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Design of Ergonomic Front-Entry Sitting Toilet System for People using Wheelchairs

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Objective: The objective of this study is to develop an ergonomic toilet system along with constituent facilities that can be used with the front-entry sitting method when transferring from wheelchair to the toilet stool, instead of using the back-entry sitting method which is currently used. This system can offer more ease, convenience and safety for wheelchair users when using the restroom.

Background: For users with disabilities, even a dedicated handicapped toilet requires maneuvering, especially when in a wheelchair. To transfer from wheelchair to the current back-entry sitting toilet, users need to get closer to the toilet and then turn or twist after erecting their body to get onto the toilet. This method induces inconvenience as well as secondary injury by falling when transferring to/from toilet.

Method: To design a front-entry sitting toilet system, an ergonomics approach was applied which introduces a new design concept for people using wheelchairs. Using this toilet system, the wheelchair users don't need to turn or twist but can simply slide forward off the wheelchair directly onto the toilet stool in an easier and safer way.

Results: The newly developed front-entry sitting toilet system is easier and safer for wheelchair users, and also space efficient requiring only two-thirds of the space of existing handicapped toilet. It is also usable by both individuals with disabilities and the general population.

Conclusion: With the spread of the front-entry sitting toilet system developed in this study, wheelchair users can benefit from enhanced convenience and safety as well as significant restroom space savings. Additional effects can also be achieved such as improved self-esteem of people with disabilities by enabling to use the toilet on their own.

Application: The newly developed front-entry sitting toilet system should enhance toilet accessibility to wheelchair users and the elderly. Introduction is needed with efforts at the national policy level and a macroscopic objective to promote the health and safety of the handicapped.

Keywords: Toilet, Restroom, Wheelchair, Disability, Handicapped, Accessibility

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1. Introduction

Disabled accessible restrooms are facilities vitally needed for realizing a discrimination-free society for persons with physical impairment, and also for enhancing social activities of persons using aids and equipment such as wheelchairs. Currently in Korea, criteria for accessible restroom for disabled persons is set forth in the Criteria on

Structure and Material of Facilities, the Enforcement Regulation of Article 8 of the Act on the Guarantee of Promotion of Convenience of Persons with Disabilities, Elderly People, Pregnant Women, etc. (hereinafter Convenience Promotion Act) by the Ministry of Health and Welfare (2015). It is further stipulated that, "Public restrooms, etc. are also required to follow installment standards as set forth by the Convenience Promotion Act". Specific guidelines provide the details for disabled accessible restroom, including place of installment, material and finish, other equipment and the installment standards for toilet stool, urinal stall, activity space of washstand, structure, handrail, etc. Installment standards for toilet stool are mandatory, while those for urinal and washstand are recommended. Restroom for persons with disabilities is categorized into exclusive type for the disabled and disabled accessible type within a regular restroom, and is stipulated for the severely handicapped using wheelchairs. Korean Agency for Technology and Standards (2007) describe similar guidelines to those prescribed in the Convenience Promotion Act.

The Ministry of Health and Welfare (2015) defines disabled accessible restroom as "restroom that is accessible by persons with disabilities", and provides the dimensions of toilet stool and activity space as follows. Effective floor area of toilet stool in a new building should be 140cm or more in width and 180cm or more in depth. To the left or right of the toilet stool, there should be open space of 75cm or more in width to enable lateral access with wheelchair. Then, to the front of the toilet stool, the wheelchair will need turning space of 140cm×140cm or more. Meanwhile, the effective floor area in existing facilities, which are not of new construction, should be 100cm or more in width and 180cm or more in depth; however, only in cases where structural reasons prevent the required installment.

Pursuant to the Americans with Disabilities Act (ADA) established in 1990 in the United States, laws continue to be revised today regarding dimensions, type, installation regulations (Figure 1), finish material, etc. of various facilities and equipment for improving wheelchair accessibility in restrooms. And in 2010, ADA Standards for Accessible Design (ADA, 2010) was announced. Such standards for better restroom accessibility of wheelchair users are also provided by the United States (2016). While slight differences are found by country, standards exist worldwide and Korea is no exception.

