Original Article

Usefulness of simulation method to improve efficiency of chair-to-wheelchair transfer of patients performed by caregivers

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Abstract. [Purpose] We aimed to clarify whether demonstration and simulated experience help the ability of care-receivers to get transferred, such as from the bed to the commode. [Participants and Methods] Participants included 28 nurses and 17 caregivers (34 females and 11 males). We developed a total floor reaction force measurement device to quantify the total loading level of care-receivers and caregivers and force shoes to quantify the loading level of the caregivers. Using these instruments, we constructed a system to measure the load on the lower limbs of the care-receivers during partial assistance. We divided the participants into the control, demonstration, and simulated experience method groups. We examined the differences in the load on the lower limbs before and after the intervention. [Results] The loads on the lower limbs of care-receivers when their buttocks were lifted from the chair were 11.7 ± 69.6, 61.8 ± 79.4, and 101.0 ± 104.0 N in the control, demonstration, and simulated experience groups. [Conclusion] These data suggest that the simulated experience method could help make use of the ability of the care-receiver to get transferred. Even care workers for the sanatorium-type sickbeds could learn to utilize the physical ability of the care-receivers using simulated experience. Key words: Chair-to-wheelchair transfer, Partial assistance, Simulated experience method

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INTRODUCTION

The proportion of aging population continues to rise in Japan, and the ratio of the active generation to the elderly is rapidly decreasing¹. In addition, as the number of elderly people is increasing, the number of individuals certified to be requiring support or care to continue their basic activities of daily living is steadily increasing, with 6.29 million such people identified as of January 2017². There is concern that a shortage of caregivers for nursing care will become a serious problem in the near future. Therefore, efforts to alleviate the burden on caregivers along with securing care workers are important. In hospitals and nursing homes, excretion care is a common task, but caregivers feel burdened when faced with this task³. For the patient to excrete in the toilet, it is necessary to transfer him/her to the toilet seat. This transfer has been reported to strain the low back of the caregivers⁴. In actual settings, caregivers’ movements to assist transfer tend to precede those of care-receivers⁵, suggesting that the former completely or partially deprive the latter of the opportunities for motor activities. These reports indicate that caregivers may not be able to successfully utilize the ability of care-receivers to get transferred. In other words, care-receivers can help facilitate transfer movements, but this is not properly advantaged. To address this, nurses and caregivers sometimes receive demonstrations from physiotherapists and occupational therapists to improve transfer assistance to
the care-receiver. Demonstrations have been reported to be useful for improving nursing skills such as using tweezers for aseptic operations\(^6\); however, it is not certain whether these demonstrations can benefit transfer assistance. Furthermore, demonstrations of transfer assistance performed by physiotherapists and occupational therapists allow for a visual teaching aid for nurses and caregivers but do not replace the actual experience; thus, their effect may be limited. Therefore, we propose a method of “experiencing” transfer assistance for rehabilitation professionals that involves simulation of care-receivers (regarding their impairments) during the transfer task (simulated experience method). The simulated experience method is advantageous as it does not impose a burden or risk on actual care-receivers. The purpose of this study was to determine whether demonstration or a simulated experience method helps take advantage of the intrinsic ability of care-receivers to get transferred by using the developed measurement system. In this study, the load on the lower limbs of the care-receiver at the time of his buttocks leaving a seat was used as the index of transfer ability\(^7\).

