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# UNDERSTANDING RISK FACTORS OF ELDERLY INPATIENT FALLS USING CONTEXTUAL MODEL

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# UNDERSTANDING RISK FACTORS OF ELDERLY INPATIENT FALLS USING CONTEXTUAL MODEL

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## Abstract

*The field of Information Systems is about bridging the digital and information divide. Advances in the digital world enable information to be stored and structured in a manner that facilitates effective use of the information for future modelling purposes. Elderly inpatient falls are a common global phenomenon, and an inpatient fall incident can have severe consequences for the patient, caregivers and the healthcare provider. An inpatient fall can result from many causes and its risk can be increased through the combination of these causes. Many risk factors of elderly inpatient falls have been reported in various papers in the literature. However, a logical comprehensive categorisation of all these factors does not currently exist.*

*The objective of this research in progress is to come up with a generic categorisation of the risk factors for elderly inpatient falls alongside the usage of a contextual model to illustrate the inherent interactions amongst these various factors. In addition, we found that the effect of the interaction amongst some risk factors is time dependent which also needs to be incorporated in the contextual model. Such comprehensive categorisation and contextual risk model will help health providers in the process of profiling of an elderly inpatient with respect to his/her fall risk. It is useful to experts in health informatics in formulating models to automate this process.*

*Keywords: Elderly inpatient falls, risk factors, contextual model, eHealth.*

# 1 INTRODUCTION

A fall during hospitalization is defined as “a conscious patient who unintentionally comes to rest on the ground or floor” (Morris & ISAACS, 1980, as cited in Donoghue, Graham, Gibbs, Mitten-Lewis, & Blay, 2003). A large number of studies on falls among the elderly have considered the average age of elderly to be 65 and older, while a few considered age as low as 55 (Wu et al., 2013) and a few with age as high as 75 (Milos et al., 2014). The chances of a fall, and the severity of associated consequences, heighten with age. The injuries sustained during the fall itself have further ramifications on the patient, and may compromise the patient’s mobility and independence. The severity of the problem has led to initiatives such as “Preventing Falls and Harm from Falls” (Australian Commission on Safety and Quality in Health Care, September, 2012), and WHO technical meetings on falls prevention (World Health Organization, 2007).

The causes of elderly inpatient falls have been well studied resulting in the identification of various fall risk factors in order to implement preventive measures where possible. However, there is a tendency to focus on only a subset of the contributing causal factors, such as factors related to a specific area in health care (Wasserstein, Farlinger, Brull, Mahomed, & Gandhi, 2013). There has been no study that proposes a comprehensive list of fall risk factors in elderly inpatients in a systematic manner. The current standardized fall risk assessment tools like Fall Risk Assessment Tool (FRAT) (Nandy et al., 2004), STRATIFY (Oliver, Britton, Seed, Martin, & Hopper, 1997) are used to profile elderly patients. However, they lack the ability to incorporate the influence of combinatorial nature of fall risk factors and the time factor associated with them in their screening mechanism.

This research aims at developing a contextual model that categorizes all of the possible risk factors in a logical manner and their possible interactions so as to enable effective screening of fall risk patients.

# 2 METHODOLOGY

The concept of context in computing was introduced in 1994 by Schilit et al. (Schilit, Adams, & Want, 1994) where a system adapting to its changing environment is said to be context aware. This was further extended by the works of Dey (Dey, 2001) in which context was tied to relevance of information given to the user, where by the context could be used to improve the system’s services and results. The idea of context has been evolving, and a few studies have tried to generalize the definition of context (Bazire & Brézillon, 2005; Zimmermann, Lorenz, & Oppermann, 2007). The authors Zimmermann et al. (Zimmermann et al., 2007) have defined context in terms of factors that influence an entity, where an entity can be a person, a place or an object. The authors further posit that these entity influencing factors can be split into five categories – temporal factors, place of event, stimulus or activity that led to event, relation amongst different factors and factors that define the entity itself. Similarly, the authors Bazire & Brézillon (Bazire & Brézillon, 2005) focus on context in the domain of psychology, and the authors attempt to extract the main parameters of the meaning of context so as to clarify the precise usage.

