SYMPOSIUM PRESENTATION 1: HOUSING AND DAILY LIVING

Care robots and service model development

W.-K. Song (Convener)

Participants*:* W.-K. Song, J. S. Hong, Y. M. Shin, C. Kim, E. C. Lee, and K. Kim (Korea). **ISSUE** Korea's population is aging rapidly. Care robots are of great help to older adults, people with severe disabilities, and caregivers. Robotic technology is used to assist caregivers with transfer, posture change, toileting, and eating among various daily life activities. Care robots require translational research between basic science and clinical research as well as the development of service models. **CONTENT** Our symposium is designed to bring together speakers developing care robots and service models in Korea to highlight 1) robotic technology for transfer, posture change, toileting, and eating, and 2) service models that use robotic technology. **STRUCTURE** W.-K. Song introduced the Korean Ministry of Health and Welfare's projects on care robots. J.S. Hong presented the results of the care burden analysis with and without robots. Y.M. Shin demonstrated a physical burden analysis of transfer devices. C. Kim presented a novel robotic transfer device. E.C. Lee focused on the application of artificial intelligence technology in robotic urine suction devices. Finally, K. Kim presented a meal-assistive robotic device that provides arm support while the user eats food. **CONCLUSION** The application of robotic technology in the care domain has the potential to improve quality of life and reduce the burden of care for older adults, people with severe disabilities, and caregivers. However, technological improvements according to the needs of consumers and demonstrations in various situations are required.

Keywords: care robot, service model, people with disability, older adults, mobility, posture control, toileting, eating
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Translational research and service model development based on smart care space for people with severely disability

W.-K. Song, K. J. Lee

Purpose Various usability evaluations with consumers or clients are required to develop care robots that support transfer, posture change, toileting, and eating (Lim et al., 2022). Therefore, it is necessary to develop products and services simultaneously for rapid market entry. This study aims to enhance the understanding of the overall task by introducing a technology development and service model for care robots, with a focus on people with disabilities. It also explains why a smart care space is required for technology development from an environmental point of view. **Method** This study consists of five steps: 1) care robot network forum and working groups operation; 2) smart care spaces establishment and utilization; 3) field demonstration; 4) user guidelines preparation; and 5) service model development, including public provision (Choi et al., 2022). Care robots are significantly affected by the environment. Three smart spaces with different sizes and purposes were designed. It is important to have an environment in which care robots can be used. Various services, including public pay, have been investigated and analyzed. **Results and Discussion** The care robot translation research, which started in 2019 (Song et al., 2020) held a network forum once or twice a year in which both experts and stakeholders participated, and held dozens of working groups by field. We built three smart care spaces at the National Rehabilitation Center in Korea. The usability evaluation focused on the harmonious performance of two or more robots or devices. Information on smart care spaces was provided to local governments in need so that it could be helpful when installing similar spaces. In the future, we plan to distribute care robots on a trial basis and conduct a follow-up research.

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Comparative study of physical care burden on caregivers for elderly excretion care between human manual care and robot-aided care based on hierarchical excretion care task model

J. B. Ko, H. J. Keom, C. K. Lee, B. H. Won, J. S. Hong

Purpose Conventional excretion care using diapers is one of the hardest task that causes severe burden on caregivers (Kumagai et al., 2005). In nursing homes, excretion care is performed about six times a day and this repeated excretion care task increases the risk of musculoskeletal disorders in caregivers. With the development of robotic technology, care robots that can help caregivers in excretion care have been developed (Yamazaki et al., 2012). However, study on the effectiveness of care robots, which quantitatively compares and evaluates the physical care burden between using diapers (MC, human manual excretion care) and care robots (RC, robot-aided excretion care) is very limited. To conduct a systematic comparative study on MC and RC, we developed a hierarchical care task model for each type. An experimental study was performed to compare physical care burden for each care task. **Method** The hierarchical excretion care task model (HECTM) was developed by classifying tasks into routine and non-routine actions in MC (Figure 1 a) and RC (Figure 1 b) and structuring them according to the excretion care task scenarios. An experiment to evaluate the physical burden of MC and RC was conducted with 10 caregivers. CareBidet (CURACO, South Korea) was used as the excretion care robot (Figure 2). The evaluation task was based on HECTM and there were 23 tasks in MC and 42 tasks in RC. The physical care burden was confirmed through muscle activity based on the electromyographic (EMG) signal measured by eight surface EMG sensors. Muscle activity was normalized to the maximum voluntary contraction for each muscle (%MVC) and the average was calculated. To study the effect of time on muscle activity, task time in %MVC (%MVC_{time}) was measured. In addition, the RPE (Rating of perceived Exertion) scale was used to confirm the subjective care burden. Finally, to compare the physical care burden of MC and RC carried out during the day in nursing homes, the number of excretion care tasks performed by caregivers at the nursing home was calculated, and three excretion care scenarios were established and compared. **Results and Discussion** As a result of comparing the physical care burden by excretion care work scenario reflecting the number of excretion care performed, MC+RC had the highest physical care burden among the three excretion care work scenarios, followed by MC_{all} and RC_{all}. Although RC could reduce the physical burden of the caregivers in excretion care during the day, the steps involved in using robot for excretion care and the management and storage of excretion care robots required heavy physical burden.

