Hand supports to assist toilet use among the elderly

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Abstract

Improving the toilet environment holds promises for increasing the quality of life for elderly and disabled persons. This is one of the goals of the Friendly Rest Room (FRR) project.

The study described in this article explored the preference and use of supports in the toilet environment during the entire toilet ritual.

An adjustable test frame was built with a toilet and three types of supports. Fourteen subjects were asked which positions they favoured for each support. After using all three supports they were asked which support they found most comfortable.

In general, the preferred positions depended on personal preferences more than on dimensions of the body. It was concluded that there is a preference for vertical supports for sitting down and standing up. During toilet use the side supports were equally appreciated.

Keywords: support, toilet, elderly

1. Introduction

For many elderly and disabled persons using the toilet is a problem: when help is needed their quality of life often drastically decreases. This research is part of the Friendly Rest Room (FRR) project which aims to study problems with existing rest rooms and to develop a friendly toilet environment: friendly to the largest possible group of users, for use at home, in homes for the elderly, hospitals or public environments. The FRR project is supported by the EU within the 'Quality of Life and Management of Living Resource' programme and Key Action 6: ‘The Ageing Population and Disabilities’ of the European Union.

Ageing people in general deal with decrease of physical, psychomotoric and sensory capacities (Molenbroek, 1987). Because sitting down and getting up require postural control, the elderly are likely to have more trouble than younger people (Mourey et al., 1998).

The most frequently applied method to deal with sitting down on and rising from toilets is the installation of a raised toilet. This possibly introduces other problems, such as increased straining and time on the toilet due to an unfavourable posture (Dov Sikirov, 2003). Kirvesoja et al. (2000) found indications for discomfort during prolonged sitting on elevated chairs.

The method of using supports is the topic of this study. Supports allow the muscles of the legs to be assisted by the muscles of the arms and enlarge the footprint, enabling a more stable sequence of movements while sitting down and standing up. Raised toilets and supports are often combined to decrease problems with toilet use.

The ultimate friendly rest room will adapt to the user, as opposed to a toilet environment that the user has to adapt to. Within the FRR project an extensive search (Buzink et al., 2005) was conducted to find relevant literature for determining support types and positions.

The most relevant publication (Bosman, 1999) reported that slightly more than half of the elderly prefer getting up with a pulling motion. A quarter of the subjects favoured a combination of pulling and pushing. The overall conclusion from this article is that the elderly use the vertical and horizontal supports in rest rooms very frequently during various actions of the toilet ritual. The ease of use of side supports or toilet rails seems to be highly dependent on the proper adjustment to the user.

Another relevant source that provides an in-depth analysis of the sit-to-stand motion is the dynamic digital human modelling system of Mitchell (2004).

The information in literature was not sufficient to determine the design of the supports, because most articles focused on specific solutions and general conclusions were hard to draw. Therefore, a test was set up to gather necessary information on preferences and use concerning supports in the toilet environment. The test set-up consisted of a Western style ceramic water closet and toilet paper according to Dutch custom, see Figure 1 for a typical Dutch toilet.

This study was conducted with a typological sample selected from the Gerontechnology Research Project of our Faculty of Industrial Design Engineering (Steenbekker and Van Beijsterveldt, 1998). The aim of this study was to find comfortable solutions for a wide range of users. In order to get a more profound insight into the use of support bars in the toilet environment, it is necessary to do more extensive research with a larger representative sample. The present study focuses only on supports around the toilet. In order to design a whole toilet room, more comprehensive design guidelines (Pinto et al., 2000) have to be taken into account.

A small sample is sufficient to get a quick overview of design problems (Kanis, 2000). With a typological sample, it is possible to identify extremes within a population. Within a small sample, only the very large differences and strong correlations will be significant, whereas smaller differences and correlations are more difficult to identify.

Figure 1 A typical Dutch toilet with supports at home

2. Goals and Research Questions

This study focuses on the use of supports within the toilet environment. Its purpose is to gain insight into preferred types of supports, the associated range of heights and distances from the toilet, and the use of different types of supports by Dutch elderly people.

In order to reach this goal the following research questions have to be answered:

(1) How do the elderly use the supports during the entire toilet ritual?

(2) Which absolute positions of the supports do elderly people find most comfortable for sitting down on and rising from a toilet?

(3) Which positions of the supports relative to the body do elderly people find most comfortable for sitting down on and standing up from a toilet?

(4) What kind of supports do elderly people prefer during each phase of the toilet ritual?

(5) What kind of support is useful for elderly people during each phase of the toilet ritual?