We adopt these principles in constructing the contextual model of fall risk factors. The event of a fall is the central entity, and the various risk factors are the influencing elements. Temporal aspects such as time of day, or duration since surgery, or drug regime period are time factors. Place of a fall, layout of fall event area, environmental conditions such as lighting can be categorized as location factors. The event or situation that precipitated the fall would be an influencing activity, as would long term factors such as posture. Relation factors are important for fall risk analysis as various individual factors can interact in combinatorial ways to alter fall risk of the patient. The individual factors would be classified under entity defining factors, and include the patient’s profile, medical history, drug regimen, psychological profile and so on. This comprehensive contextual model will be instrumental in understanding the fall risk profile of the patient.

The list of fall risk factors in elderly during hospitalization are collated from previous studies by reviewing papers from Scopus, CINAHL, Science Direct and Elsevier from 2011 onwards. To begin with, all papers identifying fall risk factors in the elderly are considered, then risk factors that are not applicable in hospital setting, e.g. falls in homes due to environmental factors are excluded. However, elderly fall factors outside hospital settings that might influence a person’s fall during hospitalization are included, e.g. substance abuse. Applying these constraints, we retrieved around 150 publications which we used in our studies.

### 3 ELDERLY FALL RISK FACTORS

Our study of the literature suggests that subsets of the causal factors of elderly falls are classified in various different ways. For example, one study classifies them into demographic factors, systems and diseases (Ambrose, Paul, & Hausdorff, 2013), another classifies the risk factor based on relevance and conflicting conclusions (Boelens, Hekman, & Verkerke, 2013), while a few others highlight the most prominent risk factors in a generic manner (Evans, Hodgkinson, Lambert, & Wood, 2001; Pfortmueller, Lindner, & Exadaktylos, 2014). As our study is on identifying fall risk factors for the purpose of patient profiling, we collate all identified factors by the previous studies, and take a more generic approach to classifying the risk factors.

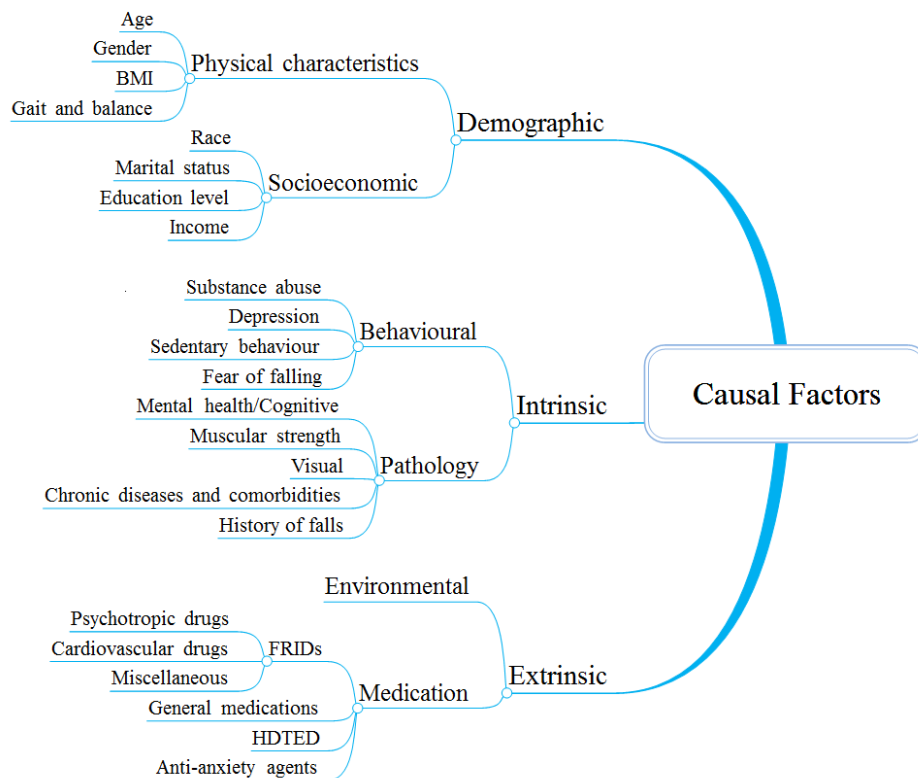


Figure 1: Classification of established causal factors.

