudham and Evans 1981, Darowski et al. 2009). Antidepressants are commonly prescribed to older people to treat depression and are often prescribed for longer periods. In addition to depression, they are also used for a variety of other indications: urinary incontinence, chronic or neuropathic pain, anxiety disorders, irritable bowel syndrome and night sedation. Antidepressants are thought to contribute to falls through several different mechanisms such as causing sedation or postural hypotension, impairing balance, delaying reaction times, and disturbing the natural sleep structure resulting in daytime drowsiness and nocturia (Ming and Zecevic 2018).
The use of *sedatives or hypnotics* is frequent in older people and has been found to be a predisposing factor for falls and injurious falls. Within the broad group of sedative or hypnotics, benzodiazepines are one of the main risk factors for falls in older people due to their effects on the central nervous system (Cumming et al. 1991, Ensrud et al. 2002). The indications for the use of benzodiazepines are anxiety, adjustment disorders and insomnias (Egan et al. 2000). Benzodiazepines have negative effects on cognition, gait, and balance and it has been reported that the pharmacodynamic responses of benzodiazepines tend to change with advancing age (Lechevallier et al. 2003). They seem to be associated with an increased risk of falls both with long-term use and after a new prescription (Glass et al. 2005, Hartikainen et al. 2007).

Antipsychotic drugs are widely used in the management of behavioral and psychiatric symptoms in older patients with dementia and they appear to be associated with an increased risk of falling. The extrapyramidal adverse effects of antipsychotic drugs are one explanation for the increased risk of falls, but also the anticholinergic properties and effects on alpha-adrenergic receptors may contribute to the risk of falling (Huang et al. 2012).

Antiepileptics also increase risk for falls due to their central nervous system side effects, such as sedation, dizziness, and ataxia. Several studies have suggested that users of anti-epileptics were about 2-4 times more likely to experience frequent falls when compared to nonusers of these drugs (Tromp et al. 2001, Ensrud et al. 2002, Askari et al. 2013).

Numerous *cardiovascular drugs* can increase the risk of falling through their effects on postural blood pressure as many of these drugs have the potential to induce cardiac arrhythmias. One group of anti-angina and antihypertensive drugs, - vasodilators can cause side effects, such as postural hypotension, dizziness and tachycardia symptoms which have been associated with any type of fall, especially injurious falls. Cardiovascular medications, such as *digoxin* and type *1 anti-*

arrhythmic drugs have been indicated to be risk factors for falls among community dwelling older adults in several studies (Leipzig et al. 1999, Huang et al. 2012). *Diuretics* may also influence the risk of falls and injurious falls among older adults. Some studies suggest that the use of diuretics may predict fracture upon falling (Myers et al. 1991).

Analgesics have been related to a high risk of falls in several studies. Their use along with CNS-active drugs may potentiate the gait and balance disturbances which can contribute to falls and injurious falls among older adults. With respect to the anti-inflammatory drugs, nonsteroidal anti-inflammatory drugs (NSAIDs) have been mostly related to the risk of falling due to their side effects, such as confusion, mood changes and dizziness (Myers et al. 1991, Leipzig et al. 1999, Boyle et al. 2010).

There are some medications which may also prevent falls and fractures. Estrogen seems to prevent postmenopausal fractures, especially wrist fractures (Honkanen et al. 2000, Randell et al. 2002). Nonetheless, its effect on the fall risk seems to be much more specific: it prevents falls only in the early postmenopausal phase, mostly only preventing nonslip falls (Randell et al 2001). Vitamin D deficiency is common among older adults and is often associated with muscle weakness, impaired posture and balance (Pérez-López 2007, Murad et al. 2011). It has been suggested that those subjects with a low serum 25-hydroxyvitamin D level (which is used as a common marker of vitamin D status) have a lower physical performance and a significant decline in functioning (Minshull et al. 2016). Studies with vitamin D supplementation have reported a reduction in fall rates by improving neuromuscular function, although the results are not totally consistent (Beaudart et al. 2014, Cangussu et al. 2016, Bolland et al. 2018, Uusi-Rasi et al. 2019). There are some reports that a vitamin D dose of 800–1000 IU/day may prevent falls (Beaudart et al. 2014) whereas some other investigators could not confirm this observation (Rosendahl-Riise et al. 2017).

Table 4. Summary of studies examining the association between medication use and falls in the older population.

Author[1]	**Year**	**A**	**N**	**Age**	**Exposure**		**Outcome**
					Medication use		**Any falls, OR (adjusted), 95% CI**
Neutel	2002	P/12mh	227 196 (w)	≥ 65	*Number*	5-9 dugs	4.0 (1.6–9.9)
						10+ drugs	5.5 (1.9–15.9)
					Type	Antidepressant	2.0 (0.7–5.2)
						Analgesic	1.5 (0.8–2.9)
Lawlor	2003	CS/12mh	4050 (w)	60–79	Type	Antidepressants	1.53 (1.15–2.02)
						Hypnotics & anxiolytics	1.41 (1.00–1.98)
						CNS drugs	1.25 (1.11–1.41)
						Analgesics	1.00 (0.79–1.25)
							Any falls, OR (crude), 95% CI
Rozenfield	2003	CS/12mh	634 (w)	≥ 60	*Type*	Antihypertensive	1.11 (0.78–1.58)
						Psychoactive agents	2.04 (1.05–3.99)
						Sedatives	1.14 (0.77–1.69)
							Any falls, OR (adjusted), 95% CI
Landi	2005	P/3mh	2854 1661 (w)	≥ 65	*Type*	Antipsychotic	1.48 (1.09–2.02)
						Benzodiazepines	1.36 (1.08–1.71)
						Antidepressants	0.92 (0.67–1.26)
						Hypnotics and sedatives	1.08 (0.83–1.41)
Buatois	2010	P/(18–36) mh	2735 1357(w)	≥ 65	*Number*	≥4 drugs	1.66 (1.06–2.60)
							Injurious falls, OR (adjusted), 95% CI
Kuschel	2015	CC/36mh	321,995 211,045 (w)	≥ 65	*Type*	Hypnotics and sedatives	w=1.21 (1.14–1.29)
						Antidepressants	w=1.76 (1.61–1.93)
						NSAIDS	w=1.14 (1.04–1.24)

A = Study type, P=Prospective, CS=Cross-sectional, CC= case-control, mh=month, N= study population, w = women, OR =Odds ratio, 95% CI= 95% Confidence Interval, [1] Only first author mentioned.

Previous falls and fractures

According to numerous studies, older adults who have experienced a previous fall, frequent falls or an injurious fall are liable to fall again (O'Loughlin et al. 1993, Tromp et al. 2001, Andresen et al. 2006). The risk of future falls and fractures does seem to be increased among older adults with a previous falling history (Geusens et al. 2003, Nordell et al. 2005). The risk of falls and the likelihood of severe injury from a fall increase with age (Nevitt et al. 1991). Following a fall-related injury, older people suffer a subsequent decline in functional status which may cause anxiety and limitations in their activities resulting in increased risk of future falls (Masud and Morris 2001). In persons aged 65 years or more, a history of falls is a factor in over 80% of all non-spinal fractures and over 90% of osteoporotic fractures (Nevitt 1997) and furthermore previous falls have been reported to be an independent predictor of hip fractures (Dargent-Molina et al. 1996). Among older adults, about 90% of hip fractures are the result of direct trauma to the hip following a fall (Geusen et al. 2002). Although, BMD is one of the major risk factors for fragility fractures, the fracture risk ultimately depends not only the mechanical strength of the bone but also on the forces applied to it. The majority of these kinds of low-trauma fractures occur as a result of a fall from standing height or less (Harvey et al. 2018). An increase in the rate of falling may reflect greater frailty with an increased risk of fracture when a fall occurs (Cummings and Nevitt 1989). Although there are rather few longitudinal studies addressing the association between types of fall and fracture risk, one study reported that the risk of fracture after a slip fall at the same level was greater than that after a fall on the same level due to intrinsic factors (Luukinen et al. 1997). In addition, fall related conditions such as decreased lower extremity muscle force, cognitive impairment, impaired gait and balance, poor visual acuity and sedative medications may increase the risk of fractures in older people (Allolio 1999, Albrand et al. 2003, Edwards et al. 2013). Some investigators have reported that patients with fall-related fractures are at a high risk of subsequent falls (Thompson et al. 2010, Dewan et al. 2018). Reduced physical activity due to pain, impaired function, a deterioration in muscle strength, balance and coordination after fractures are all factors that might increase the risk of future falls as well as the fracture risk (Nordell et al. 2003, Cho et al. 2014).

2.3.3 Health behavioral factors

Several studies have investigated the role of *physical activity* in falling risk among older adults (Gregg et al. 2000, Heesch et al. 2008, Klenk et al. 2015). The physical activity dimension consists of simple and more complex tasks (such as walking, obtaining food, and performing tasks (Atay and Akeniz 2011). It has been suggested that both high and low levels of physical activity are associated with an increased risk of falling among older people although the role of physical activity in reducing the risk of falls remains controversial (Karlsson 2004, Peeters et al. 2010, Zhuang et al. 2014). One report suggested that regular physical activity maintains good musculoskeletal health and functional independence in older adulthood, thus lowering the risk for falls and fall-related injuries (Sherrington et al. 2008). Furthermore, these factors appear to be associated with a reduced risk or slower progression of several age-related conditions which increase the risk of falls among older adults (Heesch et al. 2008). Nonetheless there is also a concern that physical activity may increase the risk of falls in vulnerable older people (Faber et al. 2006). Regular moderate physical activity in older age is integral to good health and maintaining independence, since it prevents the onset of multiple pathologies and a functional capacity decline while lowering the risk of falls and fall-related injuries through contributing to healthy bones and muscles (Atay and Akeniz 2011, Thibaud et al. 2012). Tinetti et al. suggested that falling would be negatively associated with frequent walking exercise but positively associated with other forms of physical exercise (Speechley and Tinetti 1991). It has been reported that older people who engage in vigorous-intensity physical activity have a lower fall rate but a higher risk of injuring themselves if they do fall (Faber et al. 2006). An inability to perform the activities of daily living (ADL) and self-reported limitations in mobility, are generally associated with an increased risk of falling (Lord et al. 2007). In fact, frail older people tend to fall while carrying out ADL (Kojima et al. 2008, Delgado et al. 2015, Kojima et al. 2015). Prospective studies evaluating the association of physical activity with the risk of falling have suggested that there is a U-shaped association, where the most inactive and the most active people are at the highest risk (Peeters et al. 2010). In a large prospective cohort study of 5,995 community dwelling men aged at least 65 years, Chan et al. revealed that the most active quartile had a significant greater fall risk than the least active quartile (Chan et al. 2007).

