2025 IEEE World Haptics Conference (WHC)
Suwon Convention Center, Suwon, Korea
July 8 ~ 11, 2025

A Method for Upper Body Posture Modification Using Skin Deformation Presentation on the Shoulders

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***Abstract*—The hanger reflex, induced by shear deformation of the skin, has been observed in various body regions, including the shoulders. This study presents a novel haptic feedback device that applies the hanger reflex to both shoulders, utilizing airbag-induced pressure and elastic wire deformation for effective posture correction. An experiment involving 15 participants revealed significant effects of initial posture and stimulus intensity, particularly in backward posture correction. Potential applications include factory assembly tasks, rehabilitation, dance training, and bowing posture guidance. These findings highlight the device's potential to reduce physical strain, facilitate proper posture learning, and prevent musculoskeletal disorders. Future research will focus on its application in dynamic environments and integration with other feedback methods to enhance practicality.**

***Index Terms*—Hanger Reflex, Force Perception, Posture Modification, Skin Deformation**

I. Introduction

The "hanger reflex" is an illusion where a strong rotational force is perceived when a wire hanger is placed around the head [1]. This phenomenon is caused by shear deformation of the skin due to pressure from the hanger [2]. Similar force perception has been reported in other body parts. Recent studies have also confirmed the feasibility of force presentation on the shoulder, but detailed mechanisms remain under discussion [3].

However, previous research has primarily focused on force presentation to a single shoulder, with limited investigation into bilateral force application [3]. To address this gap, we developed a device capable of presenting forces to both shoulders simultaneously and conducted preliminary experiments. The results demonstrated that presenting forces in the same direction to both shoulders induces posture changes, such as forward or backward tilting.

This intervention technique has significant potential for posture improvement, particularly in industrial environments where prolonged poor posture and repetitive movements contribute to work-related musculoskeletal disorders (MSDs) [4]. This highlights the need for technologies that reduce physical strain during work and help maintain proper posture.

Although various approaches have been proposed to address this issue [5], [6], [7], many rely on warning systems to alert users to improper posture. However, warnings often fail to elicit sufficient corrective actions, as they can be ignored or disrupt concentration, reducing work efficiency. Additionally, these methods primarily depend on passive correction and lack mechanisms for active posture adjustment. A novel approach is required to enable active posture correction while maintaining work efficiency.

We propose a dual-shoulder force presentation device utilizing the hanger reflex. Unlike conventional warning-based approaches, by applying skin shear deformation, the device assists users in adjusting their posture toward more ergonomi-

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cally favorable positions, simplifying muscle engagement and directional interpretation. This paper presents an investigation into a force feedback device designed for posture correction, evaluates its effectiveness through experiments, and explores its potential applications in posture improvement.

II. Related Work

A. Existing Methods for Posture Improvement During Work

In industrial tasks such as factory work, workers are often required to maintain improper postures or perform repetitive movements for extended periods. This can lead to Work-related Musculoskeletal Disorders (WMSDs), resulting in decreased productivity and health issues [4]. Shoulder and neck pain are common symptoms of WMSDs, particularly in tasks involving overhead work. Therefore, reducing the physical burden on the shoulder and improving posture are critical for the prevention of WMSDs.

Various approaches have been proposed to improve posture, including visual feedback [5], auditory warnings [5], [6], and vibration feedback [7], [8]. Visual feedback provides posture alerts through displays but may distract workers and reduce efficiency. Auditory warnings offer immediate alerts but can be ignored or cause mental fatigue. Vibration feedback provides tactile cues, offering intuitive guidance, but prolonged use may lead to discomfort and limited posture correction. While these methods effectively notify users of improper posture, they are often insufficient for actively correcting and maintaining proper posture during tasks.

B. Force Feedback Devices for the Shoulder

Several force feedback methods targeting the shoulder have been proposed. One approach involves exoskeleton devices equipped with actuators to provide force feedback [9], [10]. However, their weight poses a significant burden on users, limiting their practicality for long-term use. Another method uses electrical stimulation to induce force perception by activating muscles [11]. While effective for generating external force perception, this method is limited by safety concerns and is not specifically designed to target the shoulder.

C. Hanger Reflex

The hanger reflex is a phenomenon in which force perception and motion are induced through skin shear deformation caused by pressure [1]. This effect has been observed in various body parts, including the head and wrist [12], and can be replicated by controlling pressure distribution [2]. Previous studies have explored the application of the hanger reflex to various body parts, including the head, elbow, wrist, and knee [13], [12]. Various technologies, such as linear actuators [1] and lightweight airbags [12], have been utilized to induce force perception. However, applications for the shoulder remain limited, and the previous study has only investigated basic force perception on the left shoulder in the forward-backward direction [3].