HDTED: Hormones and Drugs used in the Treatment of Endocrinal Diseases.

In this research, we logically classify fall risk factors into demographic, intrinsic and extrinsic factors as shown in Figure 1. Demographics are characteristics of a population. Intrinsic factors are factors inherent to a patient and quantify the medical profile of the patient. They can be biological, behavioural, physical or pathological. Extrinsic factors are the external influences associated with increased risk of falls during hospitalization. These can be environmental, socioeconomic or due to medications.

### 3.1 Demographic

**Physical characteristics** - Age is one of the primary indicators of fall risk and features in all the studies involving fall risk factors. Gender, Body Mass Index (BMI), gait and imbalance are the other common demographic factors.

Gender is considered by most papers, and is included as a factor for fall analysis. A few of the studies indicate that fall risk is higher in males than in females (Johnson et al., 2015). However, a few others conclude the other way round as they are considered to have higher occurrence of age related risk factors (Ambrose et al., 2013; Chang & Do, 2015; Johansson, Nordström, & Nordström). Thus, we can conclude that while gender is a contributing factor, it is not an independent contributor, but influences falls risk via other factors that are in turn gender specific or gender driven.

BMI determines obesity, and to some extent malnourishment. BMI is identified as one of the independent fall risk factors causing post-operative falls (Wasserstein et al., 2013). Malnourishment is found to be a fall risk factor and has a complex association with falls (Westergren, Hagell, & Hammarlund, 2014). The study uses BMI data and using a standard malnourishment rating scale, identifies comorbidities such as mobility impact, sarcopenia etc. in relation to malnourishment, and these can cause falls in elderly. Another such fall risk study found malnutrition as a contributing factor for increased fall risk rates (Chu et al., 2015).

Gait and balance is the most influential factor for falls in elderly. Balance disorders like vestibular dysfunction is also known to increase fall risk factors (Liston et al., 2013). Multiple factors cause gait abnormality and various geriatric studies have tried to measure this using different parameters. In general, the gait and balance disorders are measured in hospital settings using various clinical assessment tools and assessment of their self-care abilities like Timed up and go (TUG) (Podsiadlo & Richardson, 1991), Functional reach (FR) (Duncan, Weiner, Chandler, & Studenski, 1990), Romberg (Jalali, Gerami, Heidarzadeh, & Soleimani, 2015) etc. While a few of these tools measure gait speed, one of the studies indicates the irrelevance of gait speed and instead establishes quadriceps strength measure as an important predictor of falls (Scott et al., 2014). The ability to perform daily activities in elderly assessed using scores like the Activities Daily Living (ADL) are affected by various other comorbidities like sarcopenia (Landi et al., 2012) and hypertension (Chiba et al., 2015).

**Socioeconomic** - The other demographic factors are socioeconomic in nature, such as race and ethnicity, marital status, education level and income. Genetics and ethnicity is known to influence a wide range of health characteristics, including falls. Studies also show that the degree of fall risk due to race varies by location, e.g. Chinese living in Australia are more prone to falls than Chinese living in Asia (Kwan et al., 2013). A few other similar studies also confirm that location is more of an influential factor than ethnicity (Karlsson et al., 2014). A previous literature review on falls with respect to impact of race and ethnicity on fall risk factors confirms the necessity to study this factor in a more comprehensive way, including migration patterns, diseases specific to races, and how do the fall factors in general vary based on these attributes (Han, Ferris, & Blaum, 2014).

For marital status (Chang & Do, 2015) showed increased associations with falls in both genders for people who were single. Men were shown to have a higher risk factor when single and surprisingly with a higher degree in conjunction with obesity. The same study also confirms that higher income negates fall risk.