(6) Does the support situation at home relate to the preference of the elderly for a certain type of support in the test set-up?

3. Methods

3.1 Set-up of the test

The study consisted of two major parts. An interview was held at the subject's home to obtain insight into the toilet situation the subjects are used to and problems they encounter in everyday toilet use.

A user test was held in the laboratory to gain information on the use and preferences regarding different types of supports.

3.1.1 Equipment

The interview was held with the help of a printed interview guide. A still camera and a tape measure were used to measure and record the toilet environments at the homes of the subjects.

The measurements at the laboratory were made using an anthropometer, tape measures, a dynamometer and a digital weight scale. Recording equipment consisted of still and video cameras and paper data record forms. The test was carried out in accordance with a written research protocol.

3.1.2 Test Frame

A test frame was developed with three types of adjustable supports and a height-adjustable toilet bowl (see Figure 2). The height of the toilet bowl had to be adjustable to eliminate the influence of a fixed toilet height on the results. The diameter of all support bars was 30 mm.

The vertical supports could be moved horizontally, parallel to the sagittal plane. The range of adjustment was 120 mm to 580 mm from the front of the toilet bowl. The two vertical supports were 650 mm apart. The range of adjustability of the vertical supports was based on a study by Molenbroek (1998) on reach envelopes.

The front support was infinitely variable in height from 20 mm to 1850 mm from the floor. The front bar was mounted between the two vertical bars with the centre of the bar approximately 35 mm closer to the body than the centre of the vertical bar.

The minimum height of the side supports was determined by the set height of the toilet, because the transfer surfaces (see Figure 2) block the side supports. The maximum height is 1850 mm from the floor. The distance between the two side bars is approximately 700 mm.

Transfer surfaces were added on both sides of the toilet to make transfers from the wheelchair to the toilet easier. They move in height with the toilet.

The height of the toilet bowl including the seat and with the subject on it could be adjusted hydraulically from 250 mm to 700 mm.

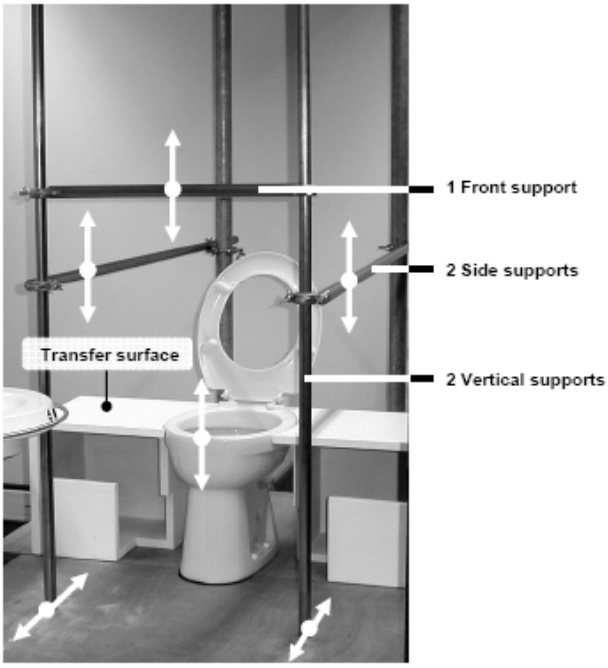

Figure 2 Test frame with adjustable parts

3.1.3 Test Procedure

After welcoming the subjects and explaining the test to them, they were asked to sign an informed consent form and a confidentiality agreement.

Body stature, body mass and gripping force were measured prior to actual testing. The subjects were also asked if they had any physical or mental complaints that influenced their daily life and if they wore glasses or contact lenses.

The subjects had to sit down and get up using the supports at various positions after having set the toilet height at a comfortable position. For each type of support, the subject had to indicate and use an optimal position after two trials at predetermined positions, see Figure 3. Finally, they were asked for each phase of toilet use (sitting down, getting up and cleansing) which of the supports were most comfortable to use. The described use of the toilet was recorded by video cameras.

3.1.4 Data Analysis

Relations between the preferred heights that emerged from the tests and the anthropometric data recorded earlier in the Gerontechnology Research Project (Steenbekker and Van Beijsterveldt, 1998) were studied. Correlations were analysed using Pearson's Correlation and were considered strong when they equal or exceed 0.8.

Differences in preferred heights between the different types of supports were tested using the Wilcoxon Signed Ranks Test. Differences in preference between experienced and inexperienced subjects were analysed using Fisher's Exact Test. The differences and correlations found in the analysis of the data were considered significant at a probability level of less than 5 % ($p<0.05$).