III. Force Feedback Device for Both Shoulders

A novel method for posture correction utilizing a force feedback device designed for both shoulders is proposed. The device directly interacts with the body to induce intuitive responses for effective posture adjustment. Below, we outline the structure and operation of the device.

A. Device Structure

Previous studies have explored the use of airbags to apply pressure and induce shear deformation of the skin, thereby triggering the hanger reflex [3]. The proposed device utilizes this principle for posture correction. It comprises two Y-shaped shoulder frames, a connecting belt, four TPU film airbags (6 cm $\times$ 6 cm), and two adjustable wires for fit (Figure 1, left). To accommodate the user's body, the frames and wires are available in two sizes, M and L, with the same size used for both sides. The frames, fabricated from PLA resin using a 3D printer, have dimensions shown in Figure 1 (right). They are connected via a belt. The airbags are constructed by heat-sealing two 6 cm square films. They are positioned on the front and back of each shoulder to apply compression upon inflation. They are controlled by a system consisting of a small pump (ZR370-01PM 4.5V, ZhiRongHuaGuan), solenoid valves (Fa0520E 4.5V, ZhiRongHuaGuan), air pressure sensors (MIS2503-015G, MetrodyneMicrosystem), and a micro-controller (ESP32-DevKitC, Espressif Systems (Shanghai) Pte. Ltd.). The internal air pressure is regulated via PD control to ensure safety and prevent overinflation or rupture.

The wires, constructed by inserting piano wire into vinyl tubing, provide elastic deformation to aid force transmission. They are available in two lengths: 42 cm for M size and 48 cm for L size. The M size accommodates shoulder circumferences of 39 – 49 cm, while the L size fits 48 – 58 cm.

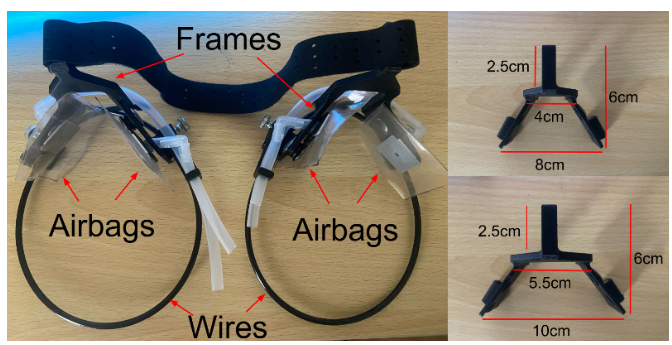

Fig. 1. Left: Force feedback device comprising frames, airbags, and wires. Right: Frame sizes (M above, L below).

B. Posture Correction Mechanism

Posture correction is achieved through two distinct airbag inflation patterns :

1) Forward Posture Adjustment(Figure 2(center)): Inflating the airbags at the front of the shoulders induces forward shear deformation. The elastic deformation of the wires

transmits force to the rear of the shoulders, creating rotational shear deformation, which encourages a forward-leaning posture.
2) Backward Posture Adjustment(Figure 2(right)): Inflating the airbags at the rear of the shoulders induces backward shear deformation. The wires transmit force to the front of the shoulders, creating rotational shear deformation, which promotes an upright posture by expanding the chest.

A preliminary experiment was conducted with lab members to evaluate their responses. The results confirmed that both forward and backward inflation patterns effectively induced the intended postural adjustments. Unlike conventional systems requiring two airbags per direction, this device leverages elastic wire deformation to achieve bidirectional posture correction with a single airbag per side, thereby reducing weight and complexity. The combination of airbag inflation and elastic deformation of the wires demonstrated the potential for effective posture correction in the forward and backward directions.

Fig. 2. Left: The device in use. Right: Mechanism of posture correction through airbag inflation patterns for forward (center) and backward (right) adjustments.

IV. Experiment

This study conducted an experiment to evaluate the posture correction capability of a force feedback device applied to both shoulders. The device was attached to participants' shoulders. Changes in tilt angle before and after stimulation were measured using an IMU sensor, while varying the initial posture, stimulation direction, and intensity. This study was approved by the local research ethics committee (applicant number: UT-IST-RE-241031-8).