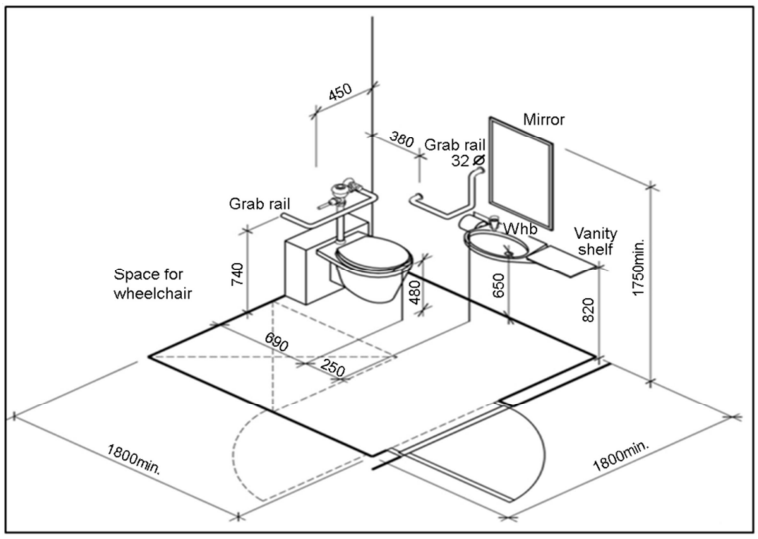


Figure 1. ADA compliance public restroom dimensions in millimeters for wheelchair accessibility (adapted from ADA (2010))

In the Republic of Korea, the Convenience Promotion Act was enacted in 1997, and implemented to legally obligate all public facilities to be equipped with disability amenities. Facilities are undergoing reconstruction and change in structure to have the

required disability amenities in place. To promote convenience of the disabled, legal standards have been enacted and enforced at the government level. Regardless, many of the measures were taken only in formality by laws requiring disability amenities, and not of much help to the disabled who are the actual users. Anti-Corruption and Civil Rights Commission (2012) reports frequent civil petitions related to the use of disabled accessible restrooms, and disability organizations are submitting various opinions on better accessibility to restroom for persons with disabilities. Moreover, according to the Disabled Facilities Conditions Census of 2013 by the Ministry of Health and Welfare (2013), among the types of disability facilities installed, the inadequate installation rate was 51.2% and the adequate installation rate was only 41.6% for hygienic facilities including restrooms.

Alongside the legal and institutional issues, not much research and development has been made on improved structure or type of disabled accessible restroom that enhances the convenience or safety of the disabled. Up to now, in regards to the handicapped restrooms, studies mainly conducted condition census according to accessibility, needs survey and analysis of inconvenience (Bichard et al., 2006; Choi et al., 2004; Kim et al., 2007; Lee et al., 2009; Lim, 2011; Seo, 2012). Studies also report on the need for a universal design for disabled accessible restrooms or make conceptual suggestions (Bichard et al., 2005; Crews and Zavotka, 2006); Erlandson, 2008); Kose, 2009; Mamee and Sahachaisaeree, 2010; Story, 2001; The Center for Universal Design, 2000). However, it is difficult to find a realistic application for wheelchair users in the restroom. Kim and Hong (2010) and Desai (2013) did develop front-entry toilet stools and had patents registered, but details of structure or implementation, installation etc. were not provided. Thus, from an architectural engineering or ergonomics perspective, it seems a stretch to apply them to real situations.

This study developed a toilet system design, a new concept from an ergonomics perspective, which resolves problems related to disabled accessible restroom based on in-depth analysis of difficulties experienced by wheelchair users using public restrooms for the disabled. Instead of the current back-entry sitting type, an ergonomic front-entry sitting type was developed for the elderly or the disabled to ease transfer from wheelchair to the toilet stool. Constituent facilities such as washstand, handrail, restroom door, toilet paper holder and flush button were included as well. With the new design, wheelchair users do not have to twist or turn the body when transferring to the toilet stool, but simply spread the legs and slide off forward onto the toilet stool. It is an easier and safer way to use the restroom, and drastically saves restroom space compared to the existing disabled accessible restroom. In this way, this study aims to promote the safety of wheelchair users and promote the spread of the new design through related research and policy planning.