The qualitative analysis of behaviour focused on the type of grip, the number of hands used, the preferred positions compared to the body, and the way subjects applied force to the supports for all three types of supports. The analyses were made for both the action of sitting down and the action of rising.

3.2 Selection of Subjects

To obtain a broad overview of the problems associated with the use of support bars, a typological sample was used. Fifty persons were selected from the subjects that were involved in the Gerontechnology Research Project (Steenbekker and Van Beijsterveldt, 1998) using the criteria described below. They were approached by a letter and a subsequent telephone call. Fourteen were willing and able to participate.

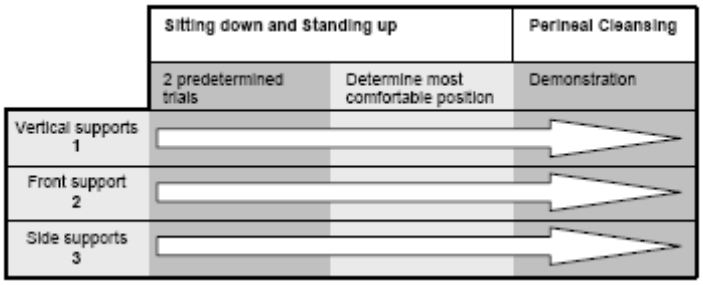

Figure 3 Sequence of testing the supports in different phases of the toilet ritual

3.2.1 Selection Criteria

In order to find a broad range of problems, the subjects were selected using criteria expected to relate to the use of the supports. Individuals of both genders were selected with both high values and low values for these characteristics.

The following characteristics were used to make a selection:

- Stature
- Body mass
- Pulling force

3.2.2 Informing the Subjects

The subjects were informed on all occasions about the nature of the research. In order to approximate the contact between the skin of the legs and the toilet seat as in real situations, the subjects had to sit on the toilet with bare thighs, leaving their underwear on. An informed consent form was signed prior to the test. Only researchers of the same gender as the subject were present in the test room during the test. Communicating this explicitly was very valuable in avoiding embarrassment.

3.2.3 The Fourteen Subjects

Five of the subjects were male and nine were female. See Table 1 for a description of the subjects regarding age, stature, body mass and gripping force.

Gripping force was measured as an indication of strength, because the equipment to measure the initial selection criterion of pulling force was not available.

One of the subjects had a stiff hip joint and inflammation of the skin on the lower legs. Another subject recently fractured the right arm and in the beginning of the test only used the left arm, but quite soon used both arms.

One subject wore a skirt. The rest of the subjects, both male and female, wore trousers during the tests.

4. Results

4.1 Exploring the use of the supports

4.1.1 Vertical supports

As illustrated in Figure 6, the subjects most frequently used both their hands with a power grip when sitting down on and rising from the toilet using the vertical supports. One used a hook grip and another used a thumb grip (see Figure 4 for an illustration of the different types of grips) while getting up.

Most of them (8/14) pulled forward to shift their centre of gravity over their feet when rising. For sitting down, most subjects (10/14) hung backwards (see Figure 7 for frequencies of applying force to supports).

Most subjects grasped the vertical support at about shoulder height (5/14) when sitting and at about elbow height when standing (7/14) (see Figure 5 for the distribution of the body-related positions).

One subject wearing a skirt preferred a different configuration of the vertical supports. Because one hand was occupied with holding up her skirt, this subject wanted to have two vertical supports on her right-hand side.

Table 1 Age and measured dimensions of subjects

	N	Minimum	Maximum	Mean	Standard Deviation
age (years)	14	58	79	66	6
stature with shoes (mm)	14	1578	1934	1756	114
body mass (kg)	14	52	142	93	23
maximum gripping force (N)	14	260	550	386	92

Figure 4 Power grip, thumb grip and hook grip illustrated

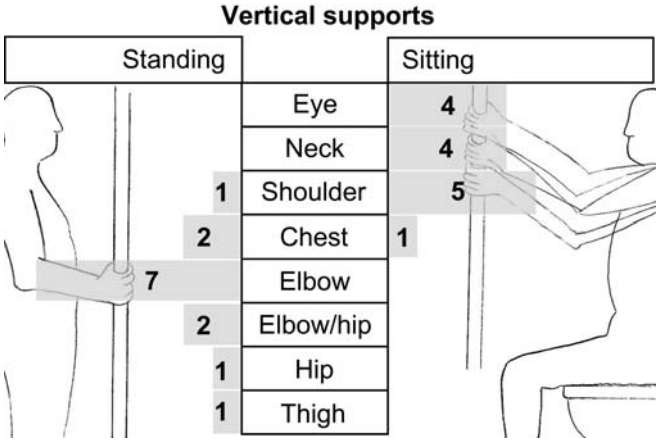

Figure 5 Distribution of heights at which vertical supports were used relative to the body

4.1.2 Front support

The ideal height of the support bar was at shoulder height (5/14) and chest height (3/14) for most subjects for standing up. For sitting down, most subjects (5/14) preferred the front bar to be between elbow and hip position (see Figure 8 for the distribution of the body-related positions).