A. Experimental Setup

A force feedback device, as described in Section III, was employed in this study. An IMU sensor ensured accurate control of the initial posture, and a device control system facilitated smooth experiment progression. Participants used these devices during the experiment (Fig. 3, left). The following outlines the IMU sensor and system setup.

1) IMU Sensor: The Movella DOT IMU sensor (Fig. 3, top right) was used to measure tilt angle changes. This 9-axis IMU provides real-time data on acceleration, angular velocity, and magnetic fields. The sensor was securely attached to a belt around the participant's waist to measure pitch angles. Participants could monitor their forward and backward tilt angles on a screen in real time (Fig. 3, bottom right). Data were sampled at 60 Hz and exported via Bluetooth in CSV format.

2) Experimental System: The experiment was controlled using software developed with Python and Unity. When angle maintenance was detected (Section IV-B), a condition-specific value was sent from Python to Unity via UDP. Unity then sent Bluetooth commands to the device control unit to deliver the corresponding stimulation.

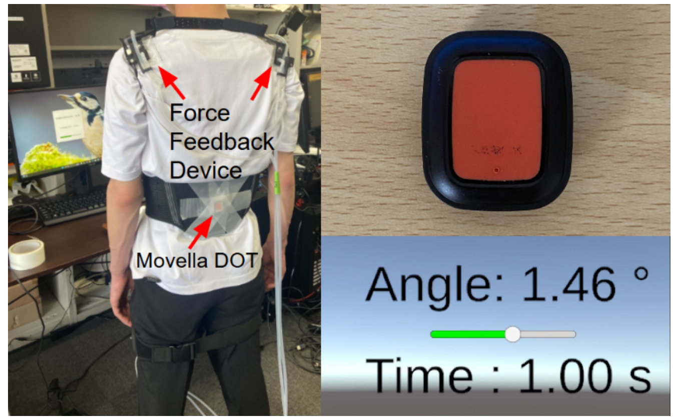

Fig. 3. Experimental setup. Left: Experimental scene with the force feedback device on the shoulders and the IMU sensor on a waist belt. Top right: The Movella DOT IMU sensor. Bottom right: Real-time tilt angle display for participants.

B. Experimental Procedure

The experimental procedure is outlined as follows: Participants were first provided with an explanation of the experiment and signed a consent form. They then completed a questionnaire regarding their age and gender. Next, shoulder dimensions were measured over thin clothing using a measuring tape from the acromion to the armpit, and the values were rounded to the nearest whole number. Based on these measurements, participants with shoulder circumferences of 48 cm or less were assigned an M-sized device, while those with 49 cm or more used an L-sized device. The devices were attached to both shoulders. Additionally, an IMU 9-axis sensor was secured to a belt placed on the lower back.

Each trial consisted of the following steps:

1) Participants maintained the forward-backward tilt angle displayed on a screen within a specified range for 2 seconds (IV-C).
2) The device was activated to apply a stimulus, and participants were instructed to allow their posture to adjust naturally without resistance.
3) The device stopped after 7 seconds, and participants returned their posture to the original position.

The trials were repeated across the experiment. Prior to the main experiment, participants completed a practice session with six randomized trials to familiarize themselves with the procedure. Each participant completed 180 measurement trials, divided into 9 sessions consisting of 20 trials each. These

9 sessions corresponded to 3 initial postures (0 degrees, 5 degrees, and 10 degrees), with each posture repeated across 3 sessions. Within each session, participants were presented with 20 trials sampled from the 6 stimulus conditions (2 directions × 3 intensities). All 180 trials were fully randomized for each participant using a uniform distribution of conditions. This ensured that each of the 6 stimulus conditions was presented exactly 10 times per posture, resulting in 180 trials total (6 conditions × 10 repetitions × 3 postures). The sequence of trials was independently randomized for each participant to minimize order effects and reduce the potential influence of learning. Participants were allowed to take voluntary breaks between sessions, with mandatory 3-minute breaks after the third and sixth sessions.

Following the experiment, participants were interviewed using the following questions: Q1: ”Did you feel a change in your posture when the device was activated?” Q2: ”How did your posture change? Please provide all applicable details.” Q3: ”Do you have any comments or observations about the experiment?”

C. Experimental Conditions

Fifteen participants (9 males, 6 females; age: 23.0 ± 1.9 years) participated in the experiment. The shoulder circumferences were 45.7 ± 5.0 cm for the right shoulder and 45.1 ± 4.9 cm for the left shoulder, all within the measurable range of 39 – 58 cm. Thirteen participants used M-size devices for both shoulders, while 2 used L-size devices.