2. Problem Analysis and Development Needs

Independent living enhances welfare of the disabled. From this perspective, public restroom for the disabled should no longer serve only as a means to put the disability welfare policy in practice; on grounds that easy access and use of public restroom is in itself a crucial issue directly linked to stronger sociality and sense of independence of a disabled person. At present, public restrooms are very lacking in terms of policy, technology and awareness for the disabled to use independently without any hindrance. Among the disability amenities, handicapped restrooms are built in a way disconnected from the real life of the disabled, as their lifestyle and dignity are poorly recognized. It is common to find even dedicated restrooms for the disabled that are not easy for a person with disabilities to use by oneself. According to a recent survey conducted by Korea Consumer Agency (2016) on 30 handicapped restrooms in metropolitan parks, 86.7% (26 restrooms) were found to have violated one or more installation regulations stipulated by the Convenience Promotion Act. Not only does this pose risk of accidents, but also found to be inconvenient to use.

Korea Institute for Health and Social Affairs (KIHASA, 2011) states that 49.5% of the disabled in Korea are physically challenged, and most of them mobilize in a wheelchair and have to use disabled accessible restrooms in order to take care of basic physiological needs. However, such restrooms do not seem to satisfy the conditions of persons with disabilities. Anti-Corruption and Civil Rights Commission (2012) and The Citizen's Coalition for Restroom (2010) present the following problems with installing and using disabled

accessible restroom in Korea.

2.1 Discrimination issue raised upon separate installation

Where a disabled accessible restroom is already installed, a door for the disabled is being installed separately and away from that of the regular restroom. The disabled will be considered special; moreover, aggravate division in society and raise discrimination issues.

2.2 Privacy infringement caused by non-separation of gender

Where space is limited in an existing facility, one gender-neutral stall may be installed for the disabled, leading to privacy violation and acts of crime.

2.3 Problem with having to turn wheelchair or body when using restroom

Space is needed to move and turn the wheelchair, and there will be difficulty in turning the body to sit on the toilet stool.

Several solutions were announced to rectify the current situation. Restroom should be installed in a way enabling universal access by any person; install a disabled accessible restroom within a gender-specific regular restroom; build a single sharing door for the handicapped and the non-handicapped if possible, and install a disability accessible toilet within the regular restroom thereby resolving sense of division and discrimination; in the case there is only a gender-neutral accessible restroom for the disabled, this should be re-installed as a multi-functional "family" restroom (equipped with amenities usable by all persons including the disabled, children, parent with child, the elderly); in the case there is only a regular restroom due to limited space in an existing building, change inner structure of a regular restroom to make it accessible by the disabled.

However, there is no mention of ways to fix the current restroom structure or problems faced by wheelchair users when using the restroom. In particular, a red flag was raised to the problem of "space is needed to move and turn the wheelchair, and there will be difficulty in turning the body to sit on the toilet stool"; however, we are still without a countermeasure or way to improve the situation.

In general, a wheelchair user accesses the restroom as follows. With the wheelchair, one first gets close to the toilet stool (Figure 2), then turns or moves on either the left/right side or in front of the toilet stool (Figure 3). As shown in Figures 2 and 3, the approach and transfer methods from the wheelchair to the toilet stool vary depending on the user's physical characteristics, disabilities and restroom structure. Regardless, such methods of approach and transfer require wheelchair users to be in very awkward postures and put excessive strain on the upper body. This leads to serious issues of safety, not to mention user inconvenience. That is, most of the wheelchair users are the elderly or the disabled with neurological system disorders or musculoskeletal disorders in the lower body, who may not have enough strength in the arms during the transfer to/from the toilet stool, and a slip or lack of attention could incur secondary injuries.

An ergonomic design could help resolve such problems, and studies to this end are highly important. Furnishing a system that enables easier, more convenient and safer transfer from/to the toilet stool, along with constituent facilities (door, washstand, grab rail, operation device, restroom accessories, etc.), could prevent secondary accidents or injuries in the restroom, and enable one to take care oneself independently and in a safer way. Studies to improve products or facilities promoting the health and safety of the socially disadvantaged are vitally needed to enhance self-esteem of the disabled and thereby social participation. Support for further research is called for at the national policy level and efforts to disseminate should follow.

