

Fall Prevention in the Toilet Environment

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Abstract. This study was carried out to determine the need for more appropriate fall preventive measures and create a knowledge base for design criteria to be implemented in the Friendly Rest Room project. Literature research and interviews with users and caretakers were used to create the FRiTA Model, which was used to identify ‘basic toilet activities’ with an increased fall risk within the ‘Dutch’ toilet ritual. Next, a new toilet support was developed which provides a fine-tuned all-in-one support solution with an inviting appeal, representing luxury, serenity and hygiene. Several elementary aspects have been implemented in FRR prototypes. The results of usability tests with these functional FRR prototypes look affirmative and promising.

Keywords. Slips, Trips and Falls, Inclusive Design, Toilet, Support, Assistive Devices

1. Introduction

Statistics show that people are getting older and in the near future, elderly people will represent an increasingly larger group of the population. Social structures are changing and many elderly people expect to enjoy a more active lifestyle and benefit from better living conditions [1,2,3]. Fall accidents are responsible for the majority of serious injuries amongst the elderly in the category of home accidents. More than one out of three people over 65 and about 50% of the elderly over 85 years of age fall at least once a year. The consequences of these fall accidents for elderly people are diverse and can affect the mental, social and physical condition of the elderly individual. That is why falls often have a strong impact on daily life [1-7]. The prevention of falls in the toilet environment is an important theme within the FRR project.

2. Investigating Fall Accidents in the Toilet Environment

The research project was started with the general aim to help prevent fall accidents of elderly people when they visit a public or semi-public toilet. The first phase existed of a profound literature investigation on related aspects in the multidisciplinary field including the geriatric process, falls and fall prevention, Dutch legislation and

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standards on rest room design and the toilet routine in general. This was complemented with a set of investigations on current available assistive devices for the toilet environment, the present-day situation for Dutch (semi-)public toilet environments for elderly people and the handicapped, the view of elderly people (n=10) and nursing professionals (n=6) on falls and fall prevention by interviewing them [2].

This knowledge was used to develop the FRiTA model for fall risks assessment in toilet routines [2]. The model was used to identify toilet activities with an increased fall risk within the 'Dutch' toilet routine and reveal potential problem areas (locations and actions) within the toilet environment and ritual. This resulted in a set of recommendations for fall preventive measures in the toilet environment as a whole [1,2,3], preliminary design criteria and a refined design assignment focussing on physical product interactions in one specific problem area and aesthetic experiences.

Additional research focussed on area-specific aspects of fall prevention, ergonomics, usability, aesthetics, and stigmatising design aspects [1,2,3]. Input on the latter aspects was obtained by literature, using collages and by means of a questionnaire filled out by seniors (n=19) on their perception of toilet environments.

2.1. The Consequences of Falls for Elderly People

For elderly people falls are, more often than in other age groups, the cause of severe physical injury and rank high on lists of causes for accidental death [2,6,8]. In the group of elderly people, 25-50% of falls cause some kind of physical injury [2,5]. Although less than 10% of all falls lead to a fracture, about 52% of fractures in the older age group are caused by a fall, with hip fractures as most frequently occurring type of fracture [7]. According to Spirduso [6], more than half of the elderly hospitalised due to a fall die within one year, and Fuller [8] additionally reports that approximately 25% of the elderly with a fractured hip as result of a fall die within six months. In general, elderly women appear to fall more often than elderly men do, whereas elderly men have a higher mortality rate due to falls.

The fear to fall alone can affect the daily life of an elderly person significantly. Next to the fear of falling again, elderly people are often afraid of their first fall accident. Many consider the occurrence of falls a sign for the beginning of the end [6]. Fall-related fears repeatedly result in stiffened locomotion, loss of self-confidence, and subsequently lead to self-inflicted functional limitations. This, unfortunately, mostly brings about an increased risk of falling and growing social isolation [2,6,7].

The fear to fall (again) often makes elderly people decide not to lock the rest room door, not even in a public or semi-public environment. The anxiety of ending up injured inside a toilet booth, helpless or even dying after a fall is stronger than the potential embarrassment of a complete stranger entering while using the toilet [2,9].

