

# Understanding Humanitude Care for Sit-to-stand Motion by Wearable Sensors

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**Abstract**—Assisting patients with dementia is a significant social issue. Currently, to assist patients with dementia, a multi-modal care technique called Humanitude is gaining popularity. In Humanitude, the patients are assisted through various techniques to stand up independently by utilizing their motor functions as much as possible. Humanitude care techniques encourage caregivers to increase the area of contact with patients during the sit-to-stand motion. However, Humanitude care techniques are not accurately performed by novice caregivers. Therefore, in this study, a smock-type wearable sensor was developed to measure the proximity between caregivers and care recipients during sit-to-stand motion assistance. A measurement experiment was conducted to evaluate the proximity differences between Humanitude care and simulated novice care. In addition, the effects of different care techniques on the center of mass (CoM) trajectory and muscle activity of the care recipients were investigated. The results showed that the caregivers tend to bring their top and middle trunk closer in Humanitude care compared with novice simulated care. Furthermore, it was observed that the CoM trajectory and muscle activity under Humanitude care were similar to those observed when the care recipient stands up independently. These results validate the effectiveness of Humanitude care and provide useful information for teaching techniques in Humanitude.

**Index Terms**—Wearable tactile sensor, Humanitude care, Sit-to-stand

## I. INTRODUCTION

Recently, the number of elderly patients with dementia has increased. Dementia causes a significant decline in the motor and cognitive functions of the patient. In addition, dementia also leads to a multitude of behavioral and psychological symptoms. Although patient care for dementia patients is an urgent issue, there is a shortage of caregivers and nurses and it becomes a heavy burden on the caregivers [1].

Therefore, a method called “Humanitude” has been proposed for improving the symptoms of patients with dementia

and reducing the burden on caregivers [2], [3]. Humanitude refers to multi-modal comprehensive care techniques for patients with dementia. It primarily comprises four elements: maintaining eye contact with the patients from a close distance, talking to the patients slowly and calmly, touching the body of the patient gently, and assisting the patients in standing up. The first three elements require excellent communication skills to develop a good relationship between caregivers and care recipients and reduce aggressive behavior in patients [4]. The last element is about maintaining patient mobility by encouraging them to stand up and walk around.

To improve the motor and cognitive functions of patients with dementia, Humanitude technique seems effective. However, it is difficult for novice caregivers to learn these techniques. Previous studies developed training systems for teaching Humanitude techniques [5], [6]. It is known that maintaining eye contact with patients from a close distance is essential for executing Humanitude techniques. However, many novice caregivers cannot maintain eye contact effectively. For training caregivers and teaching them the care skill of maintaining eye contact with the patient, a first-person video analysis system was developed, and it enabled the evaluation of eye contact between the caregivers and care recipient [5]. Furthermore, a training system with augmented reality (AR) was developed to evaluate the care skill of seeing and touching and provide feedback by using a superimposed three-dimensional CG model of the patient’s face [6]. These systems are effective for training the caregivers in the care skills of seeing and touching. However, it is still remained unclear how the Humanitude caregivers perform assistance of standing-up motion.

It is crucial to assist patients with dementia in standing up; this promotes self-consciousness and a positive physiological effect [7], [8]. In addition, it is known that performing sit-to-stand (STS) exercises is essential for daily living [9]. From observations and interviews with Humanitude experts, it was concluded that caregivers should try to increase

physical contact with care recipients and guide their posture to promote voluntary use of muscles. Care recipients should be assisted in performing STS exercises, which help in maintaining physical functions. Previous studies have used motion capture systems to measure the body kinematics of caregivers and develop a feedback system [10], [11]. However, information on contact between the caregivers and care recipients has not been quantitatively evaluated because it is difficult to obtain the information using a motion capture system owing to occlusion. Therefore, the body contact care skill (proximity) of Humanitude should be quantitatively evaluated, and its positive effect on the recipients should be monitored. Furthermore, a training program for novice caregivers should be developed to teach effective care techniques for assisting STS exercises.