By far most subjects held the front bar at shoulder width. Most subjects pulled forward (6/14) with the front bar while standing up and hung back (11/14) while sitting down (see Figure 9 for an overview of the ways subjects applied force). The majority of the subjects used a power grip and both hands as illustrated in Figure 9.

4.1.3 Side supports

The ideal height of the side supports was set at about elbow height (6/14) and chest height (5/14) for standing up by most subjects. For sitting down, the ideal side bar height was at buttock height (9/14) when standing for most subjects (see Figure 11 for the distribution of the body-related positions).

Most subjects used the side supports with a power grip and both hands.

The side supports were grasped near to the front of the toilet seat by most subjects (9/14).

The majority of the subjects pushed up using the side supports. Another observed behaviour was hanging backwards or a combination of pushing and hanging (see Figure 12 for an overview of the way subjects applied force to the side support).

Summary of exploration of use

The use of the support bars shows a large variety for the height at which the bars are used relative to the body, as can be seen in Figure 5, Figure 8 and Figure 11.

The most frequently used grip is a two-handed power grip for all supports, both for sitting down

Figure 6 Sitting down while hanging backwards with two hands in a power grip

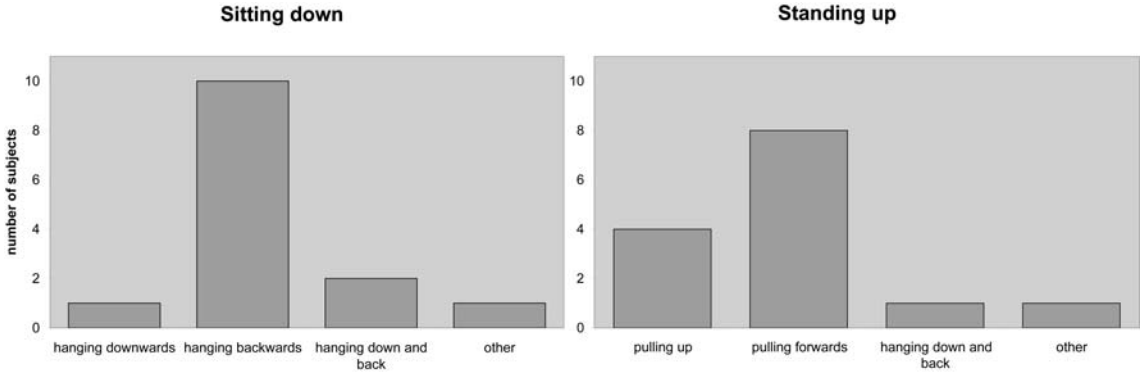

Figure 7 The way subjects applied force with the vertical supports

and standing up. For the vertical supports and the front support, a forward pulling motion was most frequently used; in contrast to the side supports where most subjects used an upward pushing motion to get up or sit down. All subjects grasped the front support at or near shoulder width.

The side supports were most frequently held near to the front of the toilet bowl. No difference was observed in the position of the hands between sitting down and standing up.

4.1.4 Analysis of exploration of use

The heights of the supports in comparison to the body are illustrated in Figure 5, Figure 8 and Figure 11, because relations were expected between the height of the supports and the anthropometry of the subjects. No strong correlations were found between the heights of the supports and the initial selection criteria: gender, stature, body mass and pulling force. From the figures it appears, however, that the preferred relative heights concentrate around certain points of the body.

No significant differences were found between the use of supports by men or women. No significant relation was found between relative preferred height and body mass or grip force; neither was a significant relation found to the way force was applied, which hands were used, nor the type of grip.