### 3.2 Intrinsic

**Behavioural** - Studies involving substance abuse analyse the influence of frequent alcohol consumption and smoking as fall risk factors. Previous studies have shown that higher alcohol consumption in older women as an independent fall risk factors along with other fall risk factors (Chang & Do, 2015). This is generally included with other comorbidities such as hypertension, diabetes etc. It also known to positively affect fall risk factors in people with dementia (Ataollahi Eshkoor, Hamid, Hassan Nudin, & Yoke Mun, 2014).

Depression is identified as an independent fall risk factor (Kvelde et al., 2015). They measure depression using the Geriatric Depression Scale (GDS). The authors find that people with depression and on anti-depressants were at a higher risk of falls. However, they also make a distinction in the influence of anti-depressants in comparison to the influence of depression over fall risk. Anti-depressants increase the risk of recurrent falls, whereas depression was a standalone factor in influencing first time fall risk. The study also found that depression in association with cognitive problems and the fear of falling more than doubled the fall risk. These findings were also reiterated by another study (Wang et al., 2012), which also goes on to highlight the amplification of the fall risk factor by 5-11 times when the person is suffering mental disorders and is on multiple medications. Chronic depression, clinically known as Major Depressive Disorder (MDD) is also being identified as an increased fall risk factor in elderly (Stubbs, Stubbs, Gnanaraj, & Soundy, 2015).

Fear of Falling (FoF) is an independent fall risk factor and it increases the rate of subsequent falls in elderly (Rossat et al., 2010). It is also known to cause adverse effects on gait and performance (Rochat et al., 2010).

**Pathology** - Pathological factors include cognitive issues, neurological diseases, vision and other comorbidities. Neurological diseases such as Dementia (Alzheimer's) and Parkinson's disease are known to effect fall risk in the elderly. Dementia doubles the risk of falling among elderly. Daytime sleepiness in people with Dementia has been identified as an independent risk factor. In general, sleep disturbances can cause an increased risk in falls (Chen, Chiu, & Chiu, 2015). Most of the elderly who have dementia are also diagnosed with Alzheimer's, which is also an identified risk factor. This study indicates that people with Alzheimer's have a fast-tracked risk of falling compared to elderly who do not have the disease (Suttanon, Hill, Said, & Dodd, 2013). The authors also show the deteriorating effects of Alzheimer's with respect to gait and balance which in turn increases the risk of falling. Higher fall risks are associated with people having dementia based on their ethnicity (Ataollahi Eshkoo et al., 2014).

Parkinson disease is a motor disease affecting the patient's ability of movement causing tremors, postural instability, rigidity, sleep disturbances and so on. This freezing of gait, degenerative muscle functionality and disorientation are high fall risk factors (T. S. Voss et al., 2012). Cerebral ataxia is another brain disease in which the brain cells that control the motor coordination are damaged. Thus the subject loses regular control on coordinating the muscle movements. This study confirms gait variability causation due to cerebral ataxia as a high fall risk factor (Schniepp et al., 2014).

Muscle strength is another determining factor of falls risk. Sarcopenia is muscular degeneration that is an invariable result of aging. Patients with sarcopenia have poor muscle mass that continues to rapidly weaken the grip. This study identifies Sarcopenia with increased fall rates independent of other factors that correlate to muscle degeneration like BMI, physical activities and number of medications (Landi et al., 2012). Another study shows that quadriceps strength is a better predictor of falls than gait speed (Scott et al., 2014). In summary, measurements of gait, balance, muscle strength and similar characteristics would be very useful indicators of fall risk in patients with mental health conditions.

Visual impairment associated with falls are age related macular degeneration (AMD), visual acuity (VA) and glaucoma. These are again identified fall risk factors and visual impairment is also known to cause recurrent falls. Another study highlights VA as a fall risk factor and suggests using Self – Reported vision (SRV) as a simpler method for measuring VA (Yeh, Wu, & Tsao, 2011). VA, AMD and glaucoma leads to FoF (Nguyen, Arora, Swenor, Friedman, & Ramulu, 2015; Van Landingham, Massof, Chan, Friedman, & Ramulu, 2014).