### PARTICIPANTS AND METHODS

In this research, the measurement system was first developed, and then the accuracy of the measurement system was confirmed secondly, and finally the method for making use of the ability of the care-receiver was verified. The details of these were described below. This study was conducted in accordance with the ethical principles of the Declaration of Helsinki and was approved by the Ethics Committee of the Kyushu University of Nursing and Social Welfare (approval number: 28-005). The study objective and content had previously been explained to all participants prior to obtaining their written informed consent to participate in this study. The experimental system was shown in Fig. 1. A total floor reaction force measurement device was developed to quantify total loading level of both the care-receivers and caregivers, and force shoes were developed to quantify the loading level of the caregivers. Force shoes were provided on the left and right feet and could measure the amount of load on the corresponding side. All the devices were developed using a stainless steel panel with 4 load cells attached (LMB-A-2KN-P; Kyowa Electronic Instruments Co., Ltd., Tokyo, Japan). We adopted a mechanism to determine the load on the lower limbs of care-receivers during transfer assistance by subtracting the value of the force shoes from the value of the total floor reaction force measurement device. Because care-receivers often have feet deformations, force shoes are not used directly for them. Furthermore, to clarify the moment when the load shifts from the hip to the plantar, a hip-floor reaction force measurement device was developed using a stainless steel panel with 4 load cells (LMB-A-2KN-P; Kyowa Electronic Instruments Co., Ltd.). Values of the vertical component of the load cells were entered into a personal computer through a Universal Recorder (Kyowa Electronic Instruments Co., Ltd.) and added for each device using LabVIEW (National Instruments Japan Corporation, Tokyo, Japan). Then, by subtracting the value of vertical component from the total floor reaction force measuring device to the force shoes, a system was constructed to determine the load on the lower limbs of the care recipient. To check the accuracy of the total floor reaction force measurement device and force shoes, values of vertical components two devices were compared to a floor reaction force meter (AMTI Japan Ltd., Kanagawa, Japan). The total floor reaction force measurement device was placed on the floor reaction force meter, and the force shoes were placed on the former device in parallel, with a distance of 30 cm between their centers. After starting data collection, the floor reaction force meter, total floor reaction force measurement device, and force shoes were synchronized with a healthy adult male (height: 176.0 cm, weight: 66.0 kg) standing on the force shoes. The sampling frequencies of all devices were set at 100 Hz. The former device in parallel, with a distance of 30 cm between their centers. After starting data collection, the floor reaction force meter, total floor reaction force measurement device, and force shoes were synchronized with a healthy adult male (height: 176.0 cm, weight: 66.0 kg) standing on the force shoes. The sampling frequencies of all devices were set at 100 Hz. The individual was instructed to stand still and then simulate a motion for transfer assistance and stand still again after completing the motion. The points of movement initiation and completion were defined as follows: initiation: 0.1 s before the moment when the floor reaction force meter indicates 657.0 N or greater or less than 647.2 N and completion: 0.1 s after the moment when it indicates 647.2 N or greater and less than 657.0 N. Values obtained within a 2.28-s period between the two points were compared.

For statistical analysis, IBM SPSS Statistics 22 (IBM Japan Ltd., Tokyo, Japan) was used. The significance level was set at 5%. Spearman’s rank correlation coefficient was used to determine the correlation of the floor reaction force meter with force shoes and total floor reaction force measurement device. In total, 45 nurses and care staff working with sanatorium-type sickbeds were the participants in this study and gave informed consent to participate in this study; of them, 28 participants were nurses and 17 were caregivers (34 females and 11 males). Furthermore, the average occupational experience of the participants was 14 ± 8 years, and they were divided into three groups: control group, group that observed demonstration by a physiotherapist (demonstration group), and simulated experience method group. For division, stratified randomization was conducted based on occupational experience so that each group contained 15 participants. The average occupational experience was 13.8 ± 9.5 years in the control group, 14.9 ± 9.7 years in the demonstration group, and 14.7 ± 6.9 years in the simulated experience method group. About the setting of care-receiver, one healthy male adult (height 177.0 cm, weight 68.0 kg) gave consent to this study to be a mock care-receiver and was fitted hip brace with dial lock mechanism (Howashi Co., Ltd., Kumamoto, Japan). The movable range of hip joint flexion on both sides was limited to 90° using the dial lock, such that the man could not stand up from the chair himself. The care-receiver was sitting in a chair of 410 mm height, so that the knee joint flexion angle was set at 90°, the ankle joint flexion angle was at 0°, and the distance between the centers of both heels was 30 cm. The wheelchair with removed foot support was set on the left side of the chair and perpendicular to the sagittal plane of the care-receiver. Participants were instructed to take as much advantage as possible of the ability of care-receiver to get transferred and then performed first transfer assistance in liberty. After the first trial of transfer assistance, participants in the demonstration group received explanations regarding points of support while observing the demonstration of transfer.
assistance by physiotherapists. Participants in the simulated experience group received an explanation regarding the points of support and then received advice regarding corrections in the direction and timing while performing transfer assistance for physiotherapists who imitated the care-receiver. Three points of support were summarized based on the functional evaluations of care-receiver by a physiotherapist who had a clinical experience of 8 years: (1) In tilting the care-receivers’ upper body forward at the standup motion from the chair, the participant (caregiver) urges the care-receiver to flex his spinal column instead of flexing the hip joint. (2) Before the buttocks of the care-receiver leave the chair, the participant pulls the upper body of the care-receiver forward instead of pulling it upward. (3) Before starting assistance, the participant takes a position to place his/her left foot in front and right foot in the back and then causes the buttocks of the care-receiver to move away from the chair while simultaneously moving his/her center of gravity to the hind leg. In addition, the tip of the right foot of the participant had to be positioned further behind half of the left foot on the sagittal plane, but the extent of that positioning was arbitrary (Fig. 2). After 3 min of intervention by the physiotherapist, the demonstration and simulated experience method groups again assisted transfer to the care-receiver. Participants in the control group again assisted transfer to the care-receiver 3 min after the first transfer assistance trial. Prior to the implementation of the second transfer assistance, the participant was instructed to make as much use as possible of the ability of the care-receiver. The time point when the value of the hip-floor reaction force measurement device was less than 9.8 N after the start of transfer assistance was taken as the time of initiation (when the buttocks leave the chair); the difference in the level of loading on the care-receivers’ lower limbs at the second trial time and the first trial time of buttocks left the chair were then calculated. For statistical analysis, IBM SPSS Statistics 22 (IBM Japan, Ltd., Tokyo, Japan) was used, and the significance level was set at 5%. Kruskal-Wallis test was used to compare the differences between the groups, and the Dann-Bonferroni’s method was used as a posteriori test.