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(a) (b)

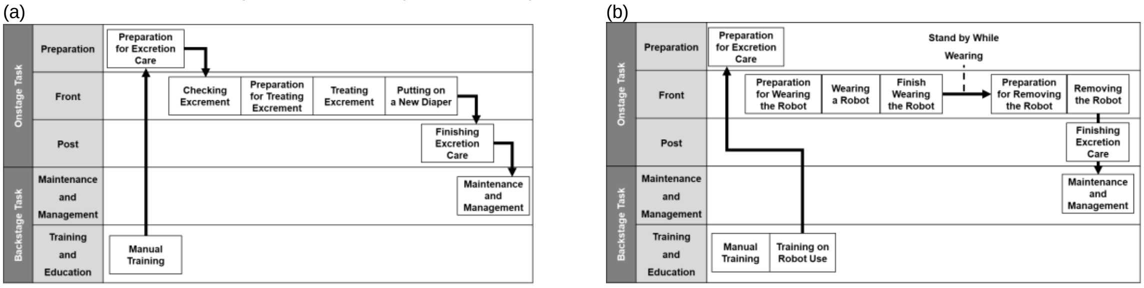

Figure 1. Hierarchical excretion care task model: (a) MC, (b) RC

Figure 2. CareBidet (CURACO, South Korea)

Comparison of physical burden of caregivers when using transfer devices

Y. M. Shin, Y. K. Kim, K. J. Lee, W.-K. Song

Purpose A variety of transfer devices are developed to provide convenience to caregivers (Lee et al., 2020). Although there are many types of transfer devices, caregivers experience a physical burden when handling them. This study aims to analyze the physical burden through EMG measurement and Rapid Entire Body Assessment (REBA) when using three types of transfer devices, including a transfer device with robot technology. **Method** Five caregivers (four social workers and one occupational therapist) performed a bed-to-wheelchair and wheelchair-to-bed transfer using three transfer devices: a dual-arm assistive robotic transfer device, a mobile hoist, and a ceiling hoist. During the transfer operation, Caregivers' EMG signals were collected. Six EMG sensors were attached to the bilateral upper trapezius muscles (RTRP, LTRP) and upper/lower erector spinae muscles (RUES, LUES, RLES, LLES), respectively. For data analysis, video and EMG signals were synchronized using an inertial measurement device. The muscle activity from EMG signals was analyzed using reference voluntary contraction. By using REBA, caregivers' posture was evaluated for each subtask. **Results and Discussion** The physical burden was different for each subtask through EMG and REBA analysis while using the transfer devices (Table 1). The subtasks of setting and removing the sling from the bed had the highest biomechanical loads in all transfer devices. Compared to other devices, the dual-arm assistive robotic transfer device had higher REBA scores in the subtask of fastening (9.6±1.5) and unfastening (9.4±1.5) the sling and the transfer device in the wheelchair. Improvements and training are needed on how to set up and remove the sling and how to attach the sling to a transfer device. This study can be utilized for the development of a useful robotic transfer device. In future research, it is necessary to improve usability when using multiple devices simultaneously under various conditions and environments.

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*Table*1. Comparison difference of EMG and REBA score of subtasks.