2.1.1. Risk Factors in General

A broad variety of intrinsic (individual/personal) and extrinsic (external/environmental) factors influence the extent and presence of the risk to fall for elderly people. These affect either the stimulus responsible for the initiation of a loss of balance, the capability to recover a loss of balance or, in some cases, have an effect on both. Most often though, falls are caused by a combination of several intrinsic and/or extrinsic factors [2,6,7,10].

Falls themselves are, apart from any fall-related fear, also responsible for increasing the risk to fall, especially when multiple falls occur within one year [2,5]. A repetitively falling person does not necessarily fall due to a similar combination of factors each time. And while many single risk factors by themselves do not entail a notably increased fall risk, interaction between risk factors can intensify the fall risk significantly. Many times, they create a vicious circle, eventually leading to a fall accident [2,6,8].

Decrease of physical activity and difficulties during the execution of movements are important contributors to the intrinsic causes for fall accidents, while physical limitations together with a more cautious performance of movements reduce the exposure to extrinsic fall risk factors. This subsequently causes a further decline of the capability to act in response to danger and risks [5,6].

3. Preventing Falls When Using the Toilet

Everybody has their own toilet ritual, which includes a variable number of relatively small movements and tasks. In early childhood, one is trained in these activities and the tasks unite to become, as it were, one activity to be performed almost automatically, without thinking. This changes when people get older. The ageing process often affects some of the movements and postures that are part of the toilet routine. This causes the ritual as a whole to disintegrate, and a task within the toilet ritual previously without a significant fall risk can suddenly change into a hazardous activity [2,11,12]. In most cases, people will first try to compensate and slightly adjust their ritual, or use already present objects for support to accommodate geriatric complaints, before relying on any additional assistive device [2,9,10].

3.1. Current Fall Prevention Strategies

Currently, a diverse range of fall prevention strategies is in use, which all attempt, by following various paths, to reduce the occurrence of falls, also for the toilet environment. The first major step in almost all of these prevention programmes is to create awareness of fall risks present in the surroundings of an elderly individual. Multi-faceted approaches tailored to the elderly individual, assessing and modifying both intrinsic and extrinsic fall risk factors, appear to be the most successful in reducing the number of fall accidents [2,6,7].

Fortunately, the use of assistive devices in toilet environments seems to be less affected by the reluctance often shown with other assistive devices [4,11]. Supports in the toilet environment are the second most frequently used type of assistive devices after ambulatory aids. For various reasons, their presence, though, does not always imply (correct) usage. Some elderly people state they not always recognize grab bars as such. In some cases they are thought to be a towel rack [10], in other cases the user lacks the necessary strength to use a particular type of support [2].

Proper installation of assistive products in toilet environments is determinative for the suitability and amount of support offered in real use [1,2,3,10,12,13]. The design of public or semi-public toilet facilities generally follows a minimal set of accessibility regulations and guidelines, which are mostly based on average dimensions. In many situations, anthropometrics guidelines based on averages are acceptable; applying these guidelines in assistive products for elderly people though, will result in excluding a

considerable number of people from (comfortable) use, since elderly people are, anthropometrically speaking, far from average.

3.2. Risk Factors within the Toilet Environment

Implementation of a broader range of fall-preventive measures in building regulations, for instance, should be considered as very important to bring down the number of falls in toilet environments. Extrinsic aspects of toilet environments can be divided into two categories: 'fixed toilet environment' (the floor, toilet bowl, etc.) and 'additional objects' (towels, floor carpets, etc.). Both categories entail a varied, though different range of risk factors. As the Friendly Rest Room project concentrates on public and semi-public toilet environments, the fall risk factors incorporated in the 'fixed toilet environment' will be focussed on.

The layout and interior design of the toilet environment has to be spacious, practical and clear to be easily accessible for elderly people. The space to manoeuvre in many toilet environments is very limited, which hinders many, especially those using a mobility aid like a rollator [2,11]. In a confined, narrow rest room it is easy to find support against walls; getting up after a fall, though, becomes almost impossible.