RESULTS

The mean difference and correlation coefficient between the floor reaction force meter and force shoes values were 0.7 ± 0.6 kg and $r^2=0.96$ (p<0.05), respectively. The mean difference and correlation coefficient between the floor reaction force meter and total floor reaction force measurement device were 1.5 ± 1.1 kg and $r^2=0.90$ (p<0.05), respectively. Regarding the load on the lower limb of the care-receiver when his buttocks left the chair, the difference between the second measurement value and the first was 11.7 ± 69.6 N for the control group, 61.8 ± 79.4 N for the demonstration group, and 101.0 ± 104.0 N for the simulated experience method group. Compared with the control group, the difference in the load on the lower limbs of the care participant significantly increased in the simulated experience method group. During the first assistance trial, 12 control participants, 13 demonstration group participants, and 12 simulated experience group participants placed the tip of their right foot behind the left foot by more than half the left foot in the sagittal plane (Table 1).

Table 1. Difference in the load on the lower limbs of care-receiver between the second transfer and the first transfer

| Group                        | Difference in the load on the lower limbs of care-receiver (N) |
|------------------------------|---------------------------------------------------------------|
| Control group                | −7.8 (−28.4 to 57.9)                                          |
| Demonstration group          | 68.6 (43.4 to 81.4)                                           |
| Simulated experience method group | 121.6 (77.5 to 146.6)*                                       |

Values are displayed as median (inter-quartile range).
*Significant difference to control group (p<0.05).
DISCUSSION

In the analysis of standing up from a sitting position, a three-dimensional motion analysis device equipped with a camera, an analysis system combining surface electromyography and force plate, and a pressure distribution measurement system or a floor reaction force meter have been used. In this study, we developed a system to measure the load on the lower limbs of the care-receivers requiring partial assistance during transfer, and then determined the most effective method to leverage the strength or the intrinsic ability of the care-receivers. The measurement system was judged to be valid based on the average difference and correlation of the difference between the floor reaction force meter and the total floor reaction force measuring device. The difference between the load amount on the lower limbs during the second and first trials was significantly larger in the simulated experience group than in the control group. In other words, with the simulated experience method, there was increase in the load on the lower limbs during supporting assistance in care-receivers whose hip joint flexion range was restricted to 90°. During standing up from the chair, it is necessary to move the center of gravity from the base of support of the buttocks to the feet and, thus, raise the buttocks to the standing posture. In addition, to move the center of gravity of the body upwards, the load on the legs must be increased at the time of the buttocks leaving the chair. The assistive method utilizes the residual function of the care-receiver, as presented by the physiotherapist; thus, it leads to an increased load on the lower limbs of the care-receiver in both the demonstration and the simulated experience method. However, there was no significant difference between the control and demonstration groups, whereas there was a difference between the control and simulated experience method groups. In the simulated experience method group, participants can experience the direction and timing of movement of the simulated care-receiver and better translate the movement of their own center of gravity during transfer assistance. The simulation differs from the demonstration group because the participants receive advice and feedback on corrections from a physiotherapist in actual experience. These differences may have contributed to the increased effectiveness of the simulated experience method. The limitation of this study is that we do not know whether the simulated experience method is effective for care-receivers with certain dysfunctions. Future studies should examine this issue. In addition, environmental factors such as the thickness of the cushion and chair height have been reported to affect the standing up motion; thus, it is necessary to verify whether the simulated experience method works effectively in various environments with modulated chair heights, etc. While these limitations exist, this research suggested that the simulated experience method could help make use of the ability of the care-receiver to get transferred. And then, it was indicated that even care workers belonging to the sanatorium-type sickbeds may be able to learn to draw out the physical ability of the care-receiver by simulated experience method.