Some studies have confirmed the association of *smoking* and low bone mineral density (BMD) with an increased risk of fracture (Nelson et al. 1994, Wong et al. 2007). Thus, the relative contribution of fracture risks due to smoking might have an indirect effect in future falling among older adults (Egger et al. 1996). The fall risk and the use of *alcohol* have been investigated in several studies (Reid et al. 2002, Sorock et al. 2006). Honkanen et al. detected a strong and dose-dependent relationship between blood alcohol level and fall risk among adults (Honkanen et al. 1983). The risk associated with alcohol maybe due to both the direct effects of alcohol, as well as detrimental health-related behaviors, comorbid conditions, and concomitant medications.

2.4 CONSEQUENCES OF FALLS

Falls have a strong impact on health and the quality of life of older people. Around 40–60% of falls lead to injuries with 30–50% being minor injuries such as bruises or lacerations, 5-6% are major injuries excluding fractures with 5% causing fractures (Kannus et al. 2005, Lehtola et al. 2006, Bergen et al. 2016). Falls account for 40% of all injury-related deaths and over 80% of all injury admissions to hospital (Kannus et al. 2006, World Health Organization, 2007, Alekna et al. 2015). Falls are the most common cause of traumatic brain injury (TBI) and account for 46% of all fall-related deaths in TBI patients (Kannus et al. 2007, Harvey and Close 2012). In Finland, the number of deaths due to falling has increased considerably (Korhonen et al. 2013). The age-adjusted severe fall-induced head injury rate dramatically increased from 1970–1995 among older adults (Kannus et al. 1999) although the rate has subsequently stabilized (Kannus et al. 2018). While less than 1% of falls are said to result in a hip fracture, 90% of all hip fractures are caused by a fall which has a significant morbidity, mortality, and cost to health service (Johnell and Kanis 2006). Following a hip fracture, 25% of older patients will die in the first year, 76% will suffer a decline in their mobility, 50% will experience a decline in their ability to perform ADL and 22% will move into a nursing home (Marks et al. 2003). Environmental factors also contribute to the fall occurrence and their injurious consequences in older people. Certain factors are found to be important risk factors for fractures i.e. if the fall is associated with a high potential energy, falling sideways and landing on a hard surface (Wei et al. 2001, Kannus et al. 2006). Many older adults are unable to get up again after a fall without assistance (Fleming et al. 2008). Thus, any subsequent "long lie" can lead to dehydration, hypothermia, pressure sore, rhabdomyolysis, and pneumonia (Tinetti et al. 1993). In addition, slipping, tripping and falls on stairs and those occurring from an upper level can result in a fracture in older adults (Luukinen et al. 1997). Around a third of older people developed a fear of falling after an incidental fall and those with a fear of falling experienced an increased risk of falling (Murphy et al. 2003). There is a report that older people who are afraid to fall tend to avoid physical activity (Hadjistavropoulos et al. 2007). This reduced mobility in turn may increase the risk of falling and lead to their social isolation (Cumming et al. 2000). In the long term, these changes may lower their quality of life with an increased risk of institutionalization (Murphy et al. 2003).

Falls and their consequences are responsible for a large part of health care costs (Heinrich et al. 2010). Fall-incurred costs can be categorized into two aspects: direct and indirect costs. Direct costs encompass health care costs such as medications and health-care-provider consultations in treatment and rehabilitation. Indirect costs are societal such as losses of productivity in individuals and family caregivers (World Health Organization, 2007). In the United States, the total direct medical costs for fall-related injuries among older adults in 2008 were US$ 23.3 billion and the fall related costs were reported to be US$ 1.6 billion in the United Kingdom (Davis et al. 2010). In Finland, hospital treatment of accidents is estimated to cost over 600 million EUR every year where about half of all inpatients are being treated for fall injuries (THL, 2018). Several studies have emphasized the substantial economic burden caused by fall-related injuries, regardless of the medical care system (Stevens et al. 2006, Burns et al. 2016). A systematic review of international studies showed that fall-related costs ranged between 0.85 to 1.5% of the total health care expenditure of different countries in North America, Australia, Europe, and the United Kingdom, representing somewhere between 0.07 to 0.20% of the Gross Domestic Product (Heinrich et al. 2010). Furthermore, falls or fall related medical events were estimated to account for 40% of nursing home placements and in this way to contribute to further increases in health care costs (Masud and Morris 2001).

2.5 FALLS BEFORE OLD AGE

The risk of falls starts to increase in women during the second half of their lives, especially among those with co-morbid conditions (Nitz, JC. and Low Choy 2008). There are several intrinsic factors which may increase the risk of falls and these starts to appear well before the age 65 (Low Choy et al. 2007). For example, it has been reported that in women, muscle weakness resulting in reducing activities and a significant reduction in ability to balance occurs between the ages of 40 and 60 (Choy et al. 2003, Nitz, JC et al. 2003, Low Choy et al. 2007). It would be important to clarify whether these changes are reflected in fall pattern changes among women younger than 65. In addition, postmenopausal women undergo physiological changes in menopause (menopause related changes in metabolic rate and body composition) which may decrease their bone mass affecting the resistance of bone to fractures (Gregorio et al. 2014, Cevei et al. 2020). The risk of falls increases even more as aging progresses (Zhao et al. 2020). It is understandable that most fall prevention interventions are currently targeted at people over 65 years (Hopewell et al. 2020). There is a gap between knowledge regarding different type of falls and factors that might contribute to future falls and fractures in younger women. Further research is needed to identify risk factors for different type of falls (slip/nonslip) in postmenopausal women in whom the changes in the sensory and motor systems have not reached a pathological level so that preventive measures on modifiable factors can be focused at a sufficiently early stage. Unfortunately, this thesis cannot solve all of the problems inherent in fall prevention, but it does add some knowledge on postmenopausal fall patterns on which future research can be based. For example, by using

OSTPRE data, one can later define trajectories from risk/prevention factors to fall/fractures in older women.

3 OBJECTIVES OF THE PRESENT STUDY

This doctoral thesis aims to identify the association between specific health–related factors and risks of falls according to the type of fall (slip/nonslip) in a population–based sample of Finnish postmenopausal women. This involved the use of data from the Kuopio Osteoporosis Risk factor and Prevention (OSTPRE) Study, a population based prospective cohort, with a total of 14,220 postmenopausal women from Kuopio Province, Eastern Finland monitored through repeated questionnaires at 5-years intervals until 2019.

3.1 OBJECTIVE OF THE STUDY I

1. The objective of the first study was to analyze the association between morbidity (number of chronic medical conditions) and falling risk according to the type of falls (slip/nonslip) among Finnish postmenopausal women.

3.2. OBJECTIVES OF THE STUDY II

1. The primary objective of the second study was to investigate the role of musculoskeletal disorders (MSDs) in falls according to the type of falls (slip/nonslip) among Finnish postmenopausal women.

2. A secondary objective was to compare these fall risks with fall risks due to different health disorders other than MSDs.

3.3 OBJECTIVES OF THE STUDY III

1. The primary objective of the third study was to evaluate if a history of falls would predict future postmenopausal fractures.

2. A secondary objective was to evaluate if the prediction of future fractures varied according to frequency (occasional/frequent), mechanism (slip/nonslip) and severity (injurious/non-injurious) of falls as well as the site of the fractures.

6 Study III A fall in the previous twelve months predicts fracture in the subsequent five years in postmenopausal women

6.1 ABSTRACT

Purpose

The purpose of this study was to evaluate if a history of falls predicts future postmenopausal fractures and if this prediction varies according to frequency, mechanism and severity of falls and site of fractures.

Methods

This study used data from OSTPRE prospective cohort. Total study population consisted of 8744 postmenopausal women (mean age 62.2 years) who responded to postal enquiry in 1999 (baseline) and in 2004 (follow-up). Women were classified by frequency (non/occasional/frequent fallers), mechanism (slip/nonslip) and severity (injurious/ non-injurious) of falls and fractures by site (major osteoporotic/ other).

Results

A total of 1693 (19.4 %) women reported a fall during the preceding 12 months in 1999; 812 a slip fall, 654 a nonslip, 379 an injurious fall and 1308 a non-injurious fall. 811 women (9.3 %) sustained a fracture during the 5-year follow-up period (1999-2004); 431 major osteoporotic fractures and 380 other fractures. Compared to non-fallers, earlier falls predicted subsequent fractures with an OR of 1.41 (95% CI 1.19 - 1.67, $p \leq 0.001$), 1.43 (95 % CI 1.14 - 1.80, $p=0.002$) for earlier slip falls and 1.35 (95 % CI 1.04 - 1.74, $p=0.02$) for earlier nonslip falls. Earlier injurious falls predicted future fractures (OR= 1.64, 95 % CI 1.21 - 2.23, $p \leq 0.01$), especially other fractures (OR = 1.86, 95 % CI 1.24 - 2.80, $p \leq 0.01$), but not major osteoporotic fractures (OR = 1.37, 95 % CI 0.89 - 2.10, $p=0.151$). Fracture risk predictions for earlier non-injurious falls was OR=1.36, 95 % CI 1.12 - 1.64, $p=0.002$. These risk patterns remain same after adjustments.