Therefore, the objectives of this study are to identify the care techniques for the caregivers and examine the effect of these techniques on the care recipients. Although Humanitude care techniques encourage caregivers to increase the area of contact, it is tacit knowledge and has not been investigated yet. Thus, in this study, it is hypothesized that proximity between the caregivers and care recipients may differ based on the different care techniques, and Humanitude care would induce a motion similar to the motion of people standing up. To identify the appropriate techniques that should be used by the caregiver, the proximity between the caregivers and care recipients was studied owing to the fact that Humanitude care encourages contact between them. In this study, the difference in care skills of expert care and novice caregivers was elucidated. Subsequently, the effect of different care skills on posture and muscle activity of care recipients during STS assistance was analyzed.

## II. METHODOLOGY

### A. Overview

In this study, a measurement experiment was performed to investigate the difference in care skills between expert Humanitude care and novice care. Furthermore, the effect of different care skills on the posture and muscle activity during STS assistance of care recipients was elucidated. Five expert nurses participated in the experiment, and they performed Humanitude care and simulated novice care. In addition, the conditions under which care recipients were able to stand up independently were recorded. An overview of the measurement system is shown in Fig. 1. During STS assistance, the proximity between the caregivers and care recipients was measured. Simultaneously, the change in muscle activity and body kinematics owing to different care skills was evaluated. Furthermore, the data obtained were compared with the conditions under which the care recipients stood up independently to investigate if the care recipients could perform STS exercise more voluntarily.

### B. Measurement System of Proximity

As mentioned in the previous section, the proximity between the caregivers and care recipients was measured. The caregivers and care recipients are in close proximity during STS assistance. Therefore, occlusion occurs easily, which makes the measurement using the existing optical

motion capture system and posture estimation using RGB-D sensors difficult. In our previous study [6], wearable tactile sensors were attached to a mannequin to evaluate how caregivers touched the mannequin. However, mannequins are not suitable for evaluating STS assistance motion because mannequins are immobile dolls. In addition, the wearable tactile sensors used in the system were heavier and stiffer than conventional clothing, which hindered the wearer from performing certain care skills. Therefore, to evaluate the motion during STS assistance, light and soft sensors, which are comfortable to wear, are required.

Figure 2 (a) shows an overview of the developed smock-type tactile sensor. In this study, to reduce the burden on the wearer and ensure that the smock is easy to wear, the smock was designed with a back opening. The developed sensor comprised a 33-channel cloth-type sensor on the upper body, including the mask cover (Fig. 2 (b)). The fabric sensor, which was made of conductive fabric, as capacitive sensor [12], This fabric sensor was incorporated into the smock as a contact sensor to detect human touch and the strength of contact. Furthermore, as a proximity sensor, it could also detect the conditions at close range. Each sensor was equipped with a small microcontroller board for measuring the capacitance. In addition, each sensor board was wired with elastic fabric conductors to send sensor values to the transmitting microcontroller (M5Stack ATOM Matrix) via I2C communication. The transmitter microcontroller transmitted all sensor data wirelessly via UDP. The sensor data was obtained at 64 Hz. Thus, in this study, the caregiver wore the smock-type sensor to measure the proximity during STS assistance.

Figures 2 (c), (d) show the examples of sensor responses. In the interface, the density of the red color indicates the intensity of the contact. Thus, by using this interface, the body parts of the caregiver that are in contact with the care recipient while STS assistance can be detected.

In this study, the sensors located at the front of the trunk were selected to evaluate the proximity between caregivers and care recipients. First, the sensor data were measured in the rest state with no obstacle around the wearer. The rest state data were defined as the calibration values, and the sensor data obtained from the caregiver performing the care skills were subtracted by this value. Sensor data from the top (CH23, CH28), the middle (CH24, CH27) and the bottom (CH25, CH26) of the trunk were averaged. Because

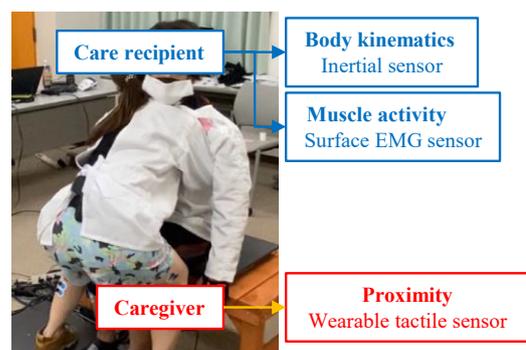


Fig. 1. Overview of measurement system.