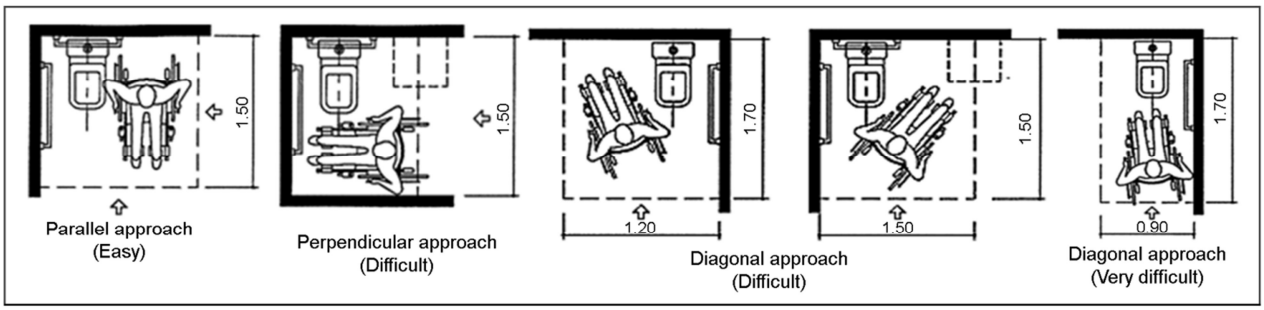


Figure 2. Approaching methods with levels of difficulty from wheelchair to toilet stool (adapted from UN (2016))

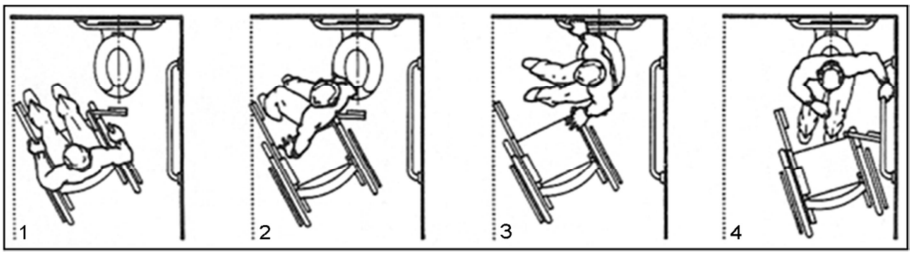


Figure 3. Transferring method (diagonal approach) from wheelchair to toilet stool (adapted from ADA (2016))

3. Method

In general, wheelchair users should be given particular consideration ahead of other physically challenged persons when constructing an environment for the physically impaired (Choi et al., 2004). The most important factor is securing space for the wheelchair to approach and move. The key is to design a toilet system that enables transfer to/from the toilet stool in an easy and safe manner, which is the most basic and crucial point for wheelchair users, and thus the objective of this study. As such, an ergonomics approach has been taken to develop a front-entry sitting toilet system for wheelchair users, and a further step to consider its practical application from the aspects of usability and concurrent engineering.

This ergonomic toilet system would be equipped with front-entry sitting toilet stool for wheelchair users, and of a design that can be easily implemented in terms of engineering and applied at low cost (cost-effective). The basic concept of the design was to develop a toilet stool and a toilet system that do not require prior experience or skills, or additional training for usage, and with an objective to enhance convenience and safety (ergonomic design factors). The following pre-requisites and considerations were established prior to design development:

- Design that is applicable to existing restroom structure and type;
- Design that improves convenience and secures safety of toilet stool, entry door, washstand, handle, operation device and other various amenities for wheelchair users;
- Design that maximizes space saving compared to existing disabled accessible restroom space;
- Design that enables usage by all persons with and without disabilities without having to additionally install disabled accessible restroom.

Along with the above requirements, this study referred to the body size survey of the disabled (wheelchair users) of Size Korea

(2016) for dimensions to be used in developing the front-entry sitting toilet system.

