UPPER-LIMB ORTHOSIS IMPLEMENTED WITH AIR DASHPOTS FOR SUPPRESSION OF PATHOLOGICAL TREMOR IN DAILY ACTIVITIES

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SUMMARY
Involuntary movement of pathological tremor was suppressed by viscous loading of air dashpots on orthoses of upper-limb segments. A prototype of orthoses for wrist and elbow movement was developed. It suppressed two-dimensional wrist movement and one-dimensional elbow movement. For fundamental analysis, involuntary movement at around the two joints was elicited by electrical stimulations against a healthy male. Amplitude of involuntary movement was measured by acceleration sensors attached on the hand and forearm orthoses. Involuntary wrist movement was reduced to 20-62% with the use of the dashpots. Involuntary elbow movement was reduced to 82%. The degree of suppression was smaller in elbow movement than that in wrist movement. The acceleration of movement became small in a heavier segment if same force was elicited electrical stimulation.

INTRODUCTION
Tremor is a rhythmical involuntary oscillatory movement shown in human body-parts [1]. It is prominent in upper-limb segments. Tremor is, in general, an invisible movement for healthy persons; therefore, it does not disturb activities of daily living such as holding up any objects. However, tremor is exaggerated by any clinical disorder and neuromuscular disease. Exaggerated tremor makes any daily activities more difficult. This type of tremor is called pathological tremor. Some forms exist in pathological tremor: essential, Parkinson and so on.

Medication is a significant treatment for suppression of pathological tremor, although some side effects are, unfortunately, caused by it. Therefore, alternative methods for tremor suppression have been required. Prochazka et al. [2] and Popovic et al. [3] developed orthoses with surface electrical stimulation for tremor suppression. The stimulation device was a useful solution; however, it would have some problems in clinical use. For example, patients feel uncomfortable in a muscular tissue by electrical stimulations.

Another solution for tremor suppression is mechanical loading. There are three kinds of loading: inertial, viscous and resistive. Inertial or resistive loading attenuates involuntary movement of pathological tremor; however, it also prevents voluntary movement in daily activities as well. Viscous loading would suppress involuntary movement and would not prevent voluntary movement because it is proportional to a velocity of movement, not to an acceleration and displacement. Morrice et al. [4] proposed a device for viscous loading for cerebellar incoordination. Mechanical devices of viscous loading have been advanced until now.

In this study, we develop a prototype of upper-limb orthoses implemented with air dashpots for involuntary movement at around wrist and elbow joints. We also quantify the degree of suppression of involuntary movement by using acceleration sensors.

METHODS
We developed a prototype of orthoses of a right upper limb for suppression of involuntary wrist and elbow movement as shown in Figure 1. We used three air dashpots (2KS160A3.0-TX, Airpot, USA) with a manually adjustable damping coefficient from 0.0-1.8kN/(m/s). The three dashpots were implemented on the forearm and upper-arm orthoses with Velcro straps for wrist and elbow movement, respectively, as shown in Figure 1. A piston rod of each dashpot was connected to the orthosis of the distal segment. Since a rod tip was a ball joint, movement of the distal segment was transmitted flexibly to the dashpot on the orthosis of the proximal segment. In particular, involuntary wrist movement was suppressed by the dashpot not only in flexion-extension but also in ulnar-radial deviation.

In this study, a healthy male (22 years) first participated in the experiment in order to obtain fundamental data for design of upper-limb orthoses. Involuntary movement at around the wrist and elbow joints was elicited by electrical stimulations with the use of a stimulator (EW6021, Panasonic, Japan). Stimulation frequency was approximately 3Hz. This was a principal frequency of Parkinson tremor. Electrodes of the stimulator were placed on the skin at around the m. flexor carpi ulnaris for wrist movement or the m. brachialis for elbow movement.

The acceleration components of involuntary wrist and elbow movement were measured by three acceleration sensors (9G111BW, NEC Avio, Japan). For wrist movement, the two sensors were placed on the hand orthosis for measurement in flexion-extension and ulnar-radial deviation. For elbow movement, only the one sensor was placed on the forearm orthosis for measurement in extension-flexion and ulnar-radial deviation. The acceleration-sensor signals were fed into charge amplifiers (6D07, NEC Avio, Japan) with a band-pass filter in the range of 0.2 to 2000Hz. The amplified signals were digitized at
100Hz and were then stored on a personal computer. The resolution of A/D conversion was 16bits.

In order to compare the degree of suppression of involuntary movement quantitatively, we estimated the root mean square (rms) value of the measured data. The rms value estimated the amplitude of involuntary movement. We compared the rms value with or without the dashpot at around the wrist and elbow joints.

Figure 1: Upper-limb orthoses for suppression of involuntary movement at around right wrist and elbow joints.

RESULTS AND DISCUSSION
A example of involuntary extension-flexion movement at around the wrist joint with the two dashpots or without the dashpot is shown in Figure 2. The damping coefficient was adjusted to 1.8kN/(m/s). Involuntary wrist movement in extension-flexion was suppressed with the use of the dashpots. Involuntary ulnar-radial deviation was also reduced.

Figure 2: Example of involuntary extension-flexion movement at around wrist elicited by electrical stimulations measured by acceleration sensors.

The degree of suppression of involuntary wrist movement was quantified by the rms value as shown in Figure 3. In extension-flexion, the rms value was reduced to 20% with the two dashpots and to 62% with the one dashpot compared to that without the dashpot. Involuntary ulnar-radial deviation was also reduced by the same degree. The piston rod was connected to the hand orthosis with the ball joint; therefore, the two-dimensional wrist movement was transferred flexibly to the air dashpots.

Figure 3: Comparison of rms value of wrist movement.

Figure 4 illustrates the degree of suppression for involuntary elbow movement. It was also reduced by the dashpot; however, the rms value was reduced only to 82% compared to that without the dashpot. Involuntary elbow movement was not reduced sufficiently because the forearm had a heavier mass than the hand. The acceleration of movement became small in a heavier segment if same force was elicited by electrical stimulations in accordance with the Newton's second law. Involuntary movement elicited was smaller at the elbow than at the wrist.

Figure 4: Comparison of rms value of elbow movement.

In this study, involuntary movement was elicited by electrical stimulations. However, elicited movement was not the same as pathological tremor. We would use this prototype to patients of pathological tremor and would investigate the degree of tremor suppression at around the elbow and wrist joints.

CONCLUSIONS
We developed a prototype of upper-limb orthoses with air dashpots for suppression of involuntary movements. Involuntary wrist movement was suppressed sufficiently by the dashpots, but involuntary elbow movement was not because a forearm had a heavier mass than a hand.

REFERENCES