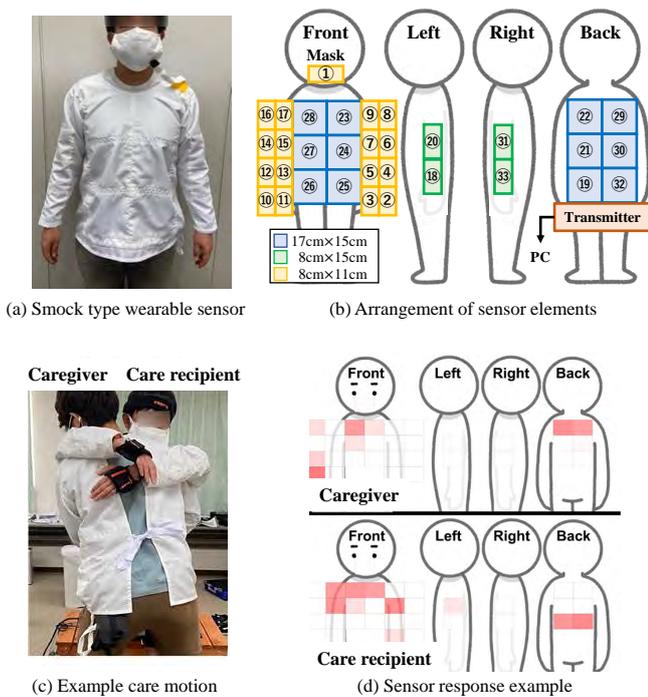


Fig. 2. Smock- type wearable sensor.

the caregivers were closer to the care recipients before the care recipients raised their hips, the proximity was evaluated before the care recipients raised their hips from the chair.

### C. Analysis of Effect of Care on Care Recipient

To assess the effect of different care skills on care recipients, body kinematics and their corresponding muscle activity was measured. Inertial sensors (Xsens, MVN Awinda) were used to measure the body kinematics, and surface EMG sensors (Cometa, Miniwave Infinity) were used to measure the muscle activity. The sensor data were collected using a wireless connection to ensure that the attachments with the sensor do not interfere with the measurement.

Because caregivers have to work in close proximity to care recipients, motion capture systems or RGB-D sensors cannot be used owing to occlusion. Therefore, in this study, inertial sensors were used to measure the body kinematics of care recipients. Seventeen inertial sensors were attached to the body parts of the care recipient to record the joint angles of the body segments at 60 Hz. After the data were obtained, the joint angles and center of mass (CoM) trajectories were calculated using the musculoskeletal model software (C-Motion, Visual 3D) to evaluate the effect of different care skills. The weight of each body part was calculated from its ratio to the total weight, and the CoM position of each body segment was calculated from the anatomical features. Finally, the overall CoM position was obtained from the average CoM of each body segment.

Muscle activity was measured to evaluate the voluntary muscle activation of the care recipients. The following five muscles were observed: gluteus maximus (GMX), vastus lateralis (VAL), rectus femoris (RF), biceps femoris long head (BFL), gastrocnemius lateralis (GAS), and tibialis anterior (TA). These muscles were selected because they are either

the extensor or flexor of the hip, knee, and ankle joints, which are activated during STS motion. The electrode location was determined based on the previous study [13], and muscle activity was measured at 1,000 Hz. All the EMG data were filtered with a 4th order Butterworth digital filter with a cut-off frequency 40-400 Hz, and the data were rectified and low-pass filtered with a 4th order Butterworth digital filter with a cut-off frequency of 4 Hz [14] [15]. By comparing the mean amplitude during STS motion, the generated muscle activity of the care recipients was evaluated.