4. Results

4.1 Front-entry sitting restroom system

Refer to Figures 4 and 5. This study developed an ergonomic design that adopts the front-entry sitting method, a new and reformed concept over the existing back-entry sitting method, and equipped with a toilet stool that can apply the new concept and constituent facilities (door and operation button, toilet flush button, washstand that can be used while sitting on toilet stool, grab rail to support transfer to/from toilet stool, mirror, toilet paper holder).

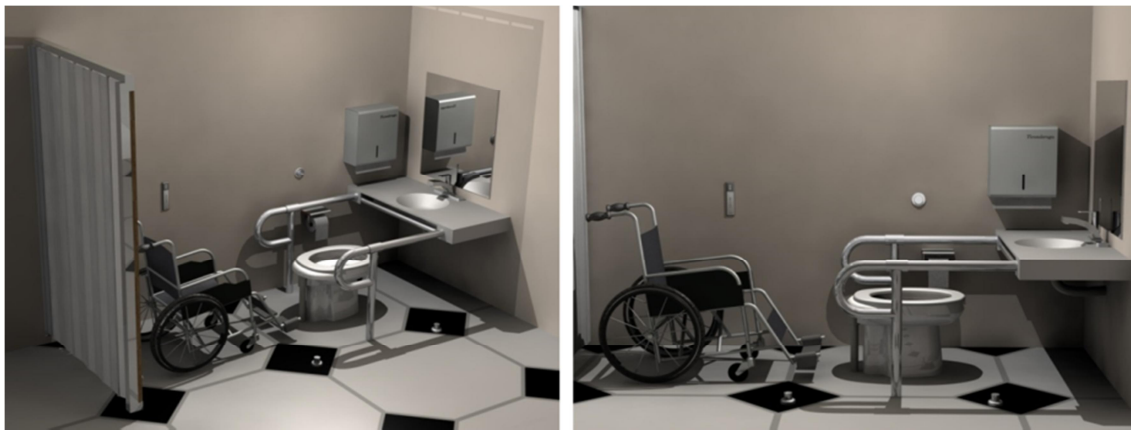


Figure 4. Front-entry sitting restroom system (diagonal & side view)



Figure 5. Front-entry sitting restroom system (backside view)

As shown in the figures, the front-entry sitting system offers more ease and safety in the restroom for a wheelchair user in the

same position coming in, as one can open the legs slightly and simply slide forward to use the toilet. Thus, there is no need to turn or twist the body. There is also no need to rotate the wheelchair so restroom space is significantly saved. Moreover, an added effect is higher self-esteem of the wheelchair user, because one can now take care of personal hygiene in private space independently and at once in the restroom. Lastly, as the front-entry sitting system can be installed in a regular restroom, the concept of a universal restroom, which is usable without distinction of the handicapped or the non-handicapped, may become widespread as needed.

To introduce the system to an existing restroom with a low-tank toilet bowl may pose a problem, in that when trying to sit on the toilet, there may not be enough space to pull down the pants and extra space needed for the knees because of the toilet tank or flush valve and pipes. In this case, higher installation of the water tank is a possibility. With a flush valve type toilet bowl, the water pipes could be buried under the floor surface and have the flush button on the floor or the wall, in order to secure adequate distance from the wall for the knees to move. In other words, the space problem could be solved by widening the distance between the toilet stool and the wall, or making a groove inside the wall for leg room. However, in order to attempt this system, the front and back of the toilet stool should be of same form; thereby, revision/complement of the current toilet stool structure and type is a prerequisite. In addition, the toilet seat and cover attached to the existing toilet stool needs to be exchanged with new ones to fit the new toilet stool design, and a universal design for toilet seat that enables front and back entry should be adopted.

More freedom is allowed in designing a new restroom structure for wheelchair users compared to using or reforming an existing restroom. Aside from the ones presented in this study, various other design ideas for front-entry sitting system may be generated and put through verification tests, to ultimately develop a toilet stool that enhances user convenience and safety.