Conclusion

History of falls (especially injurious falls) predicts subsequent fractures (mainly other fractures compared to major osteoporotic fractures) in postmenopausal women.

6.2 INTRODUCTION

Falls in the elderly are common (Tinetti et al. 1988) and result in fractures and other serious health consequences (Kannus et al. 1997). Among subjects aged 65 years or over, falls are the leading cause of injury-related death and hospitalization (Baker 1985). Thus, fall-induced injuries result in a substantial economic burden worldwide (Ray et al. 1997). Research has shown a history of falls to be associated with a higher probability for future falls and risk of subsequent fractures (Kelsey et al. 1992, Dargent-Molina et al. 1996, Schwartz et al. 2005, Van Staa et al. 2006, Harvey et al. 2018). In cold climate countries, slipping is a common fall mechanism and results often in injuries (injurious falls) (Honkanen, R. 1982). Thus far, longitudinal studies on how history of falls predicts future fractures have not been determined according to frequency, mechanism (slip/nonslip) or severity (injurious/non-injurious) of the fall (Cumming and Klineberg 1994, Tromp et al. 1998, Ensrud et al. 2007).

Previously we have found that falling risks (especially nonslip falls) increased in women with multimorbidity (multiple chronic conditions) (Afrin et al. 2016). It is probable that due to effects of health disorders, women who have multiple nonslip falls are more unwell and less physically active compared to women with slip falls (Afrin et al. 2018). Falling events resulting in injury also reflect the overall health condition of the individuals (Nevitt et al. 1991). The aim of the present study was to determine if an overall history of falls (frequency, mechanism and severity) or its parts are useful predictors of future fracture in postmenopausal women.

6.3 MATERIALS AND METHODS

6.3.1 Study design and subjects

This is a prospective cohort study. The *study population* originated from the Kuopio Osteoporosis Risk Factor and Prevention Study (OSTPRE) initiated in 1989. The baseline self-administered postal enquiry of OSTPRE was sent to all women born in 1932-41 (N=14,220) aged 47-56 years and living in Kuopio Province, Eastern Finland. Follow-up data has been collected by subsequent postal enquiries at 5- year intervals.

The *present study* included a total of 8744 women who responded to the fall questions in 1999 (baseline of the present study) and fracture questions in 2004 with no other inclusion criteria. At baseline, the mean age of the participants was 62.2 (range 57-66) years (SD 2.9) and all women were postmenopausal. The ethics committee of Kuopio University Hospital approved the OSTPRE study and participants provided a written informed consent.

6.3.2 Measurement of variables

6.3.2.1 Falls (exposure)

For the present study, we used self-reported falls. A definition of a fall was not mentioned in the questionnaire, due to the Finnish language having different words for falls on the same level versus falls from height. At baseline (May 1999), the participants were asked about history of falls, via the question *"How many times have you fallen during the last 12 months?"* If a fall was reported, they were further asked *"How did you fall last time"* with the following alternatives: (1) fall on stairs,

(2) fall from level 3) slipping on level, (3) stumbling or tripping on level, and (4) otherwise on level, specify. The severity of the falling event was determined via the question *"Did the last fall result in medical attention?"*

The women were classified according to frequency of falls i.e. 1) *non-faller* 2) *occasional faller* (one fall) and 3) *frequent faller* (more than one fall). The falling mechanism was categorized as 1) *slip on the same level* and *2) nonslip (i.e. any other than slip) on the same level* according to their last falling event. Falls were also categorized by severity *1) injurious (self-reported medically attended falls)* and *2) non-injurious.* Falls from a bicycle or while skiing were not counted as falls. Women who reported no falls (non-fallers) were considered as the reference group for all analyses (occasional, frequent, slip, nonslip, injurious or non-injurious).

6.3.2.2 Fractures (outcome)

At follow-up (in 2004), the participants were asked about the occurrence of fracture: *"Have you had fractures diagnosed by physician after May 1999?"* Those who reported a fracture were then asked, *"which bone was fractured, how it was diagnosed and where it was treated?"* The follow-up time for incident fractures was 5 years between the 1999 and 2004 questionnaire. All self-reported fractures were confirmed by patient records. In this analysis, the first fracture in each fracture site per person occurring during this follow-up time was included.

According to the FRAX (fracture risk prediction model) tool, fractures occurring at the spine, hip, distal forearm and proximal humerus are considered major osteoporotic fractures (Kanis et al. 2013), which by definition include low trauma (i.e. fall from a standing height or less) (Center 2013). Thus, we classified the fractures into *(1) major osteoporotic fracture (spine, hip, distal forearm and proximal humerus)* and (2) *other fractures (other than major osteoporotic fractures, including e.g. chest region, hand, forearm and elbow; femur, knee and leg; ankle and foot; skull, pelvis) fractures.* We investigated future fracture risk in these categories according to frequency (no/occasional /frequent), mechanism (slip/nonslip) and severity (injurious/non-injurious) of earlier falls.

6.3.2.3 Covariates

From the baseline enquiry, covariates and potential confounders were chosen based on literature and according to their potential association with fractures and falls. They included baseline age (years), body mass index (BMI; kg/m^2), dairy calcium intake (mg/day), number of prescribed medications, number of chronic health disorders, current smoking (no/yes), alcohol use (no/yes), leisure physical activity (no/yes), restricted mobility (no/yes), falls during the last 12 months and use of estrogen hormone therapy (no use/irregular use/continuous use) during 1999-2004. Previously, we have found that the effect of hormone therapy is transient so that only current but not past use prevents fractures (Randell et al. 2002). Therefore, we used follow-up hormone therapy variable during 1999-2004 (instead of baseline measurement). Dairy calcium intake was measured via the questions *1) How many deciliters (1glass=2dl; 1 dl =120 mg of calcium) dairy products (milk, sour milk, yogurt, sour whole milk) do you use daily? 2) How many cheese slices (1 slice= 87 mg of calcium) do you eat daily.*

6.3.3 Statistical analysis

Statistical analysis was conducted using SPSS, version 25.0. T-Test (Student´s T-Test) for continuous variables and Chi-square tests for categorical variables were used to identify the association between each study variable and fractures. Logistic regression models were used to analyze the crude and adjusted risk of future fractures according to frequency, mechanism and severity of earlier falls. The results were reported as Odds Ratios (OR) with 95 % confidence intervals (95% CI) and *p* values.

6.4 RESULTS

6.4.1 Baseline characteristics and incidences of falls and fractures

At the time of fall enquiry in 1999, the mean age of the participants was 62.2 (range 57-66) years (SD 2.9) and all women were postmenopausal. The women were on average 13 years since menopause as the mean age of menopause was 49.2 years (SD 4.7).

As presented Figure 1, 7051 of 8744 women (80.6%) reported no falls (*non-fallers*), 941 (10.8%) women at least one fall (*occasional fallers)* and 752 (8.6 %) women more than one fall (*frequent fallers*) in the preceding 12 months. From the total study population (n=8744), a total of 227 women did not answer the questions regarding mechanism of fall (*slip/nonslip*) and a total of 6 women did not answer the question regarding severity of fall (*injurious/non-injurious).* The number of women who reported slip or nonslip falls as the mechanism of their last fall were 812/8517 (9.5%) and 654/8517 (7.7%), respectively. A total of 379/8738 (4.4 %) women reported falls requiring medical attention (*injurious falls*) and out of these 379 women, 131 (34.6 %) women reported a fracture as the outcome of the event.

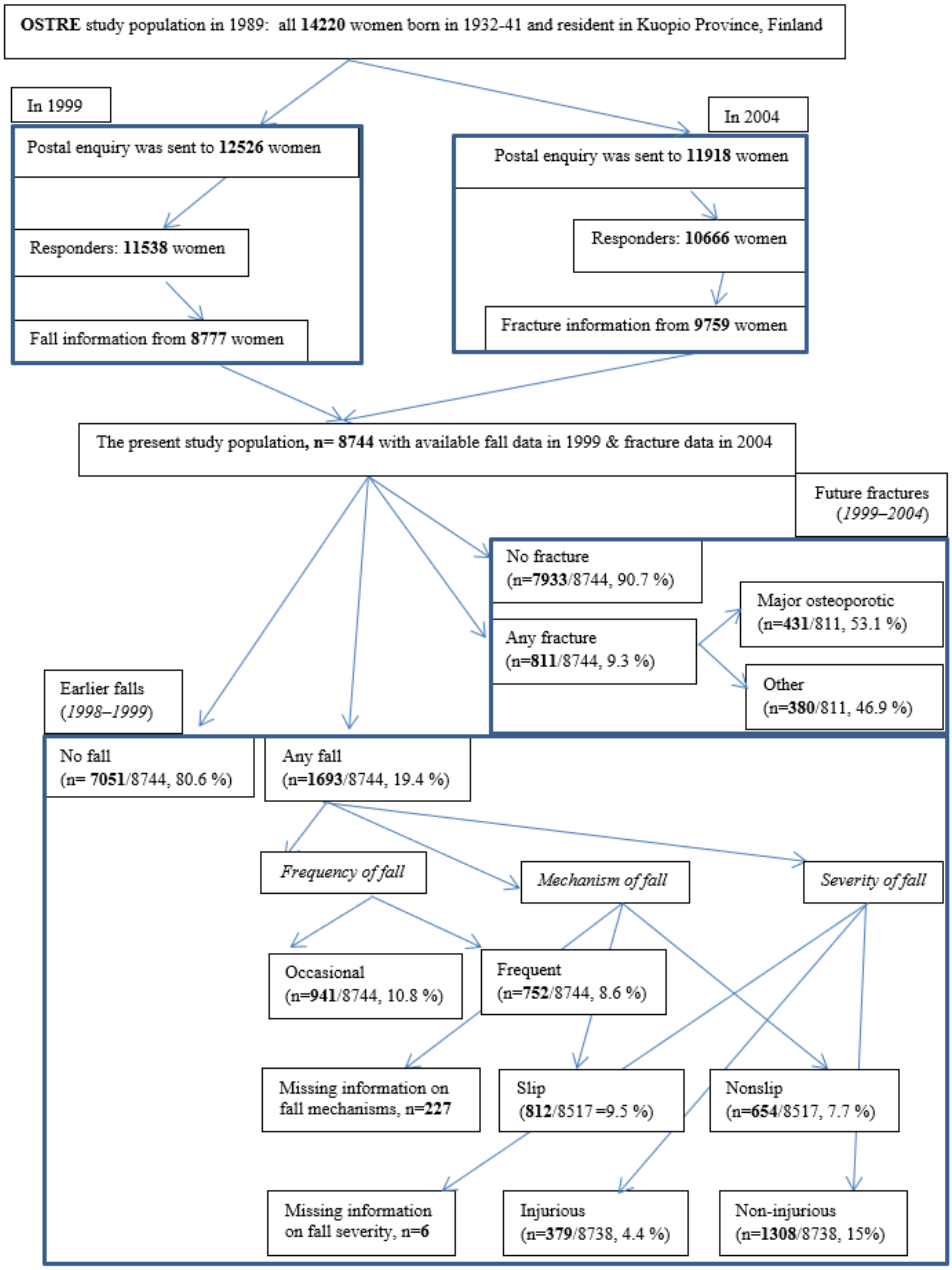

Fig.1 Distribution of the study population according to the different type of falls and fractures.