A toilet environment accessible for people using a mobility aid like a rollator should at least have the dimensions of a rest room 'plus', see Figure 1. Non-elderly users will most likely appreciate this relatively new type of spacious public toilet environment as well, for example obese people and people with infants. This set-up simultaneously removes the first barrier for many elderly to visit a public toilet, as they no longer will depend on the stigmatised toilet for the handicapped [1].

The nature of the floor surface influences the fall risk strongly. The level of slip resistance should be sufficient, both in dry and wet circumstances. Various gaits and types of shoe wear should be taken into consideration in the assessment of the floor surface as well, as combinations suitable for some can be hazardous for others [2,6].

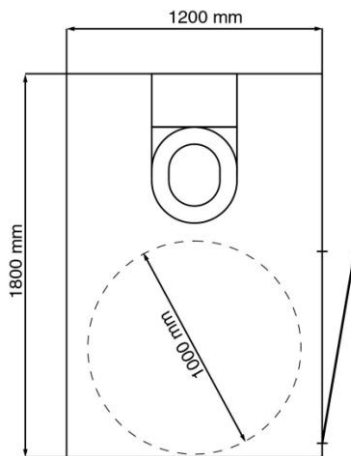


Figure 1. Dimensions of a toilet room 'plus'



Figure 2. The toilet bowl as object to trip over (upper left), lack of contrast (lower left), visual support and a deceptively continuing floor (both on right)

The floor should be level, without any thresholds or other trip objects. Wall-mounted toilet bowls are preferred over floor-mounted ones, as feet or rollator wheels easily hook behind them [2], see Figure 2.

Elderly people often experience visual difficulties. For this reason sufficient contrast between all objects in the toilet environment, including walls and floor, is indispensable, see Figure 2. Clear visual support as in contrasting vertical or horizontal lines, at or above eye height, will help many elderly people to maintain postural balance [1,2], also see Figure 2. Usage of wall plinths in the same colour as the rest room floor should be avoided. They complicate the assessment of the environment for the visually impaired by creating a deceptively continuing floor [2], see Figure 2.

Blinding or disorientation due to glare or reflections should be avoided. Sufficient lighting is essential for elderly people to assess the interior of the rest room properly, but light transitions should be gradual to avoid dizziness or disorientation when entering the room [2].



Figure 3. Manikin Mathilde demonstrates the basic toilet activities with the highest fall risk (by Landmark Design Holding BV)

The style and ambience of a toilet environment can be of influence on the possible risk to fall. Activities connected to urination and defecation are generally considered very intimate and private [11]. Thoughts about our own toilet ritual already raise some negative, uncomfortable feelings; those of strangers are seen as even more unpleasant. The more publicly accessible a toilet is and the less familiar the people are who use it, the more important it becomes that the environment appears hygienic and ‘as if never used before’. In different ways, this is connected to the perception of the toilet environment and the behaviour of people during a toilet visit [11]. The way people perceive the environment determines their well-being, which in turn influences the use of the facilities and therefore the potential fall risk. Hygiene, privacy and a safe,

comfortable surrounding should therefore also be considered as essential attributes within the overall toilet environment design to avoid fall accidents [1,3]. Elements, like assistive devices, bearing a stigma should be banned or redesigned to become an integral part of the environment.