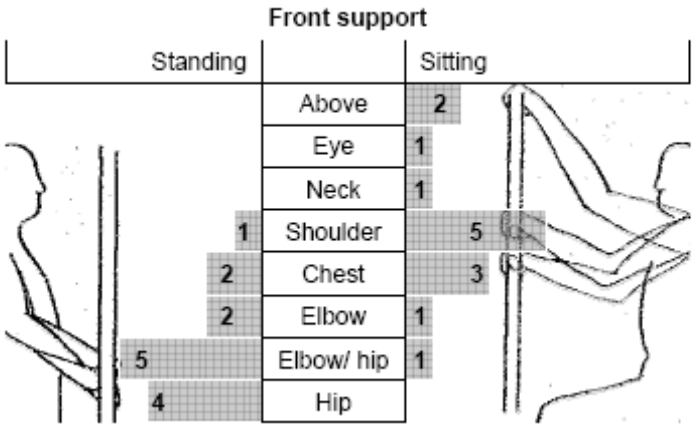

Figure 8 Distribution of heights relative to the body for the front support

Figure 9 Sequence of getting up with front bar: pulling forward with both hands in power grip

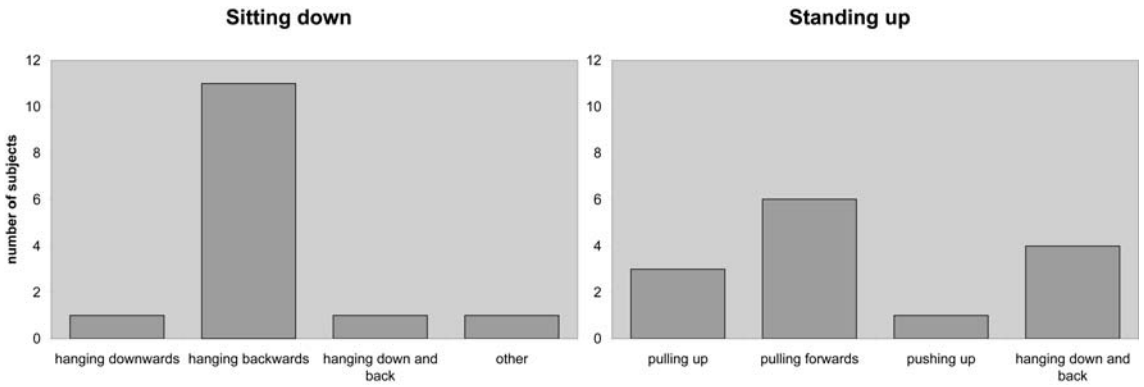

Figure 10 The way subjects applied force with the front supports

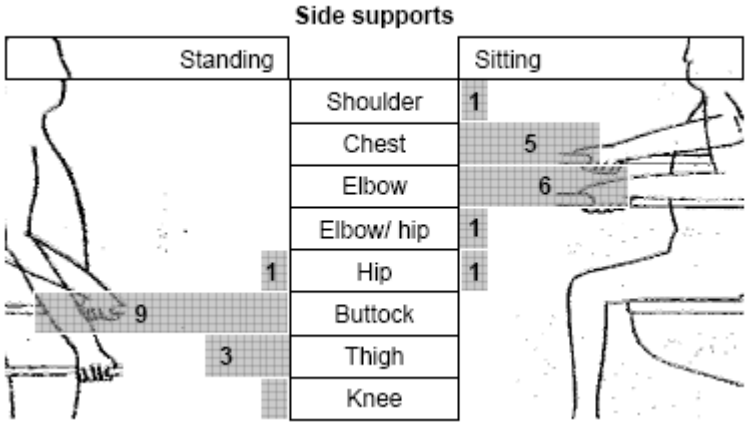

Figure 11 Distribution of heights at which side supports were used relative to the body

4.2 Absolute heights

The preferred positions for the supports are described by: the depth of the vertical supports, the depth and the height of the front support, and the height of the side supports. The heights were measured from the floor. The results of these measurements are described in Table 2.

A high kurtosis (k=2.7, sd=1.2) was found for the height of the side supports. Most subjects set the height between 750 and 813 mm.

No strong correlations were found between the positions of the supports. The preferred height for the side supports is significantly lower than the preferred height for the front support ($Z=-3.3$, $p<0.01$). This is best explained by the difference in use between the front support and the side supports: pulling motion and pushing motion respectively.

Table 2 Values for the optimal positions of the supports

	N	Minimum	Maximum	Mean	Standard Deviation
distance between toilet and vertical supports (mm)	14	175	515	338	89
height of front support (mm)	14	850	1400	1071	140
distance between toilet and front support (mm)	14	192	537	357	97
height of side support (mm)	14	650	1010	774	91

4.3 Preferred supports

For getting up and sitting down, half of the subjects (7/14) preferred the vertical supports. There was no large difference in preference for the front support or the side supports for sitting down and getting up. For a sample of 14 subjects, the standard error of means is 13.4% for a result of 50%. It is probable ($p<0.05$) that in the population more than 28% prefer the vertical supports for getting up and sitting down. The preference found does not significantly deviate from a result that would have depended on chance.