A force plate (TF3040, TechGihan Co., Ltd) was placed underneath the hip of the care recipients to record the time when the care recipients raised their hips. The data were obtained at 1,000 Hz and were filtered with the 4th order Butterworth digital filter with a cut-off frequency of 20 Hz. When the vertical reaction force to the buttocks was less than 5 N, it was considered the hips were raised. All the data were cut to 1 second before and 2 seconds after the hips were raised.

### D. Measurement Experiment

Five female nurses with expertise in Humanitude care participated in the measurement experiment as caregivers. They were all certified Humanitude care instructors. Furthermore, three of them had eight years of experience as an instructor, and two of them had five years of experience. Two healthy males (22 and 23 years old) participated in the experiment as care recipients. They were asked to play the role of patients with dementia. Hence, they had to enact a state of weakness. Two caregivers assisted one care recipient, and the rest of the caregivers assisted the other care recipient.

In the experiment, the expert caregivers performed two roles. One was to perform care skills based on the Humanitude care method, and the other was to perform the care skills as a novice caregiver. In the preliminary experiment, the expert nurses were interviewed, and it was found that novice nurses tend to rely more on their arms to hold the trunk of a care recipient for assisting STS. Thus, in the experiment, a movie on novice care skills was shown to the expert caregivers to demonstrate the methods used by a novice caregiver. In addition, the care recipients were asked to perform STS independently. The difference between the joint angles, CoM trajectory, and muscle activity during assisted STS and independent STS was evaluated. The STS care skills were performed 10 times using the Humanitude and novice method by the caregivers. Figure 3 shows how the caregivers assisted the care recipient using Humanitude care and Novice care. The experimental procedure was approved by the Ethics Committee of the Graduate School of Information Science and Electrical Engineering at Kyushu University.

## III. RESULTS

### A. Proximity during STS Care

The proximity between the front trunk of the caregiver and care recipient was evaluated, and the results are shown in Fig. 4. In this figure, the data of the five caregivers were averaged. The proximity of the top, middle, and bottom trunk are shown in Fig. 4 (a)-(c), and the red and blue lines represent the sensor data obtained from the caregivers performing the care skills using the methods of a novice



(a) Humanitude Care



(b) Novice Care

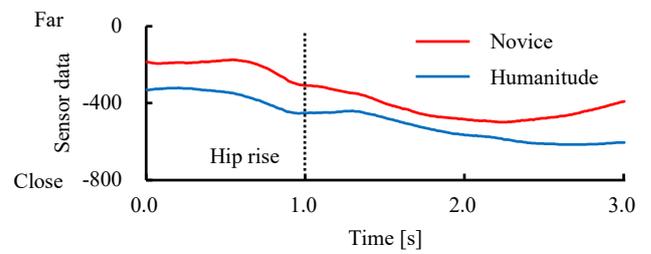
Fig. 3. Different care skills to assist STS

and the Humanitude methods. Figure 4 (d) shows the mean and standard deviation of the proximity of each part of the front trunk before the hips were raised. A t-test was performed to assess the statistical difference between novice and Humanitude care. The results indicate that compared with novice caregivers, expert caregivers tend to bring the top and middle of the front trunk significantly closer owing to the use of Humanitude care skills ( $p < 0.05$ ).

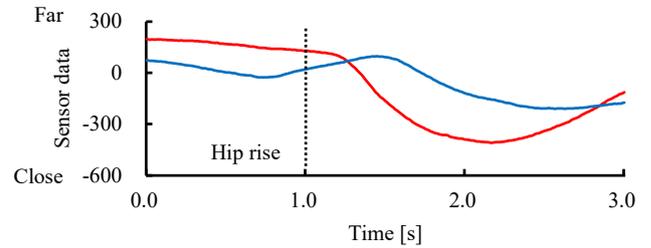
### B. Effect of Care Skill on Care Recipient

Figure 5 shows the CoM trajectories and joint angles when the care recipients stood up by themselves (black line), the caregivers performed Humanitude care (blue line), and the caregivers performed simulated novice care (red line). In Fig. 5(a), the left bottom shows the position where the care recipients sat down on the chair, and the right top shows the position where the care recipients stood up. On the horizontal axis, zero indicates the position of the ankle, and the gray square on the x-axis shows the foot support area. In contrast, the origin of the vertical axis is the floor height. From this figure, it can be inferred that the CoM of the care recipients moved more forward while receiving Humanitude care compared with novice care. The CoM trajectory while receiving Humanitude care was similar to the CoM trajectory observed when the care recipient stood up by themselves.