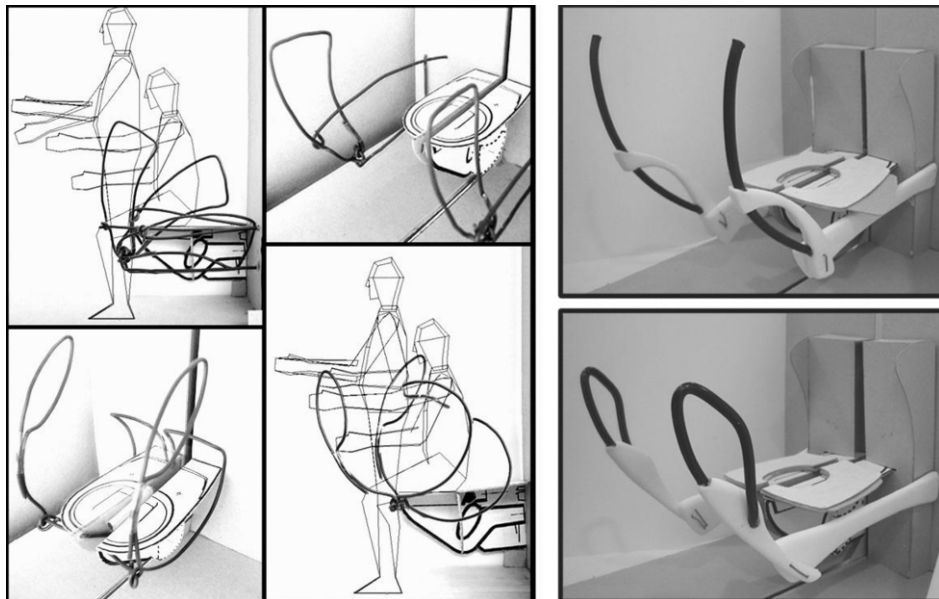


Figure 4. Several preliminary scale models in different stages of the design process

3.3. Risk Factors within the Toilet Ritual

Transfers onto and from the toilet are well known as one of the most difficult personal care activities to perform for elderly people [2,10,11]. Many elderly people also experience difficulties when rising, standing, turning, (un)dressing and reaching [9,13]. Heightened toilet seats can cause constipation problems and prolonged sitting can cause legs to ‘fall asleep’ [2,11]. To obtain a complete and proper impression of the potential risks within the toilet ritual of elderly people, a process tree of the ‘Dutch’ toilet routine was created. A broad range of over 40 activities was identified with changing movements and postures [2,11]. The basic toilet activities, which were always performed by nearly all users, are most important to focus on when designing a public or semi-public toilet environment.

An evaluation of hazardous movements within the toilet ritual was performed which revealed that the activities of opening and closing the door, manoeuvring through the rest room, turning in front of the toilet, (un)dressing, sitting down, performing perineal cleansing, rising and checking clothing after dressing were the ‘basic toilet activities’ with the highest fall risk [1,2,3,5,11]. In Figure 3, Mathilde, a manikin designed by Landmark Design Holding Bv for the FRR project, illustrates these activities.

4. The Design of a New Assistive Product to Prevent Falls

The study above was used as an outline to describe the need for an assistive product to prevent falls in toilet environments, and to define a design assignment for such a product. To design a support for a (semi-)public toilet environment with an as large assistive effect as possible, the design phase focuses on basic toilet activities, as those activities are performed almost every time by nearly all users. The largest number of fall-riskful basic toilet activities is performed by Dutch elderly people in the vicinity of the toilet bowl [2]. Therefore, the design focuses on assisting elderly people properly during their movements and postures while standing still and manoeuvring in front of the toilet bowl, (un)dressing, sitting down, performing perineal cleansing and standing up. The target group consisted of people older than 60 years of age that are able to visit a public toilet autonomously (whether or not using a simple mobility aid like a walking stick or rollator) and use the facilities in it without the help of another person. The product should in no way (physically or mentally) hinder or complicate the use of the toilet environment by any user, including secondary and tertiary users.

The semi-public environment the product is designed for implies a setting with durable products, used by multiple users with varying demands and styles of usage. This also means a relative high level of cleaning and maintenance by specialised staff (and not/less by the primary user self), and makes a product with a relative higher level of luxury, compared to a fully public situation, possible.

The emphasis in most current assistive products is on technical functionality and reliability in assistive behaviour. The new design should distinguish itself from those products by taking also the usability, ergonomic functionality and aesthetics into account as equally important.

Through a creative design phase, involving various design techniques, a broad range of ideas was generated. The most promising ideas were combined to form interim conceptual solutions. Next to additional research and design sketches, preliminary scale models played an important role during the following design process, see Figure 4.