The stimuli consisted of two directions: ”forward” (shoulder extension) and ”backward” (shoulder flexion), and three levels of compression intensity: ”weak” (4 kPa), ”medium” (12 kPa), and ”strong” (20 kPa). The compression levels corresponded to the upper and lower limits of the device’s capability, with ”medium” defined as the midpoint. This resulted in six stimulus conditions (2 directions × 3 intensities × 3 postures).

Three initial postures were tested: 0 degrees, 5 degrees forward tilt, and 10 degrees forward tilt, with an allowable error of ± 2 degrees. Each session was conducted with one posture (Set 1: 0 degrees, Set 2: 5 degrees, Set 3: 10 degrees). Within each session, participants performed 10 trials for each of the six stimulus conditions, resulting in a total of 186 trials per participant (6 practice trials + 180 measurement trials). The total duration of the experiment was approximately 75 minutes per participant.

D. Result

The experimental results are presented in Figure 4. The vertical axis represents the change in tilt angle before and after stimulation, where positive values indicate forward tilt and negative values indicate backward tilt. These values were calculated by averaging 40 data points collected at 20 Hz over a 2-second interval starting 3 seconds after device activation. To ensure stability, the data were further averaged across all participants, excluding transient effects immediately after activation. The horizontal axis indicates the stimulus conditions, while the error bars represent standard deviations.

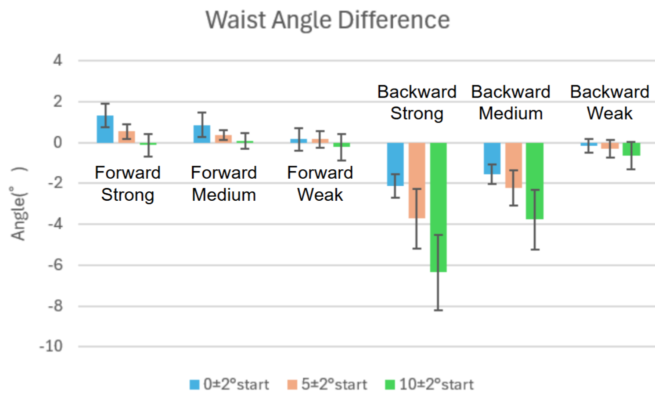

Fig. 4. Changes in tilt angle before and after stimulation under each condition. Positive values indicate forward tilt, and negative values indicate backward tilt.

A two-way analysis of variance (ANOVA) was conducted to assess the effects of initial posture and stimulation intensity on angle changes.

In the forward direction, the analysis revealed a significant main effect of initial posture (F=12.702, $p < 0.001$). However, no significant main effect was observed for stimulation intensity (F=2.046, p=0.134). Also, no significant interaction between initial posture and stimulation intensity was found (F=0.458, p=0.767). Post-hoc analysis using Tukey’s test showed no significant difference between the 0 degrees and 5 degrees conditions (p=0.051). In contrast, a significant difference was observed between the 5 degrees and 10 degrees conditions, with the 5 degrees condition producing larger changes in tilt angle (p=0.023). Additionally, the comparison between the 0 degrees and 10 degrees conditions revealed that the 0 degrees condition resulted in significantly larger changes ($p < 0.001$).

For the backward direction, the analysis demonstrated significant main effects for both initial posture (F=12.055, $p < 0.001$) and stimulation intensity (F=13.173, $p < 0.001$). However, no significant interaction effect between initial posture and stimulation intensity was observed (F=1.300, p=0.251). Tukey’s test indicated that conditions with greater initial tilts produced significantly larger angle changes across all comparisons: 0 degrees and 5 degrees (p=0.047), 5 degrees and 10 degrees (p=0.046) and 10 degrees and 0 degrees (p¡0.001) . Regarding stimulation intensity, the medium intensity condition resulted in significantly larger changes compared to the weak condition (p=0.021). Also, the strong condition produced significantly larger changes than the weak condition ($p < 0.001$). On the other hand, no significant difference was found between the medium and strong conditions (p=0.067).

In the post-experiment interviews, 14 out of 15 participants reported feeling that the device altered their posture. All 14 participants who perceived a change mentioned both the direction (forward or backward) and intensity of the stimulation, with one participant noting a twisting sensation. Some participants commented that the displayed 0 degrees posture did not feel like a straight posture. Additionally, several participants provided positive feedback, such as expressing interest in a device that could actively correct posture.

E. Discussion

Distinct effects of a bilateral force feedback device on posture correction in the forward and backward directions were observed.