In the 5-year follow-up (1999-2004), 811/8744 (9.3%) women reported fractures which were confirmed via medical records (Figure 1). Of these 811 women, 431/811 (53.1%) reported major osteoporotic fractures, 380/811 (46.9%) solely other fractures, and 38/811 (4.7%) women had both types of fractures. In general, mean number of prescribed medications and number of chronic health disorders were higher among women with at least one fracture than among women with no fracture. History of previous falls was significantly higher among women with fracture compared to women with no fracture (Table 1). In addition, use of hormone therapy was significantly lower among women with fracture (Table 1) and continuous use of hormone therapy showed a preventive effect on future fracture risks (OR=0.45, 95 % CI= 0.41 - 0.72, p values < 0.001) compared to irregular use or no use.

Table 1. Baseline characteristics of the study population according to fracture.

Baseline characteristics	No fracture (n=7933)	Any fracture (n=811)	*P* value*
	Mean (SD)	Mean (SD)	
Age, years	62.2 (2.9)	62.3 (3.0)	0.29
Body mass index, kg/m2	27.49 (4.51)	27.52 (4.41)	0.83
Dairy calcium intake, mg/d	850 (370)	828 (361)	0.11
Number of chronic health disorders	2.32 (1.78)	2.45 (1.87)	0.05
Number of prescribed medications	1.97 (1.95)	2.16 (2.11)	0.01
	Proportion as %	Proportion as %	
[a] Use of estrogen hormone therapy in 1999-2004			
no use (n=6845)	77.70 (n=6167)	83.60 (n=678)	
irregular use (n=786)	9.10 (n=721)	8.00 (n=65)	<0.001
continuous use (n=1113)	13.20 (n=1045)	8.40 (n=68)	<0.001
Current smoking (yes, n=611)	6.90 (n=548)	7.80 (n=63)	0.36
Alcohol use (yes, n=4578)	53.10 (n=4126)	56.90 (n=452)	0.05
Leisure physical activity (yes, n=6079)	71.90 (n=5513)	72.60 (n=566)	0.70
Restricted mobility (yes, n=352)	4.20 (n=314)	5.00 (n=38)	0.30
Falling history (in the past 12 months)			
no fall (n=7051)	81.20 (n=6440)	75.30 (n=611)	
occasional fall (n=941)	10.50 (n=832)	13.40 (n=109)	<0.001
frequent fall (n=752)	8.30 (n=661)	11.20 (n=91)	<0.001

SD= Standard Deviation, [a] Use of estrogen hormone therapy in 1999-2004 was obtained from the 2004 enquiry as continuous use of hormone therapy appeared to prevent falls in these women. *t-test (Student´s t-test) for continuous and Chi-square tests for categorical variables are used to find the difference between no fractures and fracture groups.

6.4.2 Future fracture risks by frequency, mechanism, and severity of earlier falls

Compared with the 7051 women who reported no fall (*reference group*) at the baseline enquiry in 1999, the OR for fracture among women who reported a previous fall was 1.41 (95% CI 1.19 - 1.67, p≤0.001), women who reported one fall (*occasional fallers*) was 1.38 (95% CI 1.11 - 1.71, p=0.003) and women who reported more than one fall (*frequent fallers*) was 1.45 (95% CI 1.15 - 1.83, p=0.002) (Table 2) in unadjusted analyses.

Table 2. Unadjusted and adjusted risks (ORs) of fractures related to history of falls in comparison to non-faller risk.

Type of fall		**Any fracture, ([a]n =811)**	**Major osteoporotic fracture (n=431)**	**Other fracture (n=380)**
Any fall		OR, 95 % CI, p value		
– *total* (n=1693)	unadjusted	1.41 (1.19 – 1.67) ***	1.26 (0.99 – 1.58)	1.54 (1.22 – 1.95) ***
	adjusted	1.38 (1.14–1.66) ***	1.15 (0.88–1.49)	1.61 (1.25–2.09) ***
– *occasional* (n=941)	unadjusted	1.38 (1.11 – 1.71) **	1.35 (1.02 – 1.80) *	1.36 (1.00 – 1.86) *
	adjusted	1.35 (1.07–1.72) *	1.28 (0.93–1.75)	1.40 (1.00–1.96) *
– *frequent* (n=752)	unadjusted	1.45 (1.15 – 1.83) **	1.14 (0.81 – 1.59)	1.77 (1.30 – 2.40) ***
	adjusted	1.42 (1.09 – 1.85) **	0.98 (0.66 – 1.47)	1.89 (1.35 – 2.65) ***
Slip fall				
– *total* (n=812)	*unadjusted*	1.43 (1.14 – 1.80) **	1.24 (0.91 – 1.70)	1.59 (1.17 – 2.17) **
	adjusted	1.47 (1.15–1.89) **	1.25 (0.89–1.76)	1.67 (1.19–2.35) **
– *occasional* (n=476)	*unadjusted*	1.38 (1.03 – 1.85) *	1.41 (0.96 – 2.06)	1.29 (0.84 – 1.98)
	adjusted	1.33 (0.96–1.85)	1.36 (0.90–2.06)	1.26 (0.78–2.03)
– frequent (n=336)	*unadjusted*	1.51 (1.08 – 2.10) *	1.01 (0.61 – 1.69)	2.04 (1.34 – 3.09) ***
	adjusted	1.67 (1.17 – 2.39) **	1.09 (0.63 – 1.90)	2.26 (1.45 – 3.53) ***
Nonslip fall				
– total (n=654)	*unadjusted*	1.35 (1.04 – 1.74) *	1.18 (0.83– 1.68)	1.50 (1.06 – 2.12) *
	adjusted	1.30 (0.98–1.73)	1.05 (0.70–1.56)	1.62 (1.11–2.36) *
– occasional (n=383)	*unadjusted*	1.30 (0.93 – 1.81)	1.17 (0.75 – 1.85)	1.41 (0.89 – 2.22)
	adjusted	1.30 (0.91–1.85)	1.10 (0.67–1.80)	1.51 (0.93–2.45)
– frequent (n=271)	*unadjusted*	1.41 (0.97 – 2.06)	1.19 (0.70 – 2.02)	1.63 (0.98 – 2.69)
	adjusted	1.31 (0.84 – 2.02)	0.88 (0.45 – 1.75)	1.77 (1.02 – 3.06) *
Injurious fall				
– total (n=379)	*unadjusted*	1.64 (1.21–2.23) **	1.37 (0.89–2.10)	1.86 (1.24–2.80) **
	adjusted	1.64 (1.18–2.29) **	1.38 (0.87–2.20)	1.85 (1.18–2.90) **
– occasional (n=299)	*unadjusted*	1.58 (1.12–2.24) **	1.45 (0.91–2.31)	1.65 (1.02–2.66) *
	adjusted	1.54 (1.06–2.25) *	1.41 (0.85–2.35)	1.61 (0.95–2.73)
– frequent (n=80)	*unadjusted*	1.86 (1.00–3.46) *	1.07 (0.39–2.93)	2.70 (1.29–5.65) **
	adjusted	2.05 (1.06–3.97) *	1.29 (0.46–3.60)	2.78 (1.24–6.23) **
Non-injurious fall				
– total (n=1308)	*unadjusted*	1.36 (1.12–1.64) **	1.23 (0.95–1.59)	1.46 (1.12–1.89) **
	adjusted	1.31 (1.06–1.62) **	1.08 (0.81–1.46)	1.55 (1.16–2.07) **
– *occasional* (n=640)	*unadjusted*	1.29 (1.00–1.68) *	1.31 (0.93–1.85)	1,24 (0.85–1.81)
	adjusted	1.27 (0.95–1.69)	1.21 (0.83–1.77)	1.31 (0.87–1.98)
– *frequent* (n=668)	unadjusted	1.41 (1.10–1.81) **	1.15 (0.81–1.64)	1.67 (1.20–2.33) **
	adjusted	1.36 (1.02–1.80) *	0.95 (0.62–1.46)	1.79 (1.25–2.57) **

[a]n =number of women, Any fall = slip/nonslip/unknown falls, OR=Odds Ratio, 95 % Confidence interval

* = $p \leq 0.05$, ** = $p \leq 0.01$, *** = $p \leq 0.001$

Adjusted for age, BMI, dairy calcium intake, number of prescribed medications, number of chronic health disorders, use of estrogen hormone therapy (1999-2004), current smoking, alcohol use, leisure physical activity and restricted mobility.