In subsequent design phases, the conceptual design was further developed to a more detailed level, mapping experiential aspects to physical properties. Design decisions were made based on aspects of usability and perception of hygiene. The limited space of toilet environments and the potential big influence of an assistive device on the perception of the whole environment require the manifestation of the design to be simple, open, and inviting.

Next to a 3D computer model (see Figure 5), a full-scale visual model of the grab bar section (see Figure 6) was made as well to evaluate the manifestation of the grab bar in full scale [1,3].

4.1. *S'wing*

The final support proposal, named *S'wing*, consists of several specially designed components (see Figure 5): a toilet lift module, a toilet seat and two grab bars alongside the toilet [1,3]. Each component provides users assistance when performing their toilet ritual and helps them prevent fall accidents. When applied collectively, though, they reduce the fall risk even further, as they intensify and supplement each other's fall-preventive qualities.



Figure 5. The 3D computer model of S'wing

The design of S'wing facilitates a varied range of support to choose from for elderly users. The design enables sufficient support and assistance for elderly people between the 5th (often a small female) and 95th (often a tall male) anthropometric percentiles during various activities of the toilet ritual.

The toilet seat and grab bars are height-adjustable because they are mounted on a lift module. Ergonomic research during the design process showed that when choosing for such a type of adjustability, anthropometric needs could be met with a design that is more compact and less visually present in direct sight. Next to a less complex product to use for the elderly, this helps to avoid a potentially deterring and stigmatising effect caused by the dimensions of the supports. The curved surface of the toilet lift module also includes a back support to provide extra stability while seated.

The toilet bowl applied is a wall-mounted type. The fact that it hangs free from the floor decreases the fall risk by tripping. The design of the toilet seat is trapezoidal. Together with the enlarged and slightly concave curved surface this shape ensures (more) stability while seated. This also reduces the hazard of sliding off the seat, while sitting on one side for wiping ones buttocks, for example. Furthermore, it eases sitting down and standing up as it offers enough space to place both hands on the seat next to the upper legs.

S'wing offers various types of support and can be used in many different ways, according to the wishes of each individual toilet visitor (see Figure 7). When a user enters the toilet environment without a FRR personified data carrier, the grab bars will be in the position shown in Figure 5, this way the user will know that at least two positions are possible.

When rotated backwards, the support bars present a grip to grasp while sitting down, as well as an armrest to use when seated. When rotated upwards S'wing offers grip in front of the toilet seat, and can also be used to lean against with the hip. The design of S'wing gives the user options to store a walking stick or small bag while toileting, for example by placing it through the V-shaped opening in the grab bars or hanging it over the vertical grab bar. In the backwards position, they present a grip to grasp while sitting down, as well as an armrest to use when seated.

The support and grab bars can be rotated between an upward (vertical) and backward (horizontal) position and fixed in in-between positions. To change the position of a grab bar the user grasps and squeezes the button on the lower arch and give it a slight push or pull in the desired direction until the preferred position is reached. During this, the mechanism inside carries the largest part of the weight. To lower or raise the whole toilet unit (including the grab bars), to flush or call someone for help, the user can use the buttons on top of one of the grab bars.

In the described version of S'wing, the handles are adjustable and actively rotated by the user. The seat can be adjusted in height and tilt, but still provides a static type of support. In a more elaborate design, S'wing could offer dynamic assistance. Sitting down and standing up could be actively assisted by a rotating movement of the support bars, for example. This would help the user to initiate and coordinate these motions.

Moreover, a more simplified edition could be marketed, which for instance only offers the grab bar(s) without the toilet lift to be installed at a personally defined, fixed height.

The colouring and use of materials is chosen such that it helps to increase the perception of hygiene and serenity. In most sanitary situations, light/pale blue appeals as more fresh and new to a user, as it is less sensitive for visual contamination and yellowing due to cleaning chemicals than white, for instance. Parting lines, surface curves and edges are designed such that they will not collect dirt, and if minimal amounts of dirt might collect, it will be out of the line of vision for users. Materials to be used will conduct heat sufficiently to maintain a relatively cold and fresh feeling when touched by human skin.

