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Paper:

Development of Leg Rehabilitation Assistance

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We propose leg rehabilitation assistance based on a new method. Many elderly temporarily recovering from disease or injury suffer functional deficit and depression because of the lack of appropriate longer-term rehabilitation, suggesting the need for assistance that individuals can use on their own over long enough periods. Such assistance must be safe, light-weight, and apply no psychological burden on users. We propose parallel-wire multi-degree-of-freedom leg rehabilitation assistance. We report the design and trial production of an experimental 2-degree-of-freedom system having flexion and extension for the knee and hip and experiments conducted with a test dummy in knee and hip flexion and extension. Our results certain training actions are possible based on the proposed system.

Keywords: rehabilitation, multi-degree-of-freedom training for joint, parallel wire mechanism

1. Introduction

The number of persons needing physical rehabilitation following disease or injury is expected to increase as society ages. Aiding such persons through proper rehabilitation is useful for improving their quality of life (QOL) and preventing increased medical and welfare costs. Due to a shortage in training capacity and trained rehabilitation personnel, including physical therapists, an alternative is needed to meet demands for assistance in rehabilitation. The elderly are particularly adversely affected by such shortages, indicating the need for a system that enables them to continue proper rehabilitation long enough to be effect, e.g., at home. Due consideration must be given to safety, weight, ease of use, and psychological burden on users.

We focused on continuous passive motion (CPM), proposed mainly to prevent contracture after surgery on joints[1], now applied to the long-term bed-ridden[2].

Training after surgery emphasizes work with a specific joint. On the other hand, the elderly often require combined training for more than one joint. Among studies on multi-degree-of-freedom training for joints[3,4], Yaskawa Electric Corp. developed a therapeutic exercise machine (TEM), making it commercially available. TEM involves a two-arm link mechanism for realizing knee and hip flexion/extension based on a locus in teaching by a therapist. This is applicable to rehabilitation from cerebral apoplexy or spinal cord injury as well as orthopedic surgery. The disposition of actuators, however, makes it difficult to conduct motions in which the number of degrees of freedom must be increased simply by expanding on conventional CPM. This is because conventional CPM supports and applies force to a leg using a rigid link, which requires greater force and larger actuators for holding and moving both the CPM apparatus and the leg. Hence multi-degree-of-freedom joint training based on new concepts is needed.

We propose parallel-wire multi-degree-of-freedom joint training that drives the target limb using multiple parallel wires.

The parallel-wire mechanism features the following:

- Since all actuators support the load individually, the required power for each actuator is made smaller.
- When this mechanism is used to exchange force with a user, the user feels less restrained, since the component directly affecting the user is light and flexible.

Studies have been conducted to apply the parallel-wire mechanism to a demonstration of force in a state of virtual reality[5] or to powered upper-limb orthoses[6].

Applying the parallel-wire mechanism to joint training is expected to provide the following feature in addition to those above:

- Treatment is provided to subjects with bedsores by placing them in different postures, based on their condition.

Section 2 details the general concepts behind proposed wire-driving leg rehabilitation assistance and outlines preliminary experiments conducted. Section 3 details the design and trial production of a 2-degree-of-freedom joint training mechanism having knee and hip flexion and expansion. Section 4 details trial motion experiments using a test dummy. Section 5 presents conclusions and projected prospects.

2. General Concepts behind Leg Rehabilitation Assistance

As shown in **Fig.1**, the leg rehabilitation assistance we propose draw the leg of a subject by multiple wires extended from surrounding points so leg joints are moved when wire length is controlled.

Based on the range of motion exercise conducted by physical therapists, it is proposed to ultimately provide separately generated continuous motions on practical basis for 6 degrees of freedom:

- knee flexion and extension
- hip flexion and extension
- external hip rotation and internal rotation
- hip adduction and abduction
- ankle dorsiflexion and plantar flexion
- inner and outer ankle repulsion

To attain this goal, the mechanism is improved along with gradually increasing the number of degrees of freedom of joint motion.

A mechanism based on a single degree of freedom of knee flexion and extension was developed for experiments[8] to confirm the efficiency of the proposed wire-driving process.

In a single degree of freedom mechanism, knee flexion and extension in supine position are chosen for experiments. A part of the thigh is drawn with a pair of wires, while a heel placed on the bed is moved directly. The single degree of freedom mechanism built for the trial consists of a suspension mechanism and a heel holding mechanism. By controlling both the length of the wire of the mechanism and the position of the sole board cooperatively, the knee joint training is conducted.