For support during use of the toilet (wiping the buttocks), the vertical supports and the side supports are preferred equally (6/14). Two subjects indicated that they do not have a preference for any particular support in this phase of the toilet ritual.

4.4 Usefulness of supports

Most subjects state that getting up and sitting down is easier with than without the supports. This applies to all three types of support.

The front support was said to cause a feeling of confinement in at least four occasions. The front supports were also physically obstructing at least three subjects when standing up.

4.5 Familiarity with supports

Almost all subjects (13/14) encounter toilets with supports in their daily lives. The five subjects described in Table 3 have supports at home or indicated use of encountered supports, and therefore are considered to have experience with supports.

Both for sitting down and standing up, all the experienced subjects prefer the vertical supports. During use of the toilet, the majority (3/5) preferred the vertical support. One subject preferred the side supports and another subject did not have a preference during wiping of the buttocks.

In contrast to inexperienced subjects, all experienced subjects favour the vertical supports for both rising and sitting down. Fisher's Exact Test shows that there is a significant relation between the experience of the subjects and the preference for the vertical support ($p=0.02$). No significant difference was found in the preference for the type of support while using the toilet between subjects with and without experience.

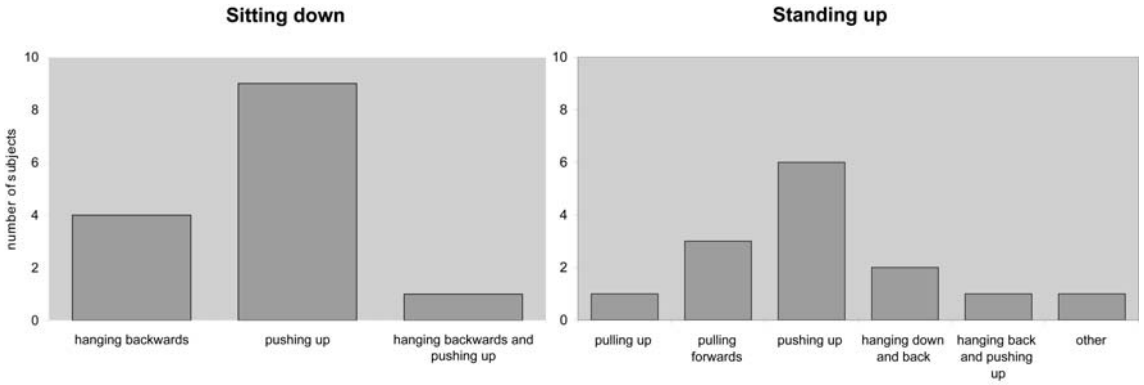

Figure 12 The way subjects applied force using the side support

Table 3 Situations for the experienced subjects

Subject	Uses supports	Has support at home	Type of support
1	Sometimes	Yes	Two vertical
5	Never	Yes	Two diagonal
9	Sometimes	No	Two vertical
11	Never	Yes	Two vertical
13	Often	Yes	One side, one diagonal