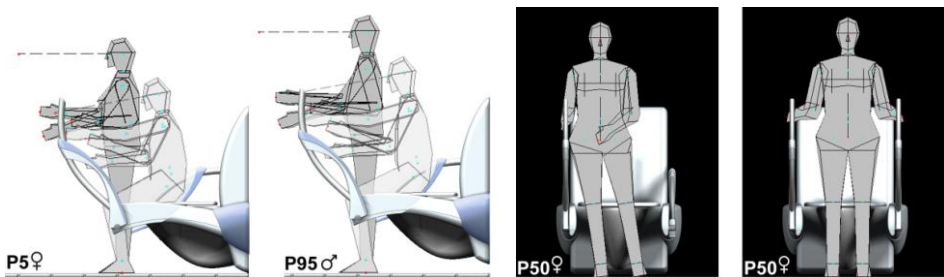


Figure 6. Computer-simulated usage examples by a small elderly female, a tall elderly male and an average elderly person

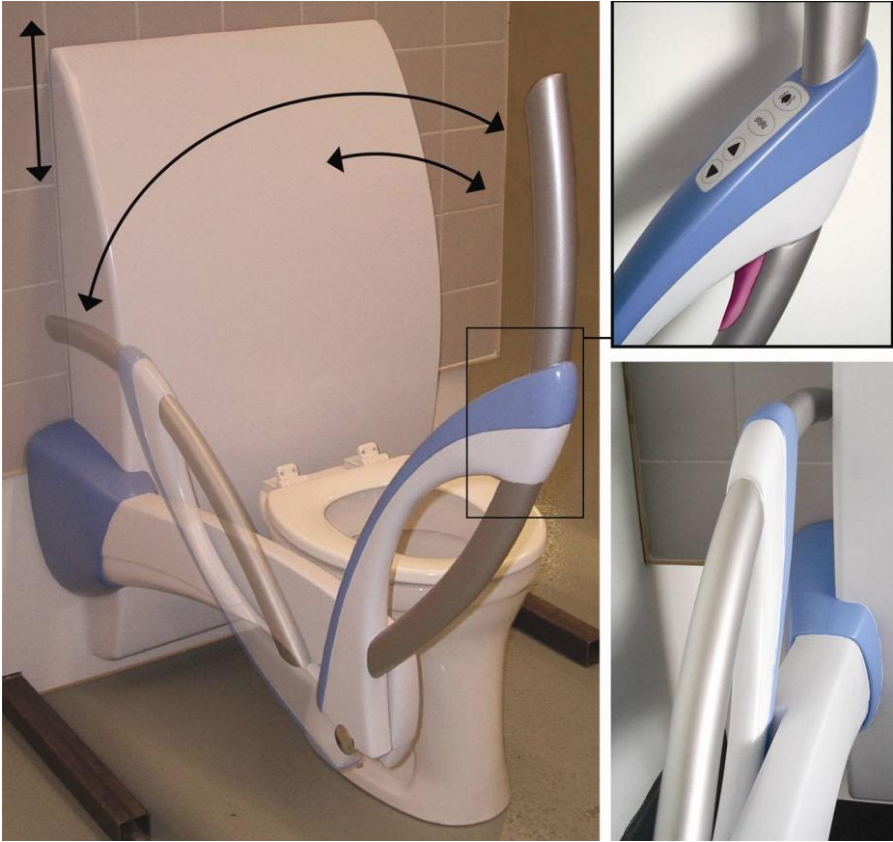


Figure 7. The visual full-scale model of the grab bar and some details

5. Conclusions

The fall risk present in toilet environments is determined by the combined action of a variety of factors. When applying fall-preventive measures in the toilet environment, the most important thing is to assess and modify the environment as a whole, taking both intrinsic and extrinsic factors into account. It is possible to reduce the influence of these factors by applying a full set of appropriate fall-preventive measures.