Device	Items	Muscles	Sling setting in bed	Sling removing in bed	Unfastening the sling and the transfer device in wheelchair	Fastening the sling and the transfer device in wheelchair
Dual-arm assistive robotic device	EMG (%RVC)	RTRP	71.3±14.2	98.7±24.0	54.3±18.6	72.3±26.3
		RUES	50.6±23.8	56.6±18.5	45.7±24.1	44.6±21.4
		RLES	35.5±6.5	33.7±12.6	26.0±10.7	27.4±8.9
		LTRP	54.5±32.8	67.3±40.4	47.2±24.9	55.7±22.7
		LUES	59.2±17.0	77.2±14.1	52.0±14.4	60.4±19.1
		LLES	39.2±16.0	37.3±17.9	31.6±11.9	36.9±18.4
	REBA (Max=15)	-	9.4±1.5	8.6±0.9	9.4±1.5	9.6±1.5
Mobile hoist	EMG (%RVC)	RTRP	96.4±22.0	102.9±26.1	59.6±25.4	66.8±28.5
		RUES	54.4±19.9	54.7±22.3	47.5±23.8	34.5±14.0
		RLES	39.7±6.5	42.2±3.8	22.6±9.4	19.9±8.5
		LTRP	57.9±19.2	54.3±30.6	39.9±30.6	43.2±29.5
		LUES	65.9±24.2	59.5±19.9	44.8±13.4	38.5±11.6
		LLES	40.6±12.1	34.8±13.3	27.3±16.0	21.8±11.9
	REBA (Max=15)	-	9.8±1.1	10.2±3.0	5.0±1.4	3.0±1.6
Ceiling hoist	EMG (%RVC)	RTRP	102.3±34.7	112.3±46.8	70.7±32.2	73.1±35.6
		RUES	59.7±18.1	58.6±17.6	38.0±15.7	36.2±12.9
		RLES	36.3±9.1	36.9±4.7	17.9±7.3	18.0±4.0
		LTRP	67.9±42.2	66.9±45.7	50.6±43.3	51.7±32.6
		LUES	66.9±5.7	65.2±10.3	54.3±17.2	51.4±12.6
		LLES	37.8±15.2	32.4±7.1	26.1±11.3	22.5±9.2
	REBA (Max=15)	-	9.8±1.5	10.2±3.0	4.0±1.4	3.8±0.8

Keywords: care robot, physical burden, transfer devices, EMG, Rapid Entire Body Assessment
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Development of patient-transfer robot considering user convenience and patient safety

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Purpose Ageing has increased considerably in recent years. Older adults and those with disabilities who are unable to move on their own require assistance in moving from bed to other places. The purpose of this study is to develop a system that allows safe and comfortable transfer of patients in facilities, such as, general hospitals and nursing hospitals, with a minimum number of nursing staff. **Method** The essential function of a patient-transfer robot is to move a patient from one place to another. To accomplish this, we developed a mobile platform (Seo et al., 2014; Kim & Seo, 2017) with two steering wheels that enabled the robot to move omnidirectionally. A hoist module with two motors was developed to lift the patient, as shown in Figure 1. Using the two-motor hoist mechanism, we aimed to change the patient's posture. In addition, to minimize the sway of the patient, the hoist employed a smart wire system that reduced the sway through a mechanism that changed the flexible wire to rigid. To transfer patients with different disorders safely, different types of slings suitable for each condition have been developed. In addition, an active safety system for a transfer robot was developed with a collision avoidance system and roll-over prevention system. The collision avoidance system used ultrasonic sensors to detect obstacles in the direction of travel and had an automatic braking function to prevent collisions. The rollover prevention system measured the inclination of the road surface on which the robots transferred the patients. If the inclination was higher than a given threshold, it prevented rollover by issuing a warning. Normal function implementation and usability were confirmed the performance evaluation of the prototype. **Results and discussion** To demonstrate the performance of the developed robotic system, several tests were conducted at the Orthopedics & Rehabilitation Engineering Center, an accredited testing institution in Korea. The test items were as follows: maximum lift weight of the patient (< 130 kg); lift speed (< 60 mm/s); weight measurement accuracy (95%); sway control performance while driving (±2°); collision and rollover warning (95% success ratio); and noise (< 65 dB). The test confirmed that all functions were operating normally and that the quantitative goal was achieved. This study presented the outcomes of the patient-transfer robot development. A mobile platform, hoisting module, and sling system for wrapping the patient were developed to meet the essential requirements of the patient-transfer robot. Although the current system focuses on the realization of functions as a prototype, future research for usability evaluation and design improvement for commercialization is planned.

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Keywords: patient-transfer robot, collision avoidance system, rollover prevention system, modular hoist

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Figure 1. Patient-transfer robot

Utilization of an artificial intelligence automatic urination handling device according to the aspect of the individuals with disorders