In the forward direction, a significant main effect of the initial posture was identified. Participants with a forward-leaning posture (e.g., 5 degrees or 10 degrees) exhibited a reduced tendency to lean further forward, potentially reflecting a natural response to prevent excessive tilt. However, no significant effect of stimulus intensity was observed. This may be attributed to the subtle perception of intensity differences or variability in device attachment and shoulder morphology, which could have affected the delivery of the stimuli. Notably, posture changes were also observed under the 0-degrees condition. While this result may not constitute posture correction in a strict sense, it may reflect subtle changes in muscle engagement or shifts in the center of gravity due to shear force input at the shoulders. These observations suggest that posture change induced by the device may be interpreted as relative waist movement rather than correction toward a fixed target posture.

In the backward direction, significant main effects were observed for both initial posture and stimulus intensity. A more forward-leaning initial posture resulted in greater backward correction, even with lower stimulus intensity, suggesting that the device may help reduce larger postural deviations. The stimuli in the backward direction were perceived more distinctly, likely because they encouraged a shift toward a less strenuous posture. The importance of considering directional effects in designing force feedback devices has been highlighted by recent observations." The lack of interaction between initial posture and stimulus intensity suggests that these factors independently influence posture correction. Future studies could investigate additional initial postures or experimental conditions to further expand the applicability of this approach.

The comments from the oral interviews were analyzed. For Q1, one participant reported not perceiving any posture correction, likely due to improper device attachment that resulted in insufficient stimulation. This indicates the need for improving attachment methods and accounting for individual differences. Regarding Q2, a participant who reported "a twisting sensation" had a shoulder circumference at the upper limit of the device's applicable range. This suggests that the device size may have been inadequate, leading to unintended sensations. Further investigation into device sizing and fitting is warranted. For Q3, participants with naturally rounded backs perceived a 0-degrees posture as reclined. This indicates the importance of measuring back angles in addition to lumbar angles for practical applications.

Although the posture changes observed were minor, typically within a few degrees, these results hold significant implications. The device may promote muscle engagement and support directional awareness during posture adjustment. Most participants reported perceiving posture correction, demonstrating the device's effectiveness. Large posture adjustments are seldom required in daily life or work environments. Minor adjustments, typically within a few degrees, are often sufficient, as excessive movements may compromise stability. The device's ability to induce small but effective corrections highlights its practical value.

While this study confirmed the effectiveness of the device under controlled conditions, further improvements are needed for broader applications. Future systems could incorporate motion capture or IMU sensors for real-time posture monitoring and activate the device when a physically demanding posture is detected. For example, excessive forward leaning could trigger the rear airbags, while excessive backward leaning could activate the front airbags. For scenarios requiring higher precision, motion capture could be used to calculate real-time posture indices, such as RULA scores [14]. These enhancements could enable immediate, effective posture corrections, reducing physical strain and improving the usability of the device.

V. Application

A force feedback device has been proposed to assist with posture correction during work, aiming to reduce physical strain. Experimental results suggest its potential for broader applications. This chapter introduces specific use cases.

A. Posture Correction During Assembly Work

Assembly work often involves prolonged repetitive motions and fixed postures, increasing the risk of musculoskeletal disorders (MSDs) [4]. The device, worn on the shoulder, provides subtle haptic stimuli when poor posture is detected, encouraging corrections. A motion capture system monitors posture in real-time by placing markers on the shoulders, waist, and back. Based on the data, methods like the RULA score [14] detect improper postures. When thresholds are exceeded, the device provides stimuli, such as pulling the shoulders backward to promote an upright posture (Fig. 5).

The system can be customized for individuals by adjusting thresholds and stimulus intensity, making it suitable for various work environments. Recorded data can also support long-term posture monitoring and feedback, reducing physical strain and health risks.

B. Posture Guidance in Rehabilitation

Rehabilitation aims to recover physical function, where proper posture is crucial [15]. This device is particularly useful in gait training, essential for recovery from stroke or spinal cord injury [16]. Issues like slouching or leaning backward can hinder progress. The device provides haptic feedback to guide posture: pulling shoulders backward to counter slouching or forward for excessive backward leaning. This helps patients