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Conflict of interest

The authors declare no competing interest.

REFERENCES

1) Cabinet Office: Heisei 30th Edition Aging Society White Paper. https://www8.cao.go.jp/kourei/whitepaper/w-2018/zenbun/30pdf_index.html (Accessed Mar. 17, 2019)
2) The Ministry of Health, Labour and Welfare: Care insurance business situation report (temporary). https://www.mhlw.go.jp/topics/kaigo/osirase/jigyo/m17/1709.html (Accessed Mar. 17, 2019)
3) Muto T: A role of moderation of care burden on a toilet activity in outreach rehabilitation. J Jpn Phys Ther Assoc, 2010, 37: 104–105 (in Japanese).
4) Kjellberg K, Lagerström M, Hagberg M: Work technique of nurses in patient transfer tasks and associations with personal factors. Scand J Work Environ Health, 2003, 29: 468–477. [Medline] [CrossRef]
5) Kobayashi K, Tsujiishi M, Okazaki D, et al.: Survey of assisting methods for ADL by care workers work in care health center for the elderly: investigation by learning theory about assisting transfer from bed to wheel chair. Rigakuryoho Kagaku, 2010, 25: 825–880 (in Japanese). [CrossRef]
6) Matsunaga Y, Miyakoshi Y, Usumi K: A study on the effectiveness to two kinds of method of demonstrating a sterilization procedure. J Jpn Acad Nurs Ed, 2008, 17: 25–35.
7) Nakano S, Wada C, Kato H: Relationships between the foot placement of the care assistant and the force required to help a person who needs transfer assistance to stand. Rigakuryoho Kagaku, 2015, 30: 725–728 (in Japanese). [CrossRef]
8) Jeng SF, Schenkman M, Riley PO, et al.: Reliability of a clinical kinematic assessment of the sit-to-stand movement. Phys Ther, 1990, 70: 511–520. [Medline] [CrossRef]
9) Millington PJ, Myklebust BM, Shambes GM: Biomechanical analysis of the sit-to-stand motion in elderly persons. Arch Phys Med Rehabil, 1992, 73: 609–617. [Medline]
10) Sato S, Mizuma M, Kawate N, et al.: Evaluation of sit-to-stand motion using a pressure distribution measurement system — effect of differences in seat hardness on sit-to-stand motion. Disabil Rehabil Assist Technol, 2011, 6: 290–298. [Medline] [CrossRef]
11) Nozawa R, Yamamoto S: The relationship of lower limb and trunk movements in sit-to-stand performed by the young and elderly. Rigakuryoho Kagaku, 2012,
12) Yoneda T, Inoue S, Kawamura H, et al.: Analysis of sit-to-stand movement by measuring floor reaction force. J Exerc Physiol, 1988, 3: 101–108 (in Japanese). [CrossRef]

13) Anan M, Okumura K, Kito N, et al.: Effects of variation in cushion thickness on the sit-to-stand motion of elderly people. J Phys Ther Sci, 2008, 20: 51–57. [CrossRef]

14) Rodosky MW, Andriacchi TP, Andersson GB: The influence of chair height on lower limb mechanics during rising. J Orthop Res, 1989, 7: 266–271. [Medline] [CrossRef]