Experiments with the single degree of freedom mechanism demonstrated the following problems:

- In multi-degree-of-freedom use, wires must not in terfere with each other.
- In expanding the joint motion range, the direction of force applied to the leg must be controlled properly. In a single degree of freedom mechanism, the wire-winding mechanism is fixed, so the angle between the tensile direction of wire and the major axis of the leg changes greatly as shown in **Fig.2**. This may be uncomfortable for users or damage tissues.

Given these problems, we developed a trial 2-degree-of-freedom joint training mechanism for the hip and knee as described below.

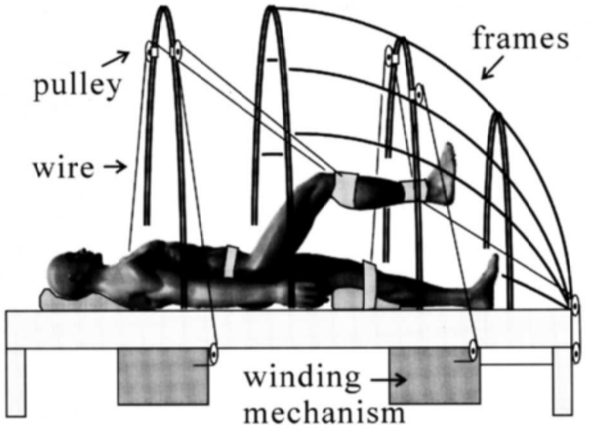


Fig. 1. Concept of the leg rehabilitation assistance.

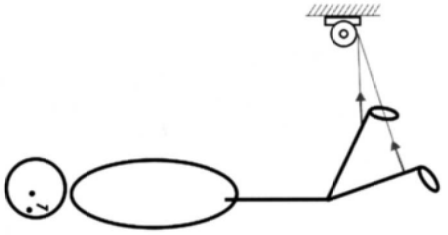


Fig. 2. Generation of tensile force of wire with fixed wire-wind mechanism.

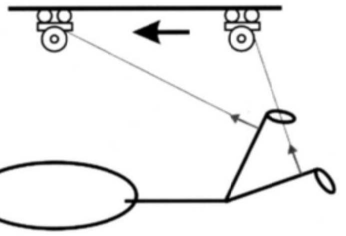


Fig. 3. Generation of tensile force of wire with moving wire-wind mechanism.

3. Two-degree-of-freedom Joint Training Mechanism

3.1. Basic Structure

This section focuses on knee and hip flexion and extension, detailing the design and trial production of a 2-degree-of-freedom joint training mechanism. We first explain the basic parallel-wire mechanism used for the joint training mechanism. The joint training mechanism is assumed to be 2-degree-of-freedom motion on the sagittal plane. The number of wires required for determining the n degrees of freedom position using the parallel-wire mechanism is at least (n+1)[9]. To determine a assumed to be 2-degree-of-freedom position on a plane, at least 3 wires are required. For the joint training mechanism, operation for determining a position is done in space. Thus tensile force is applied symmetrically to keep legs on the plane at all times, requiring 6 wires. One wire is assumed to move within the plane of the symmetric axis while 4 move, 2 at a time, mutually bisymmetrically. Thus 5 wires are attached to the joint training mechanism.

We analyzed wire control as follows: Force applied by the wires to an object depends on the intensity and direction of tensile force produced by the wires. The direction of this force depends on the two points at which one end of each wire is attached from the base and the other end is attached from the object. We controlled the direction of tensile force by moving (**Fig.3**) the wire location on the base so, even when leg posture changes, the direction of force applied to the leg is kept as vertical to the major-axial direction of the leg as possible. As detailed later, longitudinally parallel curved rails on a bed and winding mechanisms that move on the rails are used for the joint training mechanism to prevent wires from mutually interfering.

Physical therapists generally set up motion by fixing

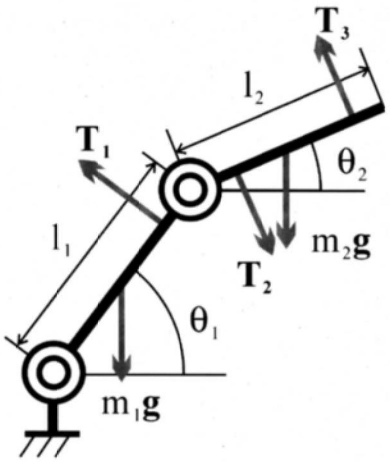


Fig. 4. 2-D model of leg suspension.