The conceptual support developed during this graduation project, offers an innovative and appropriate solution to prevent falls in the toilet environment. Its components together form a fine-tuned whole with an inviting appeal representing luxury, serenity and hygiene. In various ways, it offers an enormous improvement compared to existing assistive products for the toilet environment.

Elderly toilet visitors will no longer be forced to alter their toilet behaviour to obtain suiting support, as it offers an integrated mix of different types of support. This ensures that the number of users excluded from usage is minimal.

6. Recommendations

The next step should be the development of a fully functional prototype of the conceptual design as a whole for usability testing. Only this way it will be possible to actually verify the design decisions that have shaped the design.

Additionally more fundamental research on topics that have not thoroughly been studied before would create a better basis to determine the genuine value of the new design. This includes research into support preferences of elderly, interaction patterns with different types of support within the toilet environment, as well as a more elaborate study into the perception of toilet environments by elderly people. This will create a profound basis for further developments in the field of fall prevention in the toilet environment.

Finally, it is advisable to re-evaluate current accessibility regulations and guidelines for toilet environments in detail to include a broader range of criteria concerning fall prevention.

References

- [1] Buzink SN, Molenbroek JFM, Haagsman EM, Bruin R de, Groothuizen ThJJ. S'wing: a fall prevention product for the toilet environment. Development of a product to prevent falls in the toilet environment [in Dutch]. *Tijdschrift voor Ergonomie*. 2004;29: 4-11.
- [2] Buzink SN, Molenbroek JFM, Haagsman EM, Bruin R de, Groothuizen ThJJ. Falls in the toilet environment: a study on influential factors. *Gerontechnology*. 2005;4:15-26.
- [3] Buzink SN, Molenbroek JFM, Bruin R de, Haagsman EM, Groothuizen ThJJ. Prevention of falls in the toilet environment. In: Pikaar RN, Koningsveld EAP, Settels PJM, editors. Meeting diversity in Ergonomics. Proceedings of the 16th Triennial Congress of the International Ergonomics Association, IEA2006. 2006 Jul 10-14; Maastricht, The Netherlands. Elsevier Ltd.; 2006.
- [4] Aminzadeh F, Edwards N. Exploring seniors' views on the use of assistive devices in fall prevention. *Public Health Nursing*. 1998;15:297-304.
- [5] Bueno-Cavanillas A, Padilla-Ruiz F, Jiménez-Moleón JJ, Peinado-Alonso CA, Gálvez-Vargas R. Risk factors in falls among the elderly according to extrinsic and intrinsic precipitating causes. *European Journal of Epidemiology*. 2000;16:849-859.
- [6] Spirduso WW. Physical dimensions of aging. Champaign: Human Kinetics; 1995.
- [7] Til J van, Michels PH, Delobelle M. Privé veiligheid: voorkómen van vallen. In: Handboek lokaal ouderenwerk voorkomen van vallen [in Dutch]. Amsterdam: Stichting Consument en Veiligheid; 2003.
- [8] Fuller GF. Falls in Elderly. *American Family Physician*. 2000;61:2159-2168.
- [9] Plante RA. Toilet customs of the elderly; an exploration to find problems caused by the symptoms of old age and injury into the problems that exist when using the raised toilet seat [Student research report, in Dutch]. Delft: Delft University of Technology, Faculty of Industrial Design Engineering; 2002.
- [10] Aminzadeh F, Edwards N, Lockett D, Nair RC. (2000). Utilization of bathroom safety devices, patterns of bathing and toileting, and bathroom falls in a sample of community living older adults. *Technology and Disability*. 2000;13:95-103.
- [11] Kira A. The bathroom. New and expanded edition. New York: Viking; 1976.
- [12] Crawford J. Design regulations and bathroom accessibility for the elderly. In: Özok AF, editor. *Advances in Applied Ergonomics, ICEA '96*. West Lafayette: USA Publishing; 1996. p. 724-727.
- [13] Bosman J. Toilet usage in the living environment of elderly, research into preferences of grips and grab bars (in Dutch). *Tijdschrift voor Ergonomie*. 1999;24:36-41.