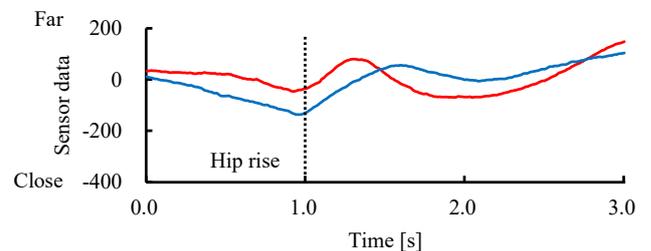
Figure 5 (b) shows the definition of the ankle, knee, and hip joint angles which are considered in this study. Figure 5 (c)-(e) show the measurement results of the ankle, knee, and hip joint angles. These results indicate that before raising the hips, the care recipients tended to dorsiflex their ankles more when they received Humanitude care compared with when they received novice care. In contrast, after the hips were raised, it was observed that the care recipients extended the knee and hip joints more under novice care than under Humanitude care. This difference can be attributed to the



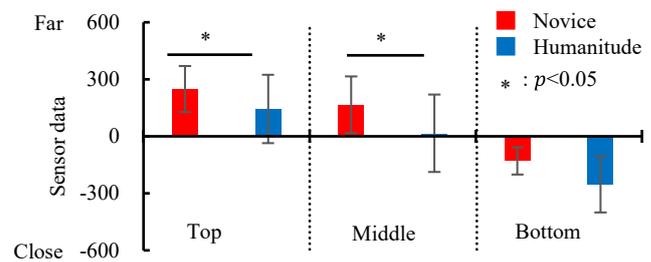
(a) Top trunk



(b) Middle trunk



(c) Bottom trunk



(d) Mean proximity of trunk

Fig. 4. Proximity of front trunk

difference in final posture after standing up. As shown in the top right figure in Fig. 3, the care recipients flexed their knee and hip joints only a small amount after completing the STS motion under Humanitude care. However, the care recipients extended their joints during the final posture when they receive novice care, as shown in the right bottom figure in Fig. 3. This can be attributed to the height difference between the caregivers and care recipients. All caregivers in the experiment were female, and all the care recipients were male. Therefore, a height difference existed owing to the difference in gender. In addition, it was assumed that the caregivers were able to fully extend the body of the care recipients as the caregivers lifted the body with their arms under simulated novice care.

### C. Effect of Care on Care Recipient

Figure 6 shows the comparison of the muscle activity of the care recipients under different types of care skills