Chronic diseases and comorbidities are established causal factors of falls. Fall risk increases with the increase in number of chronic diseases and multi-morbidity in the elderly person (Sibley, Voth, Munce, Straus, & Jaglal, 2014). While there are no definitive guidelines on what constitutes chronic diseases, the authors include 8 conditions such as heart disease, chronic obstructive pulmonary disease (COPD) and diabetes. To this recommended list of chronic diseases, they add fall context specific diseases such as dementia, osteoporosis, Parkinson's, urinary incontinence and visual impairment. The

authors were trying to identify the influence of chronic diseases on fall risk, not just by number, but also by patterns in chronic diseases that could increase fall risk. To verify the effect of chronic disease patterns on fall risk, the authors used a clustering based approach, to identify the top patterns that increase falls risk. The results show that there is a linear relationship between number of chronic diseases and fall risk. The study also identified that the pattern or combination of the comorbidities COPD and hypertension increases the fall risk.

Type 2 diabetes mellitus (DM), cancer and renal dysfunction are other chronic diseases that are known to increase fall risk. DM causes deterioration of both the bone density and body muscle mass increasing the risk of falls in the elderly (Lee et al., 2014). The presence of cancer and metastases increases fall risk (Lee et al., 2014). The study shows that cancer along with other comorbidities like gait issues, and also psychotropic medications have higher risk. It also shows how lower levels of pain increase the fall risk factor. Increased fall rates are also observed in haemodialysis patients with increased blood pressure (Polinder-Bos, Emmelot-Vonk, Gansevoort, Diepenbroek, & Gaillard, 2014). The not uncommon disease of old age, Osteoporosis is also associated increased fall risk (Lin, Hwang, Lin, & Chen, 2014). The same study exemplifies the gender dependant aspect of diseases.

History of falls is strongly associated with recurrent fallers, and also contributes to fear of falling, which is itself another fall risk factor (T. S. Voss et al., 2012).

### 3.3 Extrinsic factors

**Environmental** - The hospital settings like analysis of staffing strength, presence of a companion, assistive device for walking and bed railings can also increase the chances of falls (Schwendimann, Buhler, De Geest, & Milisen, 2008). However, these environmental factors do not contribute to patient profiling, and hence we limit our investigation to just this short description.

**Medication** - Studies involving medications deal with both identifying fall risk medications and those which increase the risk of injury. We consider only those which have a causal effect on fall. A large number of studies include Fall Risk Identified Drugs (FRIDs) for elderly fall risk detection. These mainly include psychotropic and cardiovascular medications. Frequent use of FRIDs is known to significantly increase fall risk (Milos et al., 2014). Also, any medication that is taken for disorders associated with central nervous are a major contributor to higher fall risks in elderly (Costa-Dias et al., 2014). Psychotropic medications increase the fall risk factor compared to other medications (Costa-Dias et al., 2014). Polypharmacy is also known to be associated with fall risk factors (Kojima et al., 2011). Polypharmacy is the number of drugs used, and is generally classified as polypharmacy when the number of medications is greater than 4.

While considering fall risk factors due to medications, it is also necessary to see its association with other comorbidities. E.g. Psychotropic drugs are recommended for patients with existing conditions like depression and dementia which is also a fall risk factor. We see that though the drug intake forms an independent fall risk factor, medications with pre-existing condition have more complex associations and is difficult to analyse which of these have more impact in a fall (Capone, Albert, Bena, & Tang, 2012).

## 4 CONTEXTUAL MODEL TO ILLUSTRATE INTERACTIONS AMONGST CAUSAL FACTORS

Figure 2 shows a contextual model illustrating some possible fall scenarios resulting from the interactions amongst a few fall risk factors. The next sub-sections explain how the interactions cause increased fall risk and how the interactions amongst some risk factors can increase fall risk depends on when the interactions happen.

#### 4.1 Combinatorial nature

Gender is seen to influence other risk factors (Chang & Do, 2015). Men are more prone to falls based on their marital status, education, obesity and stroke occurrence. While women are more prone to falls if they have lower income, substance abuse, increased comorbid conditions or taking a higher number of medications. Women with Osteoporosis have higher fall risks (Lin et al., 2014).