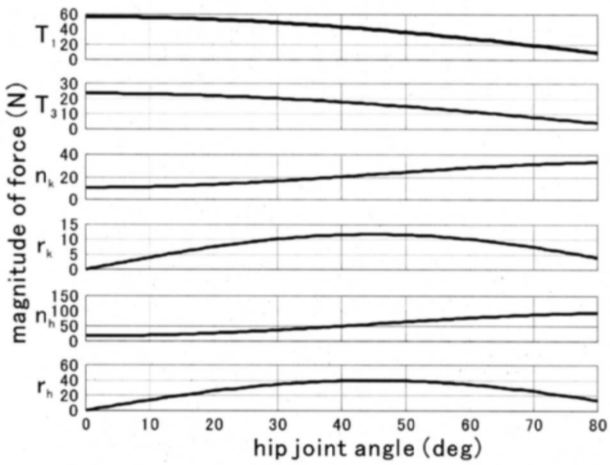


Fig. 5. Results of simulation conducted on the tensile force of each wire and reaction force of each joint.

the proximal end of a subject's leg to a certain place and applying force to the distal end of the leg - the principle used to determine a wire location on the leg.

3.2. Consideration of a 2-D Model

Using a 2-D model (**Fig.4**), we considered motions provided by mechanisms in Section 3.1.

The subject is assumed to be in supine position or in prone position with the trunk fixed. This enables the leg to be simulated by a model of 2-degree-of-freedom arm that moves on a plane. In the simulation below, this arm is assumed to be moved by external force or gravity alone.

The following notation is used in simulation:

- $\mathbf{l_1} = l_1\mathbf{w_1}$: vector directed from the proximal end toward the distal end of a thigh
- $\mathbf{l_2} = l_2\mathbf{w_2}$: vector directed from the proximal end toward the distal end of a lower leg
- l_1: length of the thigh
- l_2: length of the lower leg
- $\mathbf{w_1}$: vector in the direction of the thigh
- $\mathbf{w_2}$: vector in the direction of the lower leg
- θ_1: hip elevation angle (thigh vector ascending vertical angle)
- θ_2: knee elevation angle (lower leg vector ascending vertical angle)
- $\mathbf{d_1} = d_1\mathbf{w_1}$: vector from the rotational center of the hip to the wire-1-attachment point on the leg side
- $\mathbf{d_j} = d_j\mathbf{w_2}$: vector from the rotational center of the knee to the wire-j- attachment point on the leg side (j = 2,3)
- d_1: the distance from the rotational center of the hip to the wire-1-attachment point on the leg side
- d_j: the distance from the center of the rotational center of the knee to the wire-j-attachment point on the leg side (j = 2, 3)
- $\mathbf{T_i} = T_i\mathbf{z_i}$: tension vector of a wire (i = 1,2,3)
- T_i: intensity of the tensile force of the wire-i
- $\mathbf{z_i}$: directional vector of wire-i
- m_1: weight of the thigh
- m_2: weight of the lower leg
- $\mathbf{g}$: gravity vector
- $\mathbf{N_K} = \{r_k, n_k\}$: reaction force at the knee (horizontal component, vertical component)
- $\mathbf{N_H} = \{r_h, n_h\}$: reaction force at the hip (horizontal component, vertical component)

When flexion and extension are quasistatically provided, the equilibria of force and torque are expressed by Eqs.(1) to (4).

$$\mathbf{T_1} + \mathbf{N_H} - \mathbf{N_K} + m_1\mathbf{g} = \mathbf{0} \quad \dots\dots\dots\dots (1)$$

$$\mathbf{d_1} \times \mathbf{T_1} + \mathbf{l_1} \times \mathbf{N_K} + \frac{1}{2}\mathbf{l_1} \times m_1\mathbf{g} = \mathbf{0} \quad \dots\dots (2)$$

$$-\mathbf{T_2} + \mathbf{T_3} + \mathbf{N_K} + m_2\mathbf{g} = \mathbf{0} \quad \dots\dots\dots\dots (3)$$

$$-\mathbf{d_2} \times \mathbf{T_2} + \mathbf{d_3} \times \mathbf{T_3} + \frac{1}{2}\mathbf{l_2} \times m_2\mathbf{g} = \mathbf{0} \quad \dots\dots (4)$$

When the tensile force of each wire is applied to the major axis of the thigh or the lower leg at right angles,

$$\mathbf{w_1} \cdot \mathbf{z_1} = \mathbf{w_2} \cdot \mathbf{z_2} = \mathbf{w_2} \cdot \mathbf{z_3} = 0 \quad \dots\dots\dots\dots (5)$$

Not all unknown variables can be determined by Eqs.(1) to (5) alone, an evaluation function f is introduced.

$$f = r_h^2 + n_h^2 \rightarrow min.$$

Function f makes the reaction force applied to the hip as small as possible.