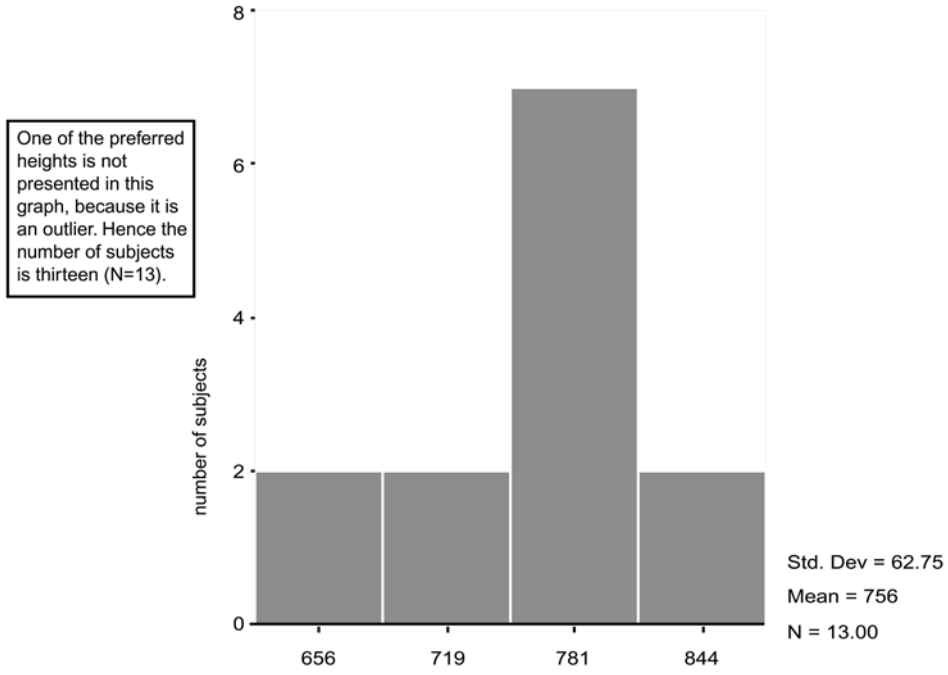

Figure 13 Histogram of the preferred heights of the side supports

5. Discussion

5.1 Results

The range of heights and distances found was larger than expected. The subjects preferred the supports in very diverse heights compared to the body. The heights for supports that the subjects considered comfortable seemed to be dependent on more factors than just anthropometry. Possible other factors could be: strength needed to lift arms, force that can be applied in different positions of the arms, pressure within the joints, clothes, habitual behaviour or other environmental, social and psychological factors. Zacharkow (1988) suggests several physiological and anatomical dimensions.

Support for the finding that there is not a strong correlation between anthropometry and preferred product settings can be found in Grandjean et al. (1983), where the preferred settings of workstations and the anthropometry of the subjects were not strongly correlated. Similarly, the optimal set height for a handrail and anthropometry did not have strong correlations for Japanese rural elderly people (Ishihara et al., 2002). Kolich (2003) found discrepancies between anthropometrical criteria and preferred settings for car seats. From these studies it is clear that preferred settings are not solely determined by anthropometry.

Another study (Yang and Yu, 1990), however, shows strong correlations between optimum kitchen sink height and anthropometry. This indicates that the discussed relation might depend on the associated task.

Clothes could be an important factor for determining behaviour, as was illustrated by the subject wearing a skirt. In order to get a good insight into the relation between clothes and behaviour, a sample with more variety in clothing is necessary. This insight is needed as in many countries skirts and dresses are more common than in the Netherlands, especially among elderly women.

Anthropometry did not have a strong correlation with the preferred heights of the supports for this sample. Within the population, the extremes will be determined by large persons preferring relatively high positions compared to the body and by small persons preferring relatively low positions compared to the body. Perhaps a more detailed postural analysis, such as the one performed by Gyi et al. (2004), will yield more information to be able to predict comfortable support positions based on anthropometry.

Within this research, no re-test was held to verify intrapersonal repeatability. So it may well be that there are comfortable zones instead of just a preferred position for supports and that the extremes of these zones will have a stronger relation to anthropometry. In other words, the borders between the comfortable and uncomfortable zones could be related to body dimensions. A fitting trial (Pheasant, 1996) could be used to reveal these zones. This, however, was expected to be too strenuous for the seniors in the test.

No evidence was found that the initial selection criteria of stature, body mass, gender and grip strength are related to the use of the supports. This can either be due to the absence of a relation or because the criteria are not related to the measured range of variables. Perhaps other variables should be measured to discover this relation, such as, for example, strength exerted on the supports and strain of the muscles. The selection of subjects in this study was based on the proposition (Kanis, 2000) that there is a relation between the anthropometrical characteristics mentioned in section 3.2.1. and the most comfortable positions for the studied supports. As no evidence for this relation was found, it can be questioned how well the current typological sample represents the extremes in the Dutch population with regard to the most comfortable positions of the supports. Because no other relations were identified, the representativeness of the current sample cannot be predicted.

The familiarity of the subjects with supports was investigated to verify whether there are biases from this experience. It was expected that the favoured support would comply with the situation that the subjects were accustomed to. This effect was not found, probably because the amount of subjects that were familiar with supports was quite small (n=5), and because the variety in types of supports was not very large.

5.2 Set-up

The distance between the supports could not be adjusted. It was fixed at 650 mm for the vertical supports and 700 mm for the side supports. The distance between the vertical supports was determined by the P95 shoulder width for men plus an extra tolerance for clothing. The construction and the former distance determined the distance between the side supports. The smallest hip width while sitting of the sample was 337 mm (Steenbekker and Van Beijsterveldt, 1998). This subject had a clearance of approximately 180 mm on either side. None of the subjects appeared to be limited by this factor. It is possible that subjects would have chosen another type of support as favourable, if the width had been adjustable.