Increase in fall rates is observed in people with gait and balance issues influenced by factors like FoF (Rochat et al., 2010), Mild Cognitive Impairment (MCI) (Montero-Odasso, Muir, & Speechley, 2012), FRIDs (de Groot et al., 2013), Alzheimer’s (Suttanon et al., 2013), COPD (Sibley et al., 2014) and intellectual disability (Enkelaar, Smulders, van Schroyensteyn Lantman-de Valk, Geurts, & Weerdsteijn, 2012). Bone and muscle strength is reduced with people having DM (Lee et al., 2014).

Mental health and cognitive impairments are influenced by other risk factors. Dementia has an increased fall risk based on the ethnicity of the person, by causal factors like substance abuse (Ataollahi Eshkoot et al., 2014). People with Parkinson’s have higher fall risks when they have a history of previous falls (T. Voss et al., 2012).

Increased fall rates are also observed with people having chronic diseases and comorbidities in conjunction with other risk factors. E.g. Hypertension with haemodialysis (Polinder-Bos et al., 2014) and with certain anti-hypertensive medication (Sibley et al., 2014), cancer with antidepressants and antipsychotic medications (Capone et al., 2012). Similar observation is made when the elderly have a case of multi-morbidity, i.e. two or more chronic conditions (Sibley et al., 2014) or with fall under the bucket of increased number of causal factors in general (Kvelde et al., 2015).