U. C. Lee

Purpose Urination patterns and frequencies of healthy individuals, individuals with disorders, and patients with dementia vary widely. At nursing facilities, most hospitalized patients experience urinary incontinence and lower urinary tract diseases. In addition, the case of nocturia is a controversial topic (Song, 2004). In circumstances when urine is not normal, potentially due to excessive flow, caregivers experiences a significant physical and mental load. The necessity to eliminate the stench and clean the stained bedsheets and garments, adds to the work load. Furthermore, in individuals with urine incontinence, if the diaper is not changed at the appropriate time, problems such as extramammary Paget disease, dermatitis, and bedsores might emerge (Cho, 2009). **Methods** By analyzing the urination characteristics of individuals and utilizing an automatic urine handling device based on the machine running HYGERA smart diaper, which enables effective excretion care, immediate and effective excretion care can be provided. As it is not possible to identify the time and amount of urination in real time based on the patient's condition, an automatic device can be used to detect the urination condition in real time. Small amounts of urination of less than 5 cc can also be detected, allowing real-time and 24-hour care for patients with urination disorders such as urinary incontinence. Therefore, skin rashes caused by incontinence can be eliminated. Furthermore, it provides daily urination records, and urination records for 24 h, 3 days, and 7 days. By applying machine learning technology that analyzes urination patterns, the urination processing device can automatically aspirate urine according to the urination state. **Conclusions and suggestions** As frequent, small-amount urination is quite common, the use of a customized-type urine suction device can effectively reduce the work load of caregivers. In addition, when operating at night, the reduced operational noise of such devices does not interfere with patient sleep. Moreover, these devices can be used on supine patients. This treatment is equally effective in patients confined to wheelchairs. In terms of patient benefits, such devices will prevent the occurrence of skin rashes and prevent secondary infections. As a result of employing smart diapers in nursing homes, where 6 out of 30 people experienced skin rashes, the skin rashes disappeared,.

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Keywords: smart diaper, urination, automatic suction of urine, artificial intelligence.

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Design, control, and evaluation of a meal-assistive robot based on gravity compensation for elderly people with muscle weakness

K. Kim, J. H. Kim, J. B. Kim

Purpose Meal assistance is a basic and important service in the care of patients or elderly people with muscle weakness. Many meal assistive devices have been developed to address the caregivers shortage (MOMO, 2020). Automatic devices are ideal for disabled people with little residual muscular strength. Arm-supported devices have been widely commercialized to augment muscle strength mainly with spring mechanisms. This study proposes a meal assistive robot with a motor for vertical movement based on gravity compensation. This method can be used by people who have difficulty with passive arm-supported devices to avoid the use of fully-automated devices. The arm-supported device can assist people with muscular dystrophy but has distinct limitations. The proposed method can assist vertical movement with an electrical motor and free horizontal movement according to the user's intention. In this method, a spring is used with the motor to reduce motor torque. The usability of the meal assistive robot is evaluated with several factors such as effectiveness and satisfaction. **Method** Figure 1 shows the schematic structure of a meal-assistive robot, IndiMeal2. The robot is fixed firmly on the table with a clamp. A user's forearm is put on the armrest of the robot and a spoon is fixed at the end of the robot with a magnet. The robotic motion is divided into horizontal and vertical movements. Three links without a motor implement horizontal movement and the vertical movement is implement using a twisted string actuator (TSA) with a spring in parallel (Gaponov et al., 2013). A controller is embedded into the robot and is controlled by a remote-control panel. A user or a caregiver can preset the mouth to food distance to ensure adequate meal behavior. The skipping function reduces the waiting time required to chew food in the mouth or scooping of food by a spoon. The repetitive up-down motion near food eases effective scooping of food. The meal assistive robot can be also controlled and monitored by a smartphone or a server PC. **Results and Discussion** This study investigates the mechanical design and control of a meal assistive robot to compensate gravity for vertical movement and ease horizontal movement with little external force (Kim et al., 2022). TSA with a spring mechanism is used for active vertical movement and gravity compensation. The controller embedded into the robot is used to preset the distance from the mouth to food. The controller can be controlled in multimodal manners, via a remote-control panel, a smartphone or a server PC. The effectiveness and satisfaction of people with muscular weakness evaluated using the usability test.

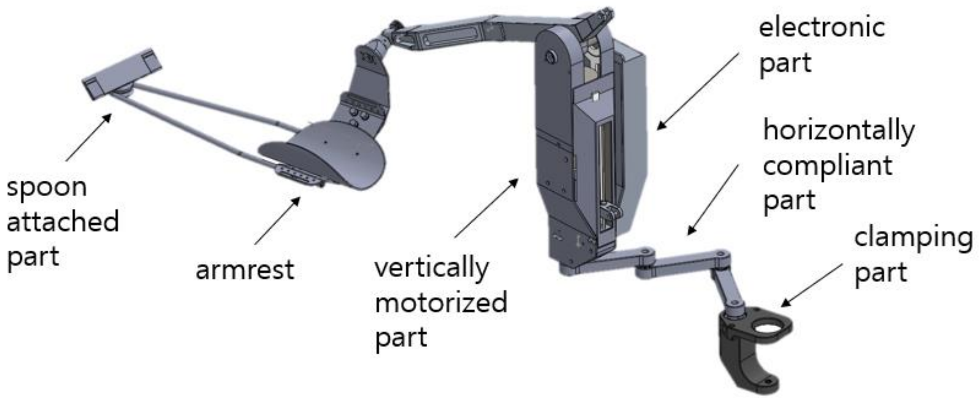

Figure. 1. Meal-assistive robot with a twisted string actuator

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