The toilet design itself is important in adopting the front-entry sitting toilet system, but it is also vital to consider the interaction with constituent facilities that will help realize the whole idea. As such, this study approached it as a system development, and not simply a new toilet stool, in order to develop a toilet system design that could support all movements involved with using the front-entry sitting toilet stool. The restroom door should be designed so that it can be freely entered and exited, opened and closed while sitting in a wheelchair. After using the toilet and wanting to wash hands, the washstand can be used while sitting, too, still on the front-entry sitting toilet stool and without having to move the body. Also included in the study were detailed designs of support structures (vertical, horizontal grab rail) - where to install, type, size, material, etc. - for transferring to/from the front-entry sitting toilet stool, using the toilet and afterwards. The type and position of amenities for after using the toilet, such as flush button for the toilet stool, toilet paper and holder and mirror, were considered from an ergonomics perspective as well.

Any disabled accessible restroom needs to provide space (1,400×1,400mm or more) for turning the wheelchair to reach the toilet stool. The current handicapped restroom is required to have a wider space of at least 2.52m^2 (1,400×1,800mm) in comparison to a regular restroom providing 1.43m^2 (1,100×1,300mm), and a space of 3.24m^2 (1,800×1,800mm) when including the washstand. The front-entry sitting restroom of this study does not require such space for turning and even upon including the washstand and all other constituent facilities, the total space needed is reduced to 2.42m^2 (1,100×2,200mm). This design not only provides more convenience, as one can use the toilet and wash up in a single trip to the restroom, but also is very significant from an economic perspective, as restroom space is drastically reduced.

4.2 Front-entry sitting restroom system - design of constituent facilities

This study did not simply develop a front-entry sitting toilet stool for wheelchair users. Interactions with constituent facilities were also considered to make effective use of the front-entry type stool. The following design suggestions for each constituent facility are very important.

4.2.1 Front-entry sitting toilet stool

The installment standards of existing handicapped restroom were followed in determining the toilet stool height (40~45cm) for wheelchair (electric, manual) users. However, regulations failed to specify the toilet stool size. The adequate length of the toilet stool, which can be applied to the front-entry sitting restroom of this study, is 45~50cm, because extra space to fixate water tank or toilet seat cover to the general toilet stool is not needed. Also, a maximum width of 35cm or less will enable easy access onto the toilet stool with opening of the legs.

The toilet stool was designed in a way that does not have the legs open too wide when sliding forward onto the toilet stool from the wheelchair and transferring back into the wheelchair thereafter, and in a streamline form with the same front and back, so that it may be used universally for front-entry sitting and back-entry sitting methods as needed. The flush type was selected when installing water pipes, which were designed to come up from the under the floor to the toilet stool. The flush valve was replaced with an electric flush button, which are largely used in recent handicapped restrooms, and installed on the wall at a height of 98.45~103.45cm. This dimension range was calculated by taking the mean sitting cervical height 58.45cm of ages 19~59 (all genders) from Size Korea (2016)'s body size survey of the disabled (wheelchair user) and adding the toilet stool height (40~45cm).

The toilet stool seat was designed without a cover to enable universal access from front or back, and to be fitted and fixated on the top side of the toilet stool. In order to apply this design, the willingness to develop by local and foreign toilet stool manufacturers is needed. Particularly with the toilet stool for the handicapped, the social minority, support at the national level is called for active engagement.

Meanwhile, adequate horizontal distance between the toilet stool and the washstand is calculated, in order to provide open leg space and use of washstand when sitting on the front-entry sitting toilet stool. The width of the washstand should be referred to first. It is 40cm from the wall according to this study, and when seated on the toilet stool, the knees should go under the washstand by 5~10cm in order to reach for and easily use the washstand. As such, the distance from the wall to the end of the user's knees should be 30~35cm. With reference to the 95th percentile of buttock-knee lengths of wheelchair users, which is 57.45cm, the distance from the end of user's buttocks to the washstand end should be 47.45~52.45cm. Thus, considering that when sitting on the toilet stool (45~50cm in length) there is room of 5~10cm in the back of the buttocks, the front end of the toilet stool should be 7.45~12.45cm away from the washstand.

4.2.2 Washstand and restroom accessories

The front-entry sitting toilet stool and the washstand (mirror, toilet paper holder, paper towel dispenser) was designed as an integral unit so that after using the toilet, one does not have to get back into the wheelchair and move with difficulty to wash the hands or look in the mirror.