The tests were held in a laboratory environment with cameras and researchers present. The subjects were consequently aware of being observed. Unobtrusive observations of actual use of the supports would probably gain more valuable information, but this is not feasible because of ethical limitations.

6. Conclusions

The answers to the research questions directed the design of the toilet environment for the FRR project. Both vertical and side supports were further developed. Based on the results of this study, the vertical supports are adjustable horizontally in the sagittal direction. The supports are designed to accommodate the behaviour and preferences that were found in this research.

In the following paragraph, conclusions are drawn for each research question:

(1) How do the elderly use the supports during the entire toilet ritual?

The support bars are used in various ways. The supports are mostly used to shift the point of gravity in the transversal plane in sagittal direction. The actions to accomplish this are pulling forward and hanging backward. The side supports were also used to bring the centre of gravity upwards. This was achieved by pushing the body up.

The supports were most frequently used with a power grip and with two hands, although some subjects showed different uses. Especially use with a skirt induces different behaviour.

(2) Which absolute positions of the supports do elderly people find most comfortable for sitting down on and standing up from a toilet?

For the vertical supports the measured range of distances from the toilet seat front is 175 mm to 515 mm with a mean of 338 mm (sd=89 mm). The height of the front support ranges from 850 mm to 1400 mm with a mean of 1071 mm (sd=140 mm). The range of distances from the toilet is 190 mm to 535 mm with a mean of 357 mm (sd=97 mm). The height of the side supports ranges from 650 mm to 1010 mm with a mean of 756 mm (sd=63 mm). Because of the relatively peaked distribution of the preferred heights (see Figure 13), the range of adjustment of a side support bar did not have to be very large.

(3) Which positions of the supports relative to the body do elderly people find most comfortable for sitting down on and standing up from a toilet?

There does not seem to be a strong relation between a person's anthropometry and the positions for the supports that he or she finds comfortable within the range of positions that were possible in the laboratory. The subjects have very different tactics for getting up and sitting down with the supports. This results in a wide variety of preferred heights compared to the subject's anthropometry.

The vertical supports were generally held at about neck height while sitting. The front support was most frequently held slightly lower than elbow height while standing. The side supports were most frequently preferred to be at buttock height while standing.

The general view of the supports is that their use is very varied and that comfortable heights cannot be accurately predicted by anthropometry alone.

(4) What kind of support do elderly people prefer during the toilet ritual?

For getting up and sitting down, more subjects prefer the vertical supports over the other types of supports. It is probable, however, that this preference can be explained by chance.

For wiping the buttocks, the vertical supports and the side supports are equally well appreciated. The front support is not appreciated for this toilet activity.

(5) What kind of support is useful for elderly people during each phase of the toilet ritual?

Most subjects stated to benefit from each support type while getting up and sitting down. The front support does have some practical and psychological disadvantages however, because some subjects nearly bumped their heads against it and some subjects felt locked in by the front support.

(6) Does the support situation at home relate to the preference of the elderly for the type of support in the test set-up?

Vertical supports seem to be significantly more preferable for people with experience with supports for getting up and sitting down than for people without this experience. For use of the support during toilet use, there is no evidence that experience relates to preference.

7. Recommendations

This study found some very valuable answers for designers of supports that were not previously known. It also found a few interesting leads that could guide future research on comfortable supports in the toilet environment.

One of the topics for future research is the description of comfort or discomfort zones for the positions of the supports and whether there is a relationship between the limits of these comfortable or uncomfortable zones and anthropometry. In order to reduce complexity of the set-up, research could focus on one type of support only. An aspect that could be paid attention to is whether comfort is related to the distance between vertical and side supports.

Another interesting research topic would be to identify other factors apart from anthropometry that could be related to the preferences of support positions, such as physiological and social aspects.

Clothing seems to be an important determinant for toilet behaviour. It could be interesting to research the relation with clothing, because in contrast to the Netherlands, differences in garment between genders are more prevalent in other countries.

Furthermore, it could be verified whether subjects with more impairments and physical limitations than the subjects in this study display other behaviour than observed in this study.

Finally, a participatory design project (Demirbilek and Demirkan, 2004) will probably yield valuable insights into the problems elderly people experience in the use of toilets and identify user requirements for the design of future toilets.

Efforts could be made to develop hand supports for use in the toilet environment based on a vertical orientation of the bars. A modular system that can accommodate the changing needs of a family could be considered. This system could for example consist of modules for vertical supports, transfer surfaces, a height-adjustable and tiltable toilet and a 3D positionable washbasin.

8. Acknowledgements

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