In fracture categories, the risk for other fractures related to fall history was higher than the corresponding risk for major osteoporotic fractures. Women who reported a previous fall were at higher risk of future other fractures (OR=1.54, 95% CI 1.22 - 1.95, p≤0.001) than major osteoporotic fractures (OR=1.26, 95% CI 0.99 - 1.58, p=0.052) compared to non-fallers (reference group) (Table 2). With the same reference group, the corresponding ORs for future other fractures in women with previous slip falls was 1.59 (95 % CI 1.17 - 2.17, p=0.003) and in women with previous nonslip falls was 1.50 (95% CI 1.06 - 2.12, p=0.02). Earlier injurious falls strongly predicted the risk of future other fracture (OR = 1.86, 95 % CI 1.24 - 2.80, p≤0.01), but not the risk of major osteoporotic fractures (OR = 1.37, 95 % CI 0.89 - 2.10, p=0.151). In addition, women who fell frequently (more than one fall) were at greater risk of future fracture (*major osteoporotic/other*) than those who fell occasionally (one fall) (Table 2). The future fracture risk estimation remained almost same following adjustment for clinically relevant predictors (age, BMI, dairy calcium intake, number of prescribed medications, number of chronic health disorders, use of estrogen hormone therapy (1999-2004), current smoking, alcohol use, leisure physical activity and restricted mobility) (Table 2).

In regard to site-specific fractures, the risk for subsequent fracture was also increased for most sites (mainly other fractures) due to earlier falls, however most failed to reach statistical significance (Figure 2). Of the fall's categories (frequency, mechanism and severity), injurious falls tended to be associated with the highest risk of site-specific fractures compared to the other categories (Appendix Table 1).

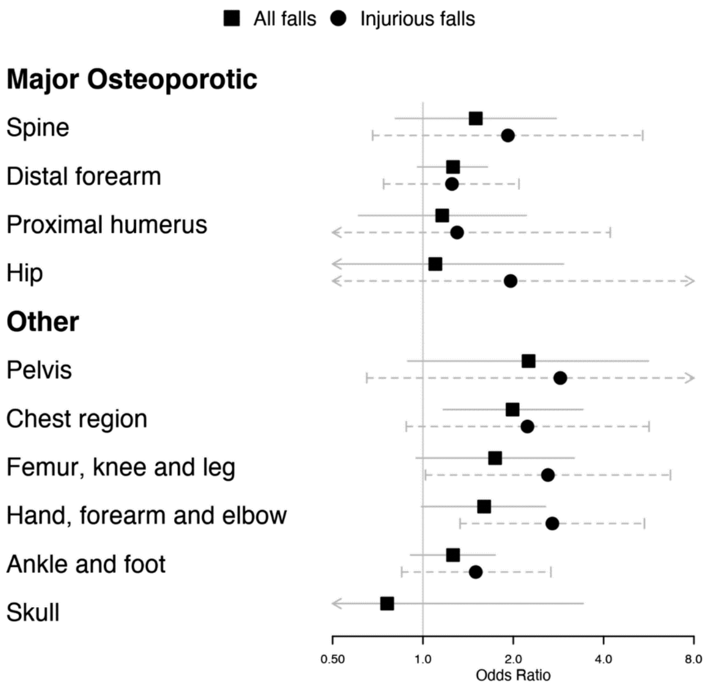

Fig.2 Specific future fracture risks (Odds Ratios with 95 % CIs) related to all and injurious earlier fall in comparison to women with no earlier falls.
*no future skull fractures were observed for women with earlier injurious fall.

6.4.3 Loss analysis

The cohort members responded better to fracture questions in 2004 (n=9759) than to fall questions in 1999 (n=8744) (Figure 1). A total of 1015 women had fracture information but no fall information. The percentages of women with incident fractures during 1999-2004 were similar in women without and with information on falls (94/1015) =9.26 % vs. (811/8744) =9.27 %, respectively.

6.5 DISCUSSION

The present study shows that a history of falls (especially injurious falls) is an important risk factor for future fracture, in particular for other fractures compared to major osteoporotic fractures among postmenopausal women. To our knowledge, fracture risk (*major osteoporotic vs other*) according to mechanism (*slip/nonslip*) and severity (*injurious/non-injurious*) of previous falls has not been previously examined in a prospective cohort study.

In the present study, the annual fall incidence rate (20%) was less than previously reported (30%) in studies including elderly women aged 65 years or over (Tinetti et al. 1988). The mean age [62.2 years (range 57-66)] of the included study population likely explains the lower incidence rate, as rate of falls increases with increasing age (Tinetti and Speechley 1989, Schwartz et al. 2005). Slipping was the most common falling mechanism, and the proportion of slip falls was clearly higher than in most studies conducted in warmer climates (Bath and Morgan 1999). The long and icy winter season in the cold climate countries, leads to frequent outdoor slip falls, which explains their higher occurrence compared to nonslip falls in the present study population (Luukinen et al. 2000). The self-reported use of estrogen hormone therapy was higher among women with no fracture and has a significant preventive effect on future fractures. This observation is in alignment with our previous studies from the OSTPRE follow-up (Randell et al. 2002, Tuppurainen et al. 2010). Although, we previously found that the use of estrogen therapy appeared to have a preventive effect on falls in early but not in late menopausal women (Randell et al. 2001). It is possible that the effects of hormone therapy on fall risk reduces with age.

By understanding how frequency, mechanism and severity of previous falls modifies the risk of future fractures (*major osteoporotic vs other*), specific measures for fracture prevention can be developed accordingly (Cumming and Klineberg 1994, Nguyen et al. 2001, Cummings and Melton 2002, Vogt et al. 2002). In the present study, we found higher future fracture risk due to previous slip falls (OR= 1.43) compared to previous nonslip falls (OR=1.35). However, there was no statistically significant difference between the two (*slip vs nonslip*) risk predictions (Table 2). A plausible explanation for the observed increase in fracture risk prediction due to slip falls could be that women who have had previous slip falls are more physically active and capable of moving outdoors more often than women with a previous history of nonslip falls. These women would have greater exposure to slippery conditions which is a known risk factor for fracture (Afrin et al. 2016, Afrin et al. 2018).

We observed that previous slip and nonslip falls were associated with other fractures but not major osteoporotic fractures. In addition, the risk of other fractures was considerably greater in relation to previous (injurious) falls. The greater other fractures risk related to previous history of falls (frequency, mechanism, and severity) could indicate that these women are healthier; they may have stronger bones and less risk factors for major osteoporotic fractures. In addition, for individuals considered frail or falls out of the ordinary caused by an unavoidable external cause (such as traffic accident or slipping outside), fracture may be inevitable and, in this sense, the fall per se may not have any significant role on such fractures.

To shed more light on these findings, we analyzed the associations between history of falls (frequency, mechanism, and severity) and site-specific fractures. According to the point estimates, previous falls (especially injurious falls) tended to increase the risk of future fractures of each of the specific sites, in particular the other fractures. However, the associations were often not statistically significant; the relatively small numbers of individual fracture types likely limited the power to detect statistical differences. Adjustment for mobility could have further clarified the findings and remains an idea for further exploration. Also, the classification of fractures into major osteoporotic vs others is not necessarily justified, since the risk for all types of fracture is increased in women with osteoporosis.

Finally, our finding suggesting that earlier injurious falls is a strong predictor for future fracture especially for other fractures compared to major osteoporotic fractures, could be a good candidate for inclusion in fracture prediction algorithms. The current FRAX (fracture risk prediction model) screening tool includes falls however, the inclusion of previous injurious falls in particular is likely to improve predictive power (Edwards et al. 2013).

The main strength of our study was its prospective population-based design and the large study population with an overall high response rate. Some limitations are also evident. There may be possible recall biases as falls are based on self-reports (Cummings et al. 1988). In addition, we classify the mechanism of fall based on the last falling event which might affect future fracture risk estimates. Therefore, further fracture risk studies with more exact fall reporting methods and detailed information on fall mechanism would have needed to confirm the results. In the current study, the self-reported fractures were confirmed via medical reports. The former validation study of self-reported fractures in OSTPRE cohort observed the sensitivity of self-report to detect fracture to be 78% and specificity 96% (Honkanen et al. 1999). So, it is true that some fractures may have been missed, but when a fracture was reported it had a positive predictive value of 84% truly to be a fracture. Thus, we can assume that there was not severe recall bias involved in the self-reported fracture rates. Even further, there is no reason to believe that self-reporting would have been systematically different between the compared groups meaning that relative risks remain unbiased even though we certainly have lost some power to detect differences and therefore the study results are likely to be rather conservative. This study includes those women who responded to the fall and fracture questionnaires. The incidence of future fractures in non-responders to fall questions was same as in responders suggesting that the fracture risks related to fall history were similar in responders and non-responders. Thus, non-response to fall questions has not severely affected the future fracture risk estimations. Non-response to fracture questions is not biasing our comparisons, but generalizations beyond the population capable of answering the questionnaires should not be made without careful justifications. The current study used the major osteoporotic fracture site criteria established by FRAX and was not aiming to separate fractures due to true status of osteoporosis or trauma energy. This approach was chosen to make our finding more comparable with other similar studies using the same classification criteria. To verify osteoporotic fracture, we would have ultimately needed BMD values, but unfortunately timely BMD measurements were available only for a small fraction of this population-based cohort and detection for truly osteoporotic fractures was impossible. In order to classify women into categories of *major osteoporotic* and *other* fractures, we considered any women who had reported at least one fracture in sites of major osteoporotic fractures to belong in major osteoporotic category and women with solely other fractures to belong in other category. So, our approach allowed us to report site-specific fracture risks in a consistent and comparable way. But as it is certainly possible that some women may have more than one fracture event, we recognize that it would be interesting to focus on that aspect in future research but that is out of scope of the current study.

In conclusion, history of falls (especially injurious falls) appeared to be an indicator for subsequent postmenopausal fracture overall. Earlier injurious falls are a stronger predictor for other fractures than for typical major osteoporotic fractures. Early identification of those at a greater risk for future fracture is the key to minimizing the associated health burden. With this knowledge, clinicians could identify those at a greater fracture risk. These findings are relevant in improving screening and prevention strategies for fractures.