According to installation standards, "The height of the washstand top for wheelchair users should be 85cm from the floor and the height of the washstand bottom should be 65cm or more. The lower part of the washstand should have room for the knees and wheelchair foothold". However, these dimensions are for use when sitting in the wheelchair, and applying the same to the front-entry sitting toilet stool would have the arms raised to chest height in order to use the washstand. It is, therefore, advisable to apply the sitting elbow height as the appropriate washstand height for the front-entry sitting toilet stool. With reference to the assessment results of ages 19~59 (all genders) from Size Korea (2016)'s body size survey of the disabled (wheelchair user), apply the 25th percentile figure (18.75cm) and add the toilet stool height (40~45cm) which makes 58.75~63.75cm. For optimum knee space in the lower part of the washstand, 75th percentile of the sitting knee height, which is 48.15cm, was applied. So the suitable thickness of the washstand would be about 10cm. For this study, ergonomics would choose the 5th percentile for the sitting elbow

height and the 95th percentile for the sitting knee height. However, there were big gaps in the relevant figures from Size Korea's body size survey of the disabled (wheelchair users) and only a very few applied; so respectively the 25th and 75th percentiles were adopted.

The washstand mirror in a handicapped restroom is commonly installed at a certain angle to incline downward. In this study, however, the washstand height is lower and a plane mirror at eye height of toilet stool sitting becomes usable. The convenient height for toilet paper holder in the front-entry sitting position was determined to be the same as that of the washstand, which is the sitting elbow height. The optimum height of the paper towel dispenser was 98.45~103.45cm, the sitting cervical height of the wheelchair user, and lever type faucet was chosen.

4.2.3 Handrail

The legal installation standards for a handrail that can serve as support for a wheelchair user entering the front-entry sitting toilet, while using the toilet and coming out the toilet is "The height of a horizontal handrail shall be 80cm or more and 90cm or under from the floor, the length shall be about 55cm from the wall, and the distance between the left and right handrails shall be about 60cm". This study determined that compliance with these standards is appropriate. Additionally, aside from the left and right handrails on both sides of the toilet stool, which enable horizontal transfer forwards and backwards; a horizontal handrail was installed in the lower part of the washstand front, to hold onto and pull the body forward when entering the toilet from the front, or while using the toilet. The diameter of the selected handrail was 32Ø (front handrail, 25Ø), and non-slip pad may be attached to prevent slipping.

4.2.4 Design suggestions for the door

In line with this study's direction, the restroom door entered and exited by wheelchair users should be convenient and minimize space. The conventional sliding or hinged door is not easy to use sitting in a wheelchair, and too much additional space is needed that makes it hard to use space efficiently. A folding door, which is often the door to the handicapped toilet within a regular restroom, offers convenience to wheelchair users when using the restroom and bi-folds inwardly or outwardly to provide wide space inside. Convenience and durability are excellent advantages, but once inside the toilet, there is that trouble of having to turn the wheelchair 180° to close the door, and then turn the wheelchair again to move towards the toilet stool. Thus, enough space to turn the wheelchair is required. An inward folding door has a disadvantage by operational principle, in that the door becomes caught in the wheelchair when trying to close the door once inside the toilet. Extra space becomes necessary. There is no such problem with an outward folding door, but it could be an obstacle for other people as the door projects outward when it is open.

An accordion door or a curtain door would not become an obstacle for the wheelchair user or outside user, and can be easily opened and closed. However, this door type does not help to minimize restroom space. After entry in the wheelchair, there is still the inconvenience of having to turn 180° to close the door, then turn around again and move to the toilet stool. Moreover, such doors serve as cover walls only and protection of privacy remains an issue, not to mention weak durability; thus far from satisfying the concept of a door. As such, taking into consideration the aforementioned problems, this study proposes an appropriate design for the front-entry sitting toilet system.

In order to apply the accordion door, the floor should be without thresholds for free wheelchair movement. A guide rail should be installed lengthwise along the entrance to guide the accordion door, with electric sliding rollers along the rail. The accordion door is each linked with pivot hinges and designed to have hinges put on together. The door size, considering the handrail space on both sides of the toilet stool, was drawn as 110cm, wider than the effective width of 80cm needed for wheelchair passage.