Behavior simulation of training with the proposed mechanism conducted with this 2-D model is detailed below.

Example of simulation: a typical pattern in training practice is related to hip flexion and extension. The subject is assumed to be in supine position, with knees extended and wire-2 of the 3 wires not used, expressed as follows:

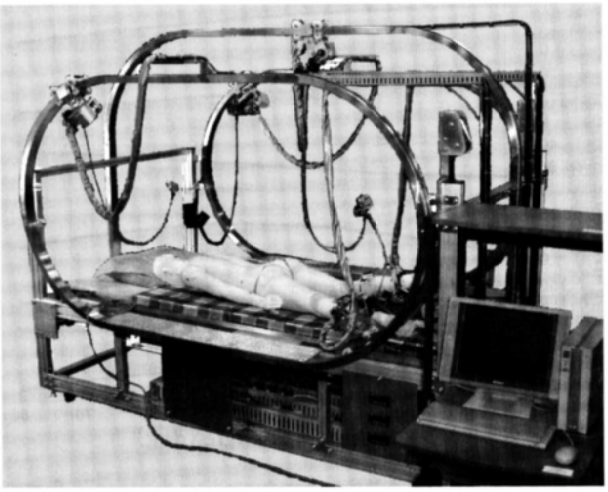


Fig. 6. Experimental system.

$$\theta_2 = \theta_1 \quad (6)$$

$$T_2 = 0 \quad (7)$$

No evaluation function is introduced to prevent redundancy.

Figure 5 shows the results of estimation conducted on the tensile force of each wire and the force applied to each joint using Eqs.(1) to (7). Shown from top to bottom are changes in the tensile force of wire-1 and wire-3, in the reaction force at the knee (horizontal component, vertical component) and the hip (horizontal component, vertical component), and in the hip flexion angle. For calculation, the following parameters are used:

$l_1 = 0.4[m]$
$l_2 = 0.37[m]$
$m_1 = 6.5[kg]$
$m_2 = 3.5[kg]$

For calculation of m_1 and m_2, body weight is assumed to be 65[kg]. The ratio of the weight of each part to body weight is shown based on measured weight of 4 Japanese adult men[10].

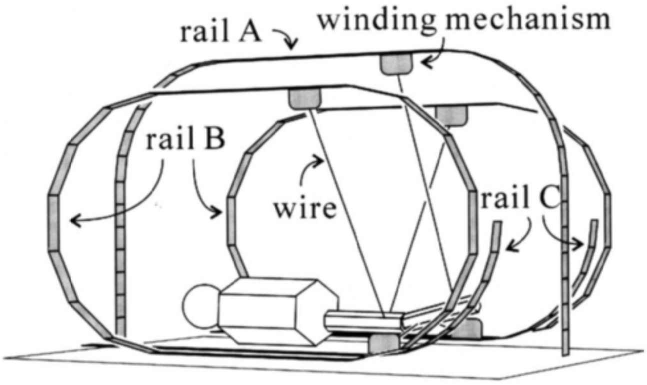
3.3. Experimental System

Figure 6 shows the experimental system. **Fig.7(a)** and **(b)** show the formation of 5 rails. The system and a bed are incorporated, measuring 2.5[m] long, 1.7[m] wide, and 2.1[m] high.

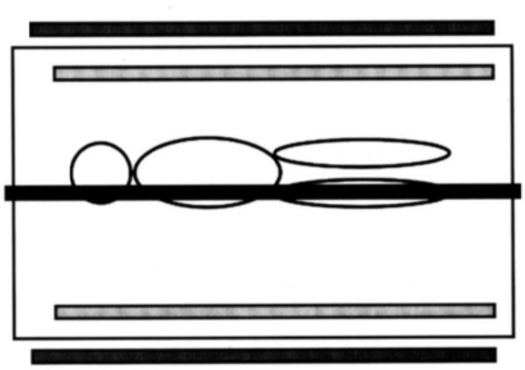
Each rail has a winding mechanism that moves on the rail via an AC 40[W] motor and a timing belt under the bed. As shown in **Fig.7(b)**, two rails B and two rails C are bisymmetrically arranged with rail A between, each rail B and C group having one locomotive motor in common.

The left and right winding mechanisms move simultaneously, and 3 motors move winding mechanisms.

The left side of a subject in supine position corresponds to left rail B and left rail