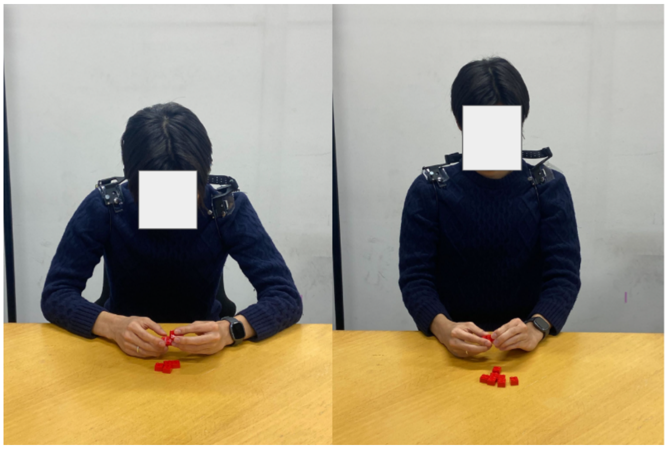

Fig. 5. Left: Slouching during assembly work. Right: Corrected posture with the device.

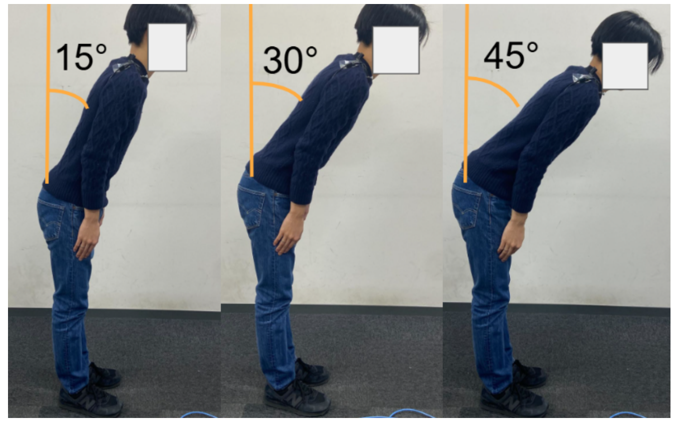

Fig. 6. Illustration of training bows at 15, 30, and 45 degrees using the device (from left to right).

learn proper posture through repeated practice. Using the device allows patients to continue rehabilitation at home, reducing therapists' workload and encouraging active participation, which can improve treatment outcomes.

C. Posture Guidance for Ballet and Dance

In ballet and dance, proper posture is fundamental to achieving both aesthetic appeal and technical precision [17], [18], [19]. The proposed device serves as an assistive tool to facilitate the acquisition of correct posture through repetitive practice. In ballet, maintaining an ideal alignment of the head, shoulders, back, pelvis, and feet requires repetitive training and heightened body awareness [20]. The device helps learners stabilize shoulder positioning, which is critical during arm movements and upper-body motions. In jazz and modern dance, performers must execute dynamic movements while maintaining core stability [18], [19]. However, the latency of approximately one second between stimulation and force perception limits the device's effectiveness for rapid or abrupt posture changes. The device is most suitable for slow-motion practice or static posture training, enabling learners to refine their movements and positions effectively. Furthermore, it reduces the need for direct physical intervention by instructors, improving the efficiency of group instruction.

D. Posture Guidance for Bowing (Ojigi)

Bowing, or "ojigi," is an essential nonverbal communication in Japanese culture, expressing respect, gratitude, or apology through a forward-leaning posture [21]. Bows are categorized by their angles: "eshaku" (15 degrees) for casual greetings, "keirei" (30 degrees) for respectful gestures, and "saikeirei" (45 degrees or more) for formal apologies or profound respect. The proposed device facilitates efficient training in achieving accurate bowing postures, which are crucial in formal and business settings (Fig. 6).

VI. Conclusion

A novel posture correction method using a haptic feedback device for both shoulders was investigated, and its effectiveness was evaluated. The device delivers force perception through shear deformation of the skin on the shoulders, supporting adjustments in upper-body posture that may reduce physical strain. This approach addresses limitations of conventional visual and auditory feedback methods, such as the tendency to ignore warnings or reduced concentration. The experimental results demonstrated that the device enabled small but consistent adjustments in posture in the backward direction, with significant effects of initial posture and stimulus intensity on angular changes. These findings suggest that the device has the potential to assist in adjusting the waist angle toward ergonomically desirable postures. In contrast, for the forward direction, the effect of stimulus intensity was not statistically significant, likely due to variations in device attachment or individual differences among participants. Further research is needed to evaluate the device's performance during task execution, particularly in addressing potential issues such as users ignoring stimuli or task interference. Additionally, further investigation is required to integrate this device with visual, auditory, and vibration feedback in order to enhance its overall effectiveness.

VII. Acknowledgement

This study was supported by JSPS KAKENHI (Grants 23K16922).

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