Development of a multi-frame active brace for selective trunk support in patients with low back pain.

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Abstract
In this study, we aimed to create a corset that limits motions causing lower back pain without restricting daily activities. We designed a corset that allows selective lumbar spine movement, improving upon traditional corsets' limitations. Using 3D-printed rigid and plastic soft materials, we crafted full-scale models that focused on controlling flexion and extension. Our prototype included a rack and pinion actuator to facilitate this. In testing, we noted a voltage drop in the actuator motor under higher loads, leading to less rack displacement. This was more pronounced in the corset than in the actuator alone, likely due to the additional weight of the corset's frame and non-vertical forces, as it's supported by two actuators. Future designs may require more axes to improve functionality.

1. Aim of Research

1-1 Background

As one of the conservative treatments for lower back pain, orthotic therapy using a corset (lumbar belt) is often utilized. The role of the corset is to stabilize the trunk by fixing the lumbar spine and compressing the abdomen, thereby achieving stability of the lumbar spine with abdominal pressure stability. However, existing corsets that uniformly fix the lumbar region can restrict movements that provoke lower back pain and provide pain relief; they can also lead to muscle weakness and impact daily life due to the restriction of movements necessary for daily activities.

1-2 Purpose

The purpose of this study is to conduct fundamental research aimed at creating a corset that improves upon the problems of traditional corsets by restricting movements that cause lower back pain while not inhibiting daily life activities. To this end, we designed and developed a corset that selectively allows movements of the lumbar spine and verified its operation.

2. Materials and Methods

2-1 Production Concept

With the aim of controlling the selective restriction of the lumbar spine's range of motion in mind, we considered the production of a corset that would brake rotational movements and flexion-extension. In this study, we created a multi-frame type corset that can control flexion and extension. (Figure 1) (Figure 2)

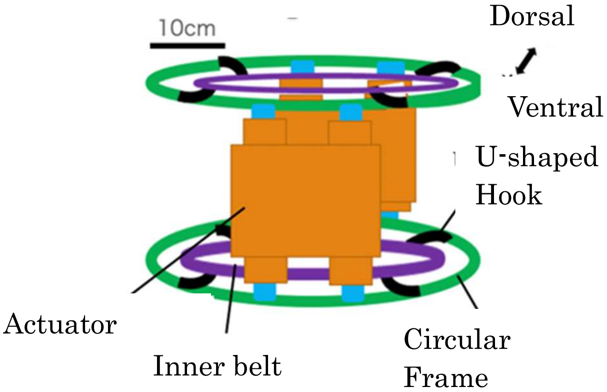

Fig.1 Cencept of the corset

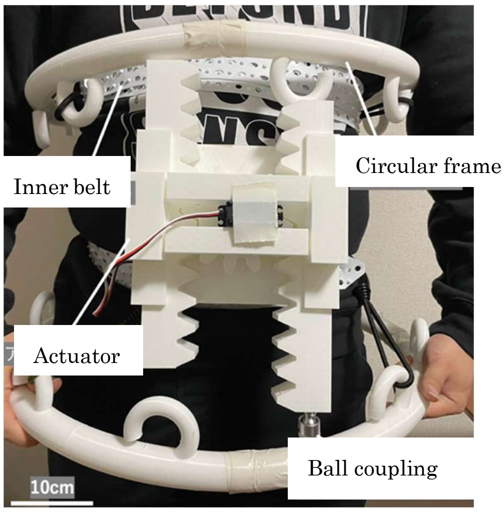

Fig.2 Prootype of the corset

Regarding the circular frame and the actuator, they were produced using a 3D printer and are made of rigid materials. Therefore, there is a possibility that the movement of the trunk cannot be freely transmitted from the circular frame. With the aim of achieving both the versatility of the circular frame and the proper fit to the trunk, we introduced an inner belt mechanism. Additionally, with a focus on the interactivity between the upper and lower frames, the actuator was designed with a rack and pinion mechanism, allowing control by a single gear. A ball cup coupling was also introduced as a joint.

2-2 Drive Performance Evaluation

The drive performance of the actuator, which is essential for the corset's operation, was evaluated. In conducting the drive performance evaluation of the corset, we assessed the drive performance of the rack and pinion, which is the power source of the corset, and experimented to see if it has the strength to support a person's actual weight. This allows us to verify to what extent it can support weight when the trunk is flexed forward. The target was set to support a weight of 70 kg, considering that the average weight of Japanese men over 20 years old is 67.3 kg. The relationship between the displacement of the rack part when the actuator is loaded with weight was evaluated, and further, the relationship between the displacement of the rack part when the load weight was applied to the corset that was produced was evaluated.

3. Results of Research

The relationship between the voltage applied to the mounted motor of the actuator and the load weight, and the relationship between the load weight and the displacement of the rack section were evaluated. As a result, a decrease in voltage was observed as the load weight increased, and these were observed simultaneously. In addition, the relationship between the load weight and the displacement of the rack part was also evaluated for the evaluation of the drivability of the corset, and the displacement became zero when the load weight was low compared to the results for the actuator alone (Figure 3).

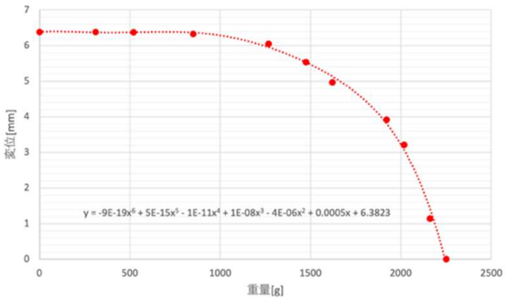

Fig. 3 The relationship between load weight and displacement in the actuator

Table. The relationship between load weight and displacement in the corset

Weight(g)	0	310	520	850	1268	1475
Displacement(mm)	4.24	2.15	1.03	0	0	0
Weight(g)	1620	1920	2017	2161	2250	
Displacement(mm)	0	0	0	0	0	

4. Discussion

There are two possible reasons why the displacement became zero at a smaller load weight in the corset's drive performance evaluation compared to the actuator alone. The first is that the weight of the corset's circular frame was loaded, and the weight of the upper and lower circular frames was added. The second is a balance issue with the corset itself. It is considered that forces other than the vertical component were applied because the corset created in this study was supported by two actuators as axes; therefore, it may be necessary to consider increasing the number of axes in the future.

5. Means of Official Announcement of Research Results

This research was presented orally at the 32nd Japan Low Back Pain Association meeting in 2023. Going forward, we plan to further advance our research, conduct clinical trials, and aim for social implementation.