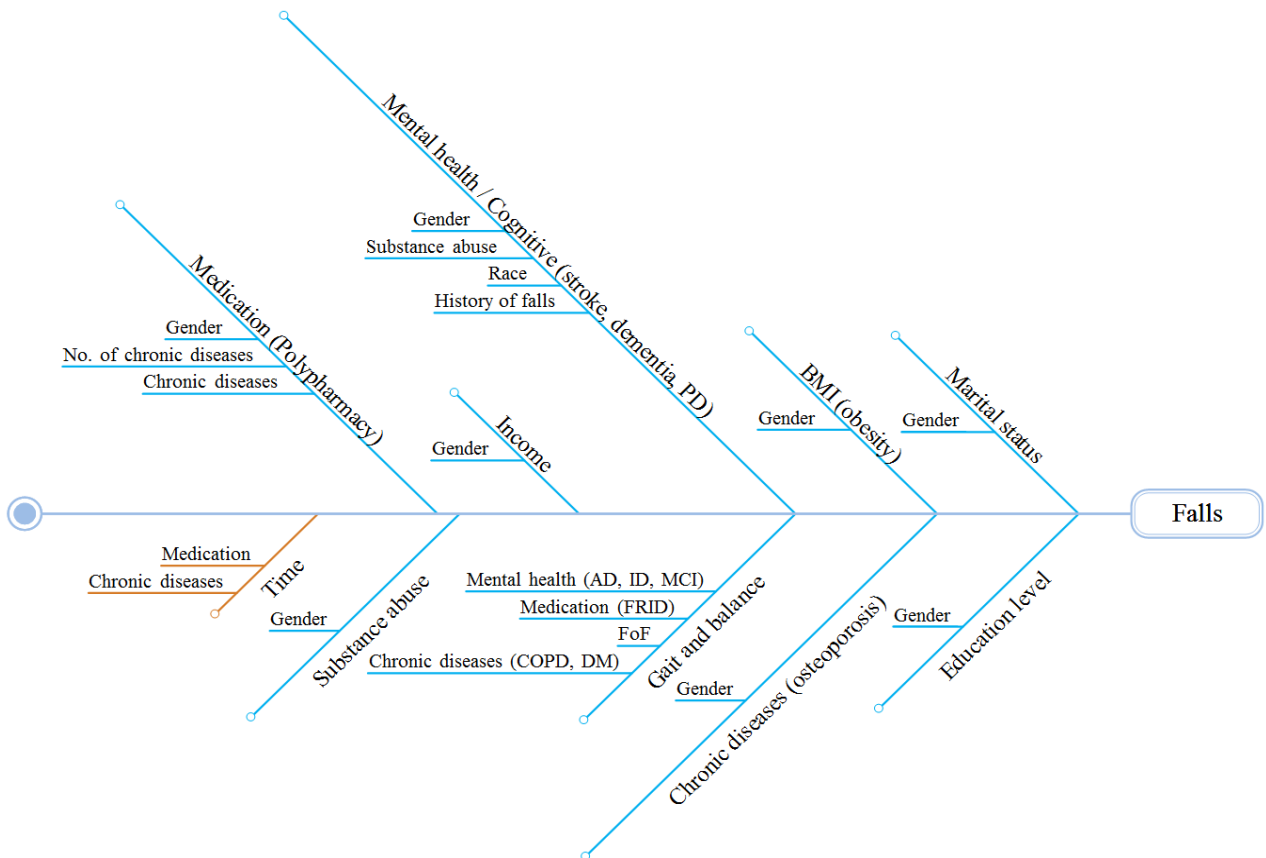


Figure 2: Combinatorial relationship between the established causal factors.



*BMI: Body mass index, PD: Parkinson's disease, AD: Alzheimer's disease, ID: Intellectual disability, MCI: Mild Cognitive Impairment, FRID: Fall risk increasing drug, FoF: Fear of falling, COPD: Chronic obstructive pulmonary disease, DM: Type 2 Diabetes Mellitus, PD (Parkinson's disease)*

## 4.2 Temporal nature

Time plays a major role in influencing a medical event. Some fall risk factors have a temporal aspect to them and it becomes an important criteria in determining the impact of the various factors on fall risk. With factors such as surgery, specific medications or anaesthesia, the degree to which they can be seen as fall risks decreases over time after the event.

Some of the factors can become risk factors only within a specific time window relative to the event, such as an anti-hypertensive drug has a time window period of 45 days from the start of drug intake during which the patient has increased risk of fall due to the drug's effect on orthostatic hypotension (Butt et al., 2013). Similarly, with cerebral ataxia the risk of falls increases within half a year from the onset of the disease (Schniepp et al., 2014)

## 5 CONCLUSION

Whilst risk factors associated with falls in the elderly have been studied extensively, different studies put different emphasis on which factors are highlighted. In this paper we propose three generic categories of fall risk factors, i.e. demographic, intrinsic and extrinsic factors. We then propose that a contextual model can be used to illustrate the combinatorial nature of the interactions amongst the risk factors in exacerbating the severity of the fall risk in the elderly. We also highlight the fact that the severity of the fall risk due to the presence of a combination of risk factors is time dependent. We use the models proposed in this paper to guide us in determining the kind of patient data we need to extract from a hospital database for the purpose of building an automated elderly inpatient profiling system against the various fall risk factors.

The study does not take into account the quantum by which the combination of factors would influence a fall risk. The combination of risk factors is based on previous studies, however it does not provide the means to learn the latent combinations of the influencing factors, and pathways to integrate risk factors that would be identified in the future. These aspects could be explored as future work.

## 6 FUTURE WORK

Further research is necessary to explore the use of the contextual model in building fall prediction and prevention systems. We believe the use of topic modelling on electronic health records enables us to build this contextual model in an automated way, thus paving the way for better fall prediction systems. Topic modelling techniques like the Latent Dirichlet Algorithm (LDA) (Blei, Ng, & Jordan, 2003) which works on the foundations of mixed membership model are inherently designed to find the topic structure of a given document. This concept can be extended to analyse health records, where each electronic record is considered to be a document and this in turn is assumed to exhibit multiple topics i.e. fall risk factors. Thus using the LDA produces clusters of co-occurring words, i.e. clusters of fall risk factors. However, LDA assumes these fall-risk factors to be independent of each other, whereas the factors might in fact be correlated. There is also a limitation that the number of fall risk factors need to be known prior to modelling. Future work could include exploring algorithms which would capture the correlation between the fall risk factors (David & Lafferty, 2007; Li & McCallum, 2006), utilize prior domain knowledge (Andrzejewski, Zhu, & Craven, 2009) and use the Bayesian non parametric method which allows for the controlled growth in clustering of the fall risk factors (Teh, Jordan, Beal, & Blei, 2006).

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