In order to use the proposed accordion door, the door should always remain open when the restroom is not in use. Once inside, push of a button closes the door and to come out, another push of the button opens the door. The wheelchair user, once inside the restroom, should be able to operate an electric button for opening and closing the accordion door while sitting in the wheelchair and without having to turn the wheelchair. As such, the electric button method for sliding doors, which is generally and widely used on doors, was adopted. The vertical installation height of the operation button was set as the sitting cervical height of 98.45~103.45cm and the horizontal installation point was where the hand rests when the arm is put on the armrest sitting in the wheelchair.

All facilities other than the aforementioned, including entrance facilities such as the ramp to the restroom, guidance facilities (Braille or punctiform blocks) and interior slip prevention facilities will comply with the installation standards of the Convenience Promotion Act.

5. Discussion & Conclusion

The front-entry sitting toilet system developed in this study is of a design that enables the elderly and the handicapped in wheelchairs to use the toilet without having to turn the body from the wheelchair to sit on the toilet stool; but simply stay in the same position coming in the wheelchair, grab the handrails on both sides of the toilet stool and with the legs slightly apart, slide forward onto the toilet stool. One can use the toilet and thereafter even use the washstand staying on the stool.

In this way, the wheelchair user no longer has the trouble and inconvenience of having to turn 180° to move awkwardly from the wheelchair to sit on the toilet stool. At the same time, the elderly with little strength in the arms have better access and moving conditions to the toilet stool, thereby preventing uncomfortable posture and reducing excessive use of energy which could have caused secondary accidents such as falling. The long-term perspective is good not only for the individual person with disabilities, but also at the national level reducing medical costs and creating economic benefits. The expected effects are huge as well. Promoting the use of the front-entry sitting toilet stool over the urinal will resolve the hygienic problem of exposed urine, help solve the burdening task of cleaning oneself after bowel movement and enhance the self-esteem of a physically-challenged or elderly person who was able to use the restroom in a single trip, by oneself without the help of another person. The system has yet to be implemented in our daily environment but will minimize inconvenience with using the handicapped restroom. This study is very noteworthy in terms of not only realizing human respect and dignity, the ultimate goal of human engineering, but also convenience, efficiency and safety. Therefore, in introducing the front-entry sitting toilet system, efforts at the national policy level is also called for with a macroscopic objective to promote national health and safety.

Various suggestions have been proposed up to now by civic groups or individuals for improving and further developing disabled accessible restroom. Unfortunately, we have yet to find a viable idea that can be applied to daily life. This study has taken a new direction in this field with an integrative design that also considers the interaction between the front-entry sitting toilet stool, which has been developed for wheelchair users, and constituent facilities (door, washstand, operation device, accessories, etc.). In addition, the study's reference to Korean body size dimensions (Size Korea, 2016) in the design process of the front-entry sitting toilet system should help with practical application of the study results. Its reach is anticipated to be far and wide within and across nations.

Furthermore, significant space saving is anticipated with the widespread use of the front-entry sitting toilet system, aside from the already mentioned convenience and safety effects. Compared to a regular restroom, wider space is required for the wheelchair to move to the toilet stool in the current handicapped restroom. The front-entry sitting restroom, however, does not need this turning space and thereby greatly reduce restroom space and make economic sense. That is, a newly built restroom or change to an existing one will suffice with a smaller area of 2.42m^2 instead of the needed area of 3.24m^2 in a handicapped restroom.

Furthermore, there is no need to install separately a disabled accessible restroom because both the handicapped and the non-handicapped will be able to use the front-entry sitting type, which maximizes restroom usage and creates huge economic benefits in the longer term.

The direction and details of related research for the future are suggested as follows. Foremost, the front-entry sitting toilet system needs to be applied to actual situations and have wheelchair users try it out in usability tests. These should include comprise objective evaluations, such as biomechanics and physiological assessment, as well as subjective preference surveys. Based on the results, improvements and continuous revision/complementary work should take place. Furthermore, efforts should follow to set up laws and policies, time period to introduce the front-entry sitting toilet system, and suggest ways for development considering effectiveness.

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