7 GENERAL DISCUSSION

This doctoral thesis provides information about health-related factors as predictors of falls and fractures according to the type of fall in postmenopausal women. Associations between multimorbidity, musculoskeletal disorders and future fall risk were evaluated using data from a large population-based OSTPRE Study. In Study I, the associations of (multi)morbidity in 1989 as the exposure and falls in 1994 as the outcome were prospectively evaluated among 10,594 postmenopausal women aged 52–61 who responded to postal inquiries both in 1989 and 1994. The following results emerged from Study I; the most common morbidities increase the risk of falls but also the fall patterns change with age. Thus, in Study II, the role of musculoskeletal disorders (MSDs) as the exposure in 1999 and falls as the outcome was investigated in 8656 postmenopausal women aged 57–66 in 2004. Study III examined how fall history in 1999 predicted fractures in 1999-2004 (n=8744).

The definition of what constituted a fall was not defined in the OSTPRE questionnaire. We have utilized the fall definition of the ICD-10, which included self-reported common falls on the same level and less common but more severe falls on stairs but excluding falls from one level to another. Falls from a bicycle or falls while skiing or skating, falls caused due to a collision with a motorized vehicle or by other kinds of exceptionally high energy impacts were excluded. Thus the material for this study consisted of both indoor and outdoor falls. Falls were classified according to the frequency (occasional/frequent), mechanism (slip/nonslip) and severity (injurious/non-injurious). Potential confounders were chosen based on the literature and according to their potential association with multimorbidity, MSDs, falls causing fractures for adjustment of the results. Logistic regression model was the main statistical method applied in the statistical assessment of the results.

The prevalences of falls in the study population in 1994, 1999 and 2004 were 33.9%, 20% and 39.2% respectively, values which are similar to those reported in previous studies investigating the fall occurrence among postmenopausal women (Geusens et al. 2002, Barrett-Connor et al. 2009). The low occurrence of falls in 1999 is due to a change in fall question in 1999 (*Have you fallen within the last twelve months?*) compared to question about falls used in 1989 and in 2004 (*Have you fallen within the last 12 months including falls not causing an injury?*). One can roughly estimate the fall rate in 1999 by computing the mean of rates in 1999 and 2004, if similar question had been used. All the fall risk factors investigated in the thesis were significantly associated with frequent falls, but none of the factors were associated with occasional falls. Previously, it has been reported that the associations between risk factors and occasional falls are weak when compared with those for frequent falls (Nevitt et al. 1989). Anyone can fall once due to environmental factors (extrinsic) as well as individual (intrinsic) factors, which may explain why we could detect no factors that were significantly associated with occasional falls.

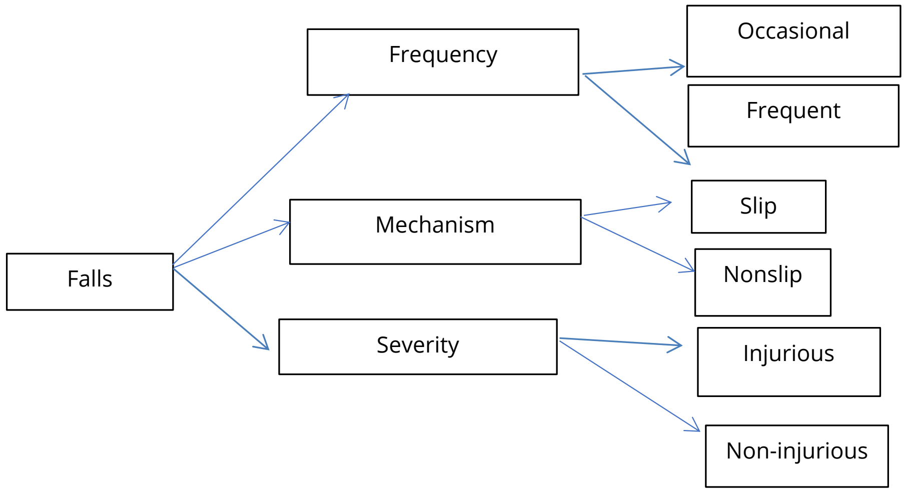

Fig 1. Classification of falls according to frequency, mechanism, and severity in this present thesis.

In this study population, slip was the most common falling mechanism. The main reason for the higher occurrence of slip compared to nonslip falls may be the northern location of the study area (Kuopio, Finland) at a latitude of 64° where snow and ice are on the ground for five months of the year (Rikkonen et al. 2010) and slips are the most common type of adult fall (Honkanen 1982). Another possible explanation is that the younger study population might have a more active lifestyle and they spend more time pursuing activities which could increase their chances of falling after a slip (Ryynänen et al. 1991, Kelsey et al. 2010).

7.1 MULTIMORBIDITY AND FALLS IN POSTMENOPAUSAL WOMEN

Chronic medical conditions (morbidity) have been identified as risk factors for falls among the older population (Sibley, Voth et al. 2014). Rather few investigators have assessed if there is a relationship between falls and multiple chronic conditions (multimorbidity) (Shumway-Cook et al. 2009, Lawlor et al. 2003). There has been no detailed information about the role of multimorbidity as a risk factor for falls subdivided according to the type of falls (slip/nonslip). The association between multimorbidity and slip/nonslip falls among postmenopausal women was examined in this thesis. A trend of an increasing risk of falls was found along with the number of chronic medical conditions. Postmenopausal women with multimorbidity had a significantly higher risk of falling when compared with women without chronic conditions. Nonslip falls were more linked than slip falls to multimorbidity.

The results showed a strong association between multimorbidity and frequent falls, a finding which is in accordance with previous studies (Lawlor et al. 2003, Sibley et al. 2014). Chronic medical conditions may increase the risk of falls through both a direct effect of the disease and indirect effects such as muscle weakness and poor balance which may explain the higher risk of falls (especially nonslip falls) observed in the present study (Paliwal et al. 2017). In addition to chronic medical conditions, the medication prescribed to treat these conditions may impair psychomotor performance and increase the risk of nonslip falling (Tinetti et al, 1988, Kuschel et al. 2015). However, although we have adjusted the fall risks due to MSDs for the number of prescribed medications, the effect was negligible. The results of the present study hint at an additive effect of multiple medical conditions on different falling risks among postmenopausal women. We found that nonslip falling was significantly associated with neurological, mental, cardiovascular, respiratory and musculoskeletal disorders. It is proposed that slip falls are more dependent on extrinsic environmental factors and affect healthy, active individuals whereas nonslip falls seem to be more dependent on intrinsic human factors and occur in individuals with poor health and a low functional ability (Bergland et al. 2003). This may explain the higher risk of nonslip falls observed in this study. Previous studies found that clustering of chronic disease (combination of chronic disease) may vary by nature and severity of health disorders and may play a significant role in determining the higher risk of falling (Immonen et al. 2020). However, in this study, there was no specific clustering of disease categories.

This study has several implications for clinical practice. The results may inform health professionals about the "at risk" population at an early stage. As current fall prevention guidelines do not explicitly take into account the role of morbidity or multimorbidity, clinicians may find these new findings useful to consider when adopting these guidelines (Panel on Prevention of Falls in Older Persons, American Geriatrics Society and British Geriatrics Society 2011). While designing programs to reduce the risk factors for falls, in particular, the number of chronic medical conditions should be considered since multimorbidity shows a strong relationship with the individual's risk of falling. Thus, targeting this "at risk" population with collaborative prevention and disease management strategies at the individual, clinical and community levels could be an efficient fall reduction approach.

7.2 MUSCULOSKELETAL DISORDERS AND FALLS IN POSTMENOPAUSAL WOMEN

Although musculoskeletal disorders (MSDs) are recognized as an independent risk factor for falling, the effect of MSDs on different types of falls along with aging has rarely if ever been examined (Nevitt et al. 1989, Armstrong et al. 2005). This doctoral thesis evaluated the role of MSDs in different type of falls (slip vs nonslip) among women aged 62-71. MSDs were common with a prevalence of 53% and seemed to be a significant predictor of falls. The corresponding risk elevations were higher for women with nonslip than slip falls. In addition, multiple MSDs also increased the overall fall risks in a dose-dependent manner.

The finding that falls were related to MDSs supports previous reports (Jamison et al. 2003, Smulders et al. 2009). The role of MSDs in falls among postmenopausal women is likely due to the prevalence of MSDs and the elevated risk related to MSDs. An important finding emerging from this study is the strong association between nonslip falls and MSDs, particularly multiple MSDs which exert an additive effect on fall risks irrespective of the type of the individual MSDs. We suggest that the main reasons for these changes are due to the increase in the prevalence of MSDs and the reduction of outdoor activities, collectively leading to an increased risk of nonslip falls. By comparing slip and nonslip fall risk prediction, valuable information may be gained about the potential targets to be given to the individuals with MSDs with respect to fall prevention strategies. Different MSDs (rheumatoid arthritis (RA), osteoarthritis (OA) and back pain) and the risk of falls were investigated in this study. Women with RA, OA or back pain all had higher risks of falling than women without these disorders, but these risks did not differ from each other. There is evidence for the presence of a functional limitation in subjects with RA (Quach and Burr 2018), which may be an important contributing factor for the increased nonslip falls associated with RA found here. In addition, older people with RA have a reduced bone mass and are therefore at an increased risk of suffering fractures (Haugeberg et al. 2000). Our results highlight the relatively high frequency of falls in RA patients. Thus, attempts to prevent fractures should also focus on ways to prevent falls. The joint pain and stiffness resulting from OA may lead to poor and limited functional performance, muscle weakness and balance impairments which may explain the higher risk of nonslip falls observed in the present and former studies (Ng and Tan 2013, Stubbs et al. 2014). Falls may be preventable when the pain associated with OA is relieved by medical care (Muraki et al. 2011). Nonetheless, it has been reported that the medication used in the treatment of MSDs may elevate the risk of falling due to their side effects. Another explanation is that the elevated risk of falling might result from the combined effects of disease itself and medication (Boyle et al. 2010). However, the differentiation between these phenomena is difficult. In this thesis, we investigated the risk of slip and nonslip falls according to different OA sites (hand, hip, knee, cervical spine, lumber spine) as this has been studied sparsely. The site of OA did not significantly alter the falling risks; perhaps because of relatively small numbers of OA subjects examined here, the associations did not attain the level of statistical significance.

These results have practical implications with respect to fall prevention. Clinicians should be aware of the high incidence of falls among community dwelling older people and factors associated with falls. At their regular health care check-ups, older people should be asked about their fall incidence and fall types including injuries with follow-up screening for underlying risk factors related to MSDs in high risk populations. Later, these individuals can be advised to participate in a fall prevention program such as one with muscle strengthening, balance training and physical fitness as a way of preventing future falls (Pluijm et al. 2006). A significant number of older adults who fall are not willing to talk about the event with their health care provider (Shumway-Cook et al. 2009). Thus, fall education programs targeting older adults would also be necessary in order to successfully implement an effective fall risk assessment and management program (Fortinsky et al. 2004).

7.3 HISTORY OF FALLS AND FUTURE POSTMENOPAUSAL FRACTURES

Additionally, this thesis investigated the relationship between a history of falls (frequency, mechanism, and severity) and future fractures (major osteoporotic / others) as this has not been examined in depth among postmenopausal women. We found that an increase rate of falling (especially injurious falling) was associated with a higher rate of subsequent fractures. This provides additional information regarding the subsequent fracture risk as compared with the number of falls (occasional/frequent) (Cumming and Klineberg 1994, Luukinen et al. 2000). We detected a higher fracture risk due to previous slip falls compared with previous nonslip falls. One plausible explanation for the observed increase in fracture prediction due to slip falls could be that women who had slip falls are more physically active and capable of moving around outdoors in contrast to women experiencing a nonslip fall. These women would have greater exposure to slippery conditions which are a known risk factor for a fracture. This study found that previous falls were associated with other fractures but not with major osteoporotic fractures. This finding is in contrast to some reports describing the factors associated with an increased risk of major osteoporotic fractures (Nguyen et al. 2001). Some osteoporotic fractures (e.g. hip and proximal fractures) are considered as frailty fractures (Vogt et al. 2002). Thus, the higher risk of other fractures related to a previous history of falls could indicate that these women may be healthier, have stronger bones and less risk factors for major osteoporotic fractures. We found that an injurious fall seemed to be a strong predictor of other fractures as compared to non-injurious falls in postmenopausal women. However, the classification of fractures into major osteoporotic versus other fractures is not necessarily justified from our study results. BMD values would be needed in order to verify that these were truly osteoporotic fractures. In the site-specific fracture estimation, although injurious falls tended to increase the risk of future fractures of each of the specific sites, the associations were not statistically significant. The relatively small numbers of individual fractures types likely limited the statistical power to detect this kind of difference. In addition, further adjustment for difficult-to-measure factors like mobility could have further clarified the results; this may be a fruitful area for future investigation.

This study has important implications in improving screening and prevention strategies for future fractures. The identification of predicting factors of different type of fractures in older women suggests that it may now be possible to identify those women at increased risk of future fractures and to design intervention strategies to reduce the incidence of these fractures. Then, during a health care visit, the primary health care physician would be able to identify these women by eliciting information on whether she has fallen during the previous year. Research has shown that a targeted intervention (comprising a combination of medication adjustment, behavioral recommendations and exercise) can reduce the rate of falling and total health care costs in an older population (Vieira et al. 2016).

7.4 STRENGTHS AND LIMITATIONS OF THE STUDY

There are several strengths in this thesis. It is a part of the large population-based, prospective cohort study, the Kuopio Osteoporosis Risk Factor and Prevention (OSTPRE) study (n=14220) with a 30-year follow–up and a postal enquiry performed at 5-year intervals. The relatively large sample enabled us to assess predictors of falls among individuals representing the general Finnish population. Another strength was the relatively high response rate. In the first study, only 11% of the study subjects did not respond to questions regarding falls, resulting in a combined response rate of 80% (i.e., 0.89 × 0.90 = 0.80) which indicates that we have obtained unbiased estimates of the falling prevalence. Thus, it is unlikely that non-response to the fall questions has severely affected the observed relationship between multimorbidity and the risk of falls. In the second study, a high response rate was also acquired at both baselines (87.9%) and follow-up (80.8%). The self-reported prevalence of musculoskeletal diseases at baseline in those who returned the questionnaire without responding to the fall enquiry at follow-up was similar to those who responded to the fall question (53.0 vs. 53.5%) suggesting that the fall risk related to MSD would be similar in both responders and non-responders. Thus, a non-response has not severely affected the fall risk estimates related to MSD. Another strength is that we conducted comparisons of slip and nonslip fall risks and the population attributable fraction (PAF) which make it possible to estimate the role of MSDs in falls (10.3%).

This thesis also has some limitations. The information on morbidity, falls and fractures was based on self-reports. Falls were identified by recall over the previous twelve months. Therefore, recall biases may have affected the risk estimates (Cummings et al. 1988, Coughlin 1990, Podsakoff et al. 2003). Although other methods of fall reporting are more accurate (Zieschang et al. 2012), 12 months' recall is representative of clinical practice and it is the recommended method for assessing fall risk in the published fall prevention guidelines (Panel on Prevention of Falls in Older Persons, American Geriatrics Society and British Geriatrics Society 2011). It is also unlikely that recall of falls is significantly affected according to morbidity status as the higher odds ratios for injurious (which are better recalled) than non-injurious falls supports the idea that the fall risks related to morbidity, MSD, and their differences are true. Thus, a greater recall bias is unlikely. One important aspect observed in this study was the low occurrence of falls in 1999 when the text part of the question *(Have you fallen within the last twelve months **including falls without injury**?)* was omitted. It is interesting to note that this kind of small difference in the wording of a question may cause such a major difference in fall occurrence. Another limitation is that we had fall type (slip/nonslip) information only about the last falling event, which may also have affected the risk estimates. Therefore, further fall risk studies are needed and these should differentiate between the type of fall and with more exact fall reporting methods (Gates et al. 2008). We did not classify falls according to the place of where they occurred (*outdoor/indoor*). It would be important to further examine the effect of fall circumstances on different fall patterns (*slip/nonslip*) as risk factors may vary by location and activity at the time of the fall (Kelsey et al.2012). Our results on slip falls may not be directly comparable with those from warmer countries but highlight the importance for future research which should consider fall patterns in many countries. Another limitation was the long interval (5 years) between the collection of morbidity data (in 1989 vs 1999) fall data (in 1999 vs 2004) which may cause incomplete or erroneous recall of falls. In addition, the self-report of health disorders diagnosed by a physician may have been incomplete. Furthermore, new health disorders may have occurred during the 5-year follow-up which could have diluted the true effect of morbidity on falling risks. Therefore, morbidity data may have been incomplete and thus have led to an underestimation of the true fall and fracture risk. On the other hand, the cohort was relatively large, and follow-up was good. It will be important to have the present study findings evaluated by other investigators.

With regard to fractures, the self-reported data were confirmed from medical reports. A former validation study of self-reported fractures in OSTPRE cohort observed the sensitivity of self-report to detect fracture to be 78% with a specificity of 96% (Honkanen et al. 1999). Thus, it is possible that a few fractures may have been missed, but when a fracture was reported, it had a positive predictive value of 84% of truly being a fracture. Thus, we can assume that there was no severe recall bias involved in the self-reported fracture rates. In this thesis, we used the major osteoporotic fracture site criteria established by FRAX® so that our findings would be more comparable with other similar studies using the same classification criteria. To verify an osteoporotic fracture, we would have ultimately needed BMD values, but unfortunately appropriately timed BMD measurements were available for only a small fraction of this population-based cohort and therefore the detection for definitive osteoporotic fractures was impossible. For that reason, we considered any women who had reported at least one fracture in sites of major osteoporotic fractures to belong to the major osteoporotic category and women solely with other fractures were designated into the other category. As it is certainly possible that some women may have had more than one fracture event, we recognize that it would be interesting to examine that possibility in future research but that is outside the scope of the current study.

7.5 FUTURE ASPECTS

This doctoral thesis found that multimorbidity and musculoskeletal disorders (MSDs) were important risk factors of falls among postmenopausal women in Finland. These findings are supported by the previous literature recognizing the association between number and types of morbidity and risk of falls among the older population (Deandrea et al. 2010, Tinetti et al. 2010). Falls are still the second leading cause of unintentional injury deaths throughout the world (WHO, 2020). Falls often result in moderate-to- severe injuries, hospitalization, reduced quality of life, and even death. Fall related injuries also place a huge financial burden on national health care systems (Heinrich et al. 2010, Burns et al. 2016). As the population grows older, the burden of falls will increase in the near future. Women are at a higher risk of falling than men and early identification of those women who are at a high risk for future falls and fractures would be an effective approach to control the burden of fall and fall related injuries (Zhao et al. 2020). Clinicians should adopt a consistent practice related to the assessment of the fall risk in older adults. All postmenopausal women should be asked about their fall history at their regular visits in health centers, with follow-up screening for the underlying risk factors, including the number of chronic medical conditions and musculoskeletal disorders in the high risk population. Inclusion of the history of injurious falls in the FRAX® model could be beneficial for future fracture predictions, as this thesis found that injurious falls were a strong predictor for future falls. When conducting regional or international comparative fall studies, the knowledge of the slip/nonslip ratio would be useful. Novel tools can be designed and used in fall risk assessment. For example, the individual´s smartphone could be used to collect his/her fall incidence soon after they have fallen rather than data being collected from a fall diary or some other traditional method (Vilpunaho et al. 2019). This might significantly minimize any recall bias. A recent review on mobile technology reported that so-called smart phone technology is becoming a promising tool with which to assess balance and posture in a fall risk assessment among the older population (Roeing et al. 2017). Due to their cost-efficiency and portability, smart phones have a significant potential to become a tool for balance screening in non-laboratory settings (Hsieh et al. 2019). Thus, smart phones could be an effective method for fall assessment in conjunction with an effective device for transmitting guidance and instructions to provide a daily or weekly physical exercise routine (Tsinganos and Skodras 2017). It is evident that the management of fall risk factors needs to be better integrated. Exercise-based interventions, including balance training are becoming a popular approach in fall prevention programs and there is an extensive body of evidence suggesting that these interventions can be effective in reducing falls and the risk of falling among the older adults with MSDs (Vieira et al. 2016, Sherrington et al. 2019). A pragmatic exercise-based RCT among community living older women has recently been completed in the Kuopio Fall Prevention Study (Vilpunaho et al. 2019) (KFPS). Nonetheless, there are issues with regards to exercise interventions. Supervised interventions with the participant and trainer are resource intensive in term of cost and time.

An improved understanding of the relationship between falls and health-related risk factors is needed in order to issue recommendations to clinicians and researchers who provide care for older adults with a high fall risk. This thesis addressed some of the gaps in the literature by exploring the association between morbidity and future fall and fracture risks among postmenopausal women in Finland. Continued work will be required to design effective fall prevention strategies for fall management in both postmenopausal and geriatric populations. The OSTPRE cohort women have now been followed-up for 30 years from the age of 47-56 to the age of 78-87 years. That means that it should now be possible 1) to investigate age related changes in the fall /fracture occurrence in old age, 2) to define trajectories from postmenopausal risk/preventive factors to fall/fractures in old age which could be perhaps prevented by interventions targeting modifiable risk/preventive factors. This thesis cannot solve all of the problems encountered in fall prevention but certainly can add some knowledge on postmenopausal fall patterns which later researchers can utilize.

8 CONCLUSIONS

The following conclusions can be deduced from this study on health-related predictors and outcomes of falls in postmenopausal women.

1. In addition to providing further evidence confirming previous studies that chronic medical conditions increase the risk of falls, we found here that the risk was higher in postmenopausal women with multiple chronic conditions (multimorbidity). Multimorbidity exerted a greater effect on nonslip falls than on slip falls.

2. This study highlighted that the role of musculoskeletal disorders (MSDs) as a considerable risk factor for falls in late middle aged postmenopausal women – about 10 % of these falls were due to MSDs. A significant association was observed between MSDs and nonslip falling risk. In addition to multimorbidity, the presence of multiple MSDs doubled the risk for nonslip falls among postmenopausal women.

3. A history of injurious falls was predictive of future postmenopausal fractures. There was a difference in the types of fracture while making predictions in relation to fall risks. Injurious falls were a stronger predictor for other fractures than they were for major osteoporotic fractures.

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Appendix table 1. Unadjusted risks of specific type of fractures related to history of falls in comparison to non-faller risk.

	Major osteoporotic fractures				**Other fractures**					
	Spine ([a]n=53)	Hip (n=24)	Distal forearm (n=313)	Proximal humerus (n=55)	Hand, forearm and elbow (n=87)	Chest region (n=62)	Skull (n=13)	Pelvis (n=20)	Femur, knee and leg (n=51)	Ankle and foot (n=212)
Fall type **Any fall**	OR (95 % CI)				OR (95 % CI)					
-total	1.50 (0.81 - 2.77)	1.10 (0.41 - 2.94)	1.26 (0.96 - 1.64)	1.16 (0.61 - 2.21)	1.60(1.00 - 2.56) *	1.99 (1.17 - 3.41) **	0.76 (0.17 - 3.42)	2.25 (0.89 - 5.64)	1.74 (0.95-3.19)	1.26 (0.91 - 1.74)
-occasional	1.74 (0.84 - 3.60)	0.79 (0.18 - 3.39)	1.35 (0.97 - 1.89)	1.40 (0.66 - 2.98)	1.68 (0.94 - 3.00)	1.79 (0.90 - 3.59)	0.68 (0.09 - 5.28)	2.31 (0.75 - 7.10)	1.25 (0.53 - 2.98)	1.06 (0.68 - 1.65)
-frequent	1.20 (0.47 - 3.06)	1.48 (0.44 - 5.02)	1.13 (0.77 - 1.68)	0.87 (0.31 - 2.44)	1.50 (0.76 - 2.93)	2.25 (1.12 - 4.50) *	0.85 (0.11 - 6.61)	2.17 (0.62 - 7.63)	2.36 (1.13 - 4.92) *	1.51 (0.99 - 2.30) *
Slip fall										
-total	1.34 (0.57 - 3.17)	0	1.31 (0.92 - 1.88)	1.42(0.64 - 3.16)	0.97 (0.44 - 2.11)	2.08 (1.04 - 4.16) *	0.79 (0.10 - 6.12)	1.34 (0.30 - 5.93)	1.21 (0.47 - 3.09)	1.57 (1.05 - 2.34) *
-occasional	1.52 (0.54 - 4.28)	0	1.44 (0.93 - 2.22)	1.73 (0.68 - 4.39)	0.7 0(0.22 - 2.25)	2.13(0.90 - 5.04)	0	1.14 (0.15 - 8.73)	0.82 (0.20 - 3.43)	1.19 (0.67 - 2.10)
-frequent	1.08 (0.26 - 4.48)	0	1.14 (0.64 - 2.01)	0.98 (0.24 - 4.05)	1.34 (0.48 - 3.69)	2.01 (0.72 - 5.64)	1.91 (0.25 - 14.84)	1.62 (0.21 - 12.39)	1.76 (0.54 - 5.73)	2.11 (1.25 - 3.57) **
Nonslip fall										
-total	1.39 (0.54 - 3.53)	1.14 (0.26 - 4.89)	1.12 (0.74 - 1.71)	1.26 (0.50 - 3.18)	1.90 (1.00 - 3.62) *	2.33 (1.13 - 4.81) *	0	2.50 (0.71 - 8.78)	2.41 (1.12 - 5.21) *	0.92 (0.53 - 1.61)
-occasional	1.42 (0.44 - 4.61)	0.97 (0.13 - 7.26)	1.15(0.68 - 1.96)	1.29 (0.40 - 4.17)	2.70 (1.32 - 5.41) **	1.76 (0.63 - 4.94)	0	2.84 (0.64 - 12.64)	2.06 (0.73 - 5.81)	0.67 (0.30 - 1.53)
-frequent	1.34 (0.32 - 5.57)	1.37 (0.18 - 10.28)	1.08(0.57 - 2.06)	1.21 (0.29 - 5.03)	0.83 (0.21 - 3.39)	3.14 (1.23 - 8.00) *	0	2.01 (0.26 - 15.38)	2.92 (1.03 - 8.26) *	1.29 (0.63 - 2.64)
Injurious fall										
-total	1.92 (0.68 - 5.40)	1.96 (0.46 - 8.46)	1.25 (0.74 - 2.09)	1.30 (0.40 - 4.21)	2.70 (1.33 - 5.47) **	2.23 (0.88 - 5.67)	0	2.87 (0.65 - 12.77)	2.61 (1.02 - 6.68) *	1.50 (0.85 - 2.67)
-occasional	2.44 (0.87 - 6.87)	1.24 (0.17 - 9.31)	1.49 (0.87 - 2.55)	0.55 (0.08 - 3.99)	2.27 (0.98 - 5.29)	1.69 (0.52 - 5.49)	0	1.82 (0.24 - 13.93)	1.98 (0.61 - 6.45)	1.46 (0.76 - 2.80)
-frequent	0	4.69 (0.62 - 35.43)	0.36 (0.05 - 2.58)	4.18 (1.00 - 17.55) *	4.32 (1.33 - 14.06) **	4.28 (1.02 - 17.99) *	0	6.85 (0.89 - 53.02)	5.00 (1.18 - 21.12) *	1.65 (0.51 - 5.27)

Non-injurious fall										
-total	1.39 (0.69 - 2.78)	0.85 (0.25 - 2.88)	1.26 (0.94 - 1.70)	1.13 (0.55 - 2.32)	1.29 (0.73 - 2.27)	1.94 (1.07 - 3.50) *	0.98 (0.22 - 4.43)	2.08 (0.74 - 5.84)	1.50 (0.74 - 3.03)	1.20 (0.83 - 1.72)
-occasional	1.42 (0.56 - 3.60)	0.58 (0.08 - 4.33	1.29 (0.87 - 1.93)	1.80 (0.81 - 4.02)	1.40 (0.67 - 2.94)	1.85 (0.83 - 4.13)	1.00 (0.13 - 7.77)	2.55 (0.73 - 8.97)	0.92 (0.28 - 2.99)	0.88 (0.50 - 1.55)
-frequent	1.36 (0.53 - 3.45)	1.11 (0.26 - 4.78)	1.24 (0.83 - 1.84)	0.49 (0.12 - 2.03)	1.18 (0.54 - 2.58)	2.02 (0.95 - 4.33)	0.96 (0.13 - 7.44)	1.63 (0.37 - 7.22)	2.06 (0.92 - 4.66)	1.51 (0.97 - 2.35)

[a]n =number of women, Any fall = slip/nonslip/unknown falls, OR=Odds Ratio, 95 % Confidence interval, * = $p \leq 0.05$ and ** = $p \leq 0.0$

NADIA AFRIN

The falls are common and a major health concern among the older population. However, there is limited research evidence in early identification of fall risk factors before old age. This study examined health related risk of falls and fractures among Finnish postmenopausal women. The results revealed that multimorbidity and musculoskeletal disorders are important risk factors for falls, especially nonslip falls. A stronger association was also observed between a history of falls causing injuries and fractures other than major osteoporotic fractures.

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