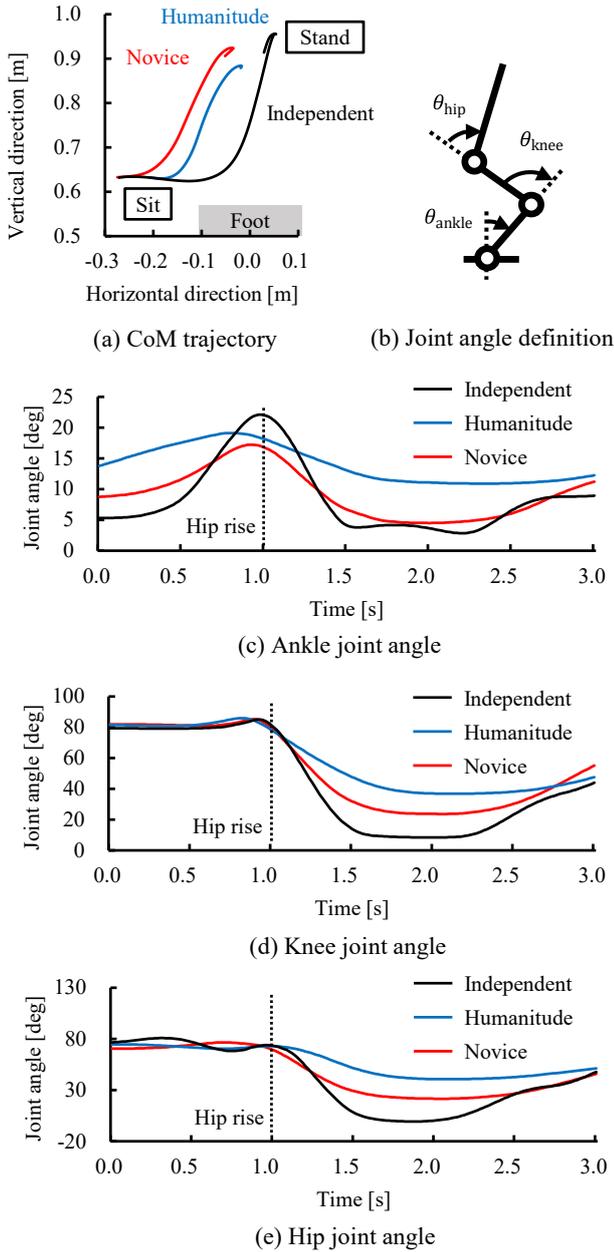


Fig. 5. Center of mass trajectory and joint angles.

and when the care recipients stood up by themselves. The mean muscle activity of the caregivers was calculated when a caregiver interacted with a care recipient. Subsequently, the mean and standard deviation were calculated for the five caregivers (Fig. 6(a)). It was found that the care recipients activated their GMAX, VL, BFL, and TA muscles more in Humanitude care than in novice care. However, no statistical significance was observed when ANOVA was performed to assess the effect of different types of care on muscle activity. Typical muscle activities of VAL and GMAX during different types of care are shown in Fig. 6 (b) and (c). These results demonstrated that Humanitude care can induce greater muscle activity than novice care.

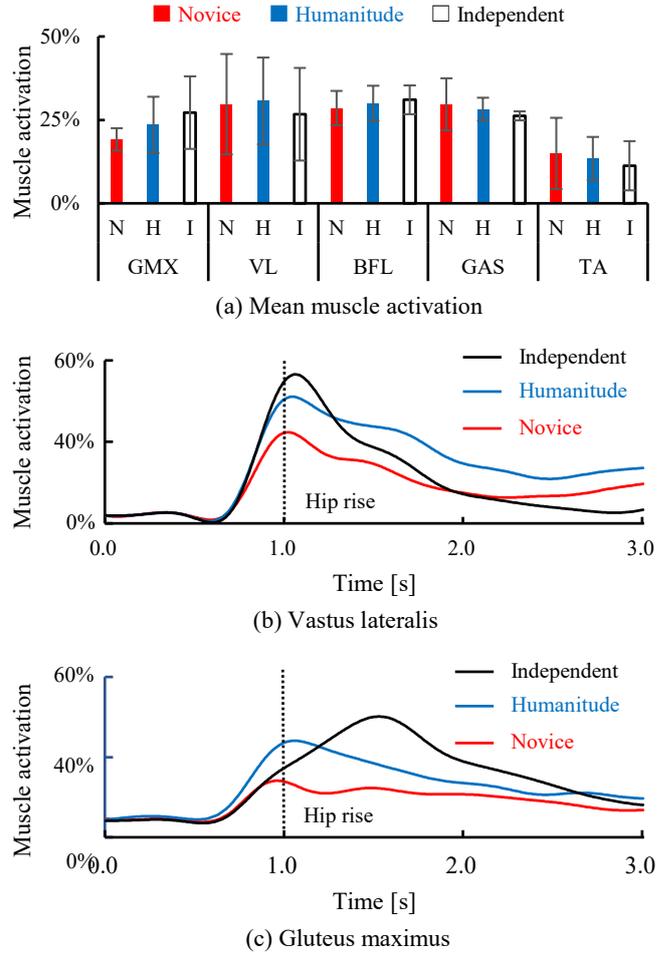


Fig. 6. Muscle activity during STS assistance.

#### IV. DISCUSSION

In this study, the proximity between caregivers and care recipients was analyzed to elucidate the difference between Humanitude and novice types of care. To measure the proximity during STS assistance, a smock-type wearable proximity sensor was developed that was lightweight and soft; this ensured that the wearer could perform STS care without any discomfort. The results validated the hypothesis that the caregivers tend to move their trunks closer to the care recipients and touch the care recipients more in Humanitude care. In novice care, caregivers stand relatively far from care recipients and assist STS mainly by using their arms. In contrast, in Humanitude care, caregivers touch the care recipients more. Furthermore, Humanitude care resulted in the care recipients following the guidance of the caregivers and shifting their CoM forward before raising their hips. These results are similar to the previous study [10], which reported that expert caregivers spend longer time before they raise the hips of the care recipients when they transfer them from a bed to a wheelchair. A significant finding of this study is that the posture of the patient should be carefully prepared before raising their hips.

Humanitude care provides a positive effect on the care recipients. By shifting their CoM closer to the base of support in Humanitude care, care recipients feel secure and exert

their own muscle activity. In contrast, in novice care, the CoM moves backwards. Therefore, even though the caregiver supports the body of the care recipients with their arms, they may feel fear of falling. Therefore, they may not be able to fully activate their own muscles. For providing care to people with dementia, it is very important for the care recipients themselves to activate their own muscles and maintain a standing posture [7], [8]. Therefore, Humanitude care can be considered to be superior to novice care.

The findings of this study can provide guidance for developing a training program for novice caregivers. In Humanitude care, caregivers tend to touch the patients more at the top and middle of the trunk; this enables caregivers to guide the CoM of the care recipient forward to the base of support. By combining the developed wearable smock-type sensor and other motion sensors, such as IMU sensors, it is possible to construct an evaluation and feedback system for STS. Currently, the authors are developing a training program (cellphone application) that provides audible feedback according to the proximity of the front trunk, as shown in Fig. 7. Developing such a system and validating its effectiveness will be one of the future studies by the authors.

One of the limitations of this study is the characteristics of care recipients. Only healthy participants were used as simulated patients. However, the primary objective of Humanitude care is treating dementia patients. Although no significant difference was observed with regard to the exertion of muscle activity, the characteristics of the care recipient are significant factors contributing to the efficacy of this method. Therefore, future researchers should employ patients with dementia to elucidate how they activate their muscles when they receive different care.

## V. CONCLUSION

Maintaining a standing posture is important for people with dementia to retain their cognitive and physical functions. This study reported that Humanitude care differed from other types of care, which are performed by novice caregivers. A smock-type wearable proximity sensor was developed. The sensor was soft and light and could accurately measure STS motion. It was observed that expert caregivers brought their top and middle of the trunk closer to care recipients in Humanitude care. The results also indicated that CoM trajectory in Humanitude care is similar to that observed

in independent STS, and care recipients tend to activate their extensor muscles more. The results also showed it is important to increase the touch area between caregivers and care recipients.

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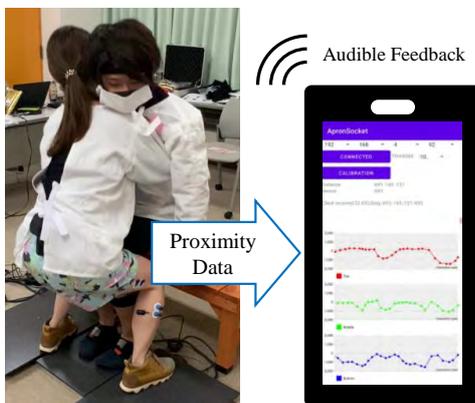


Fig. 7. Audible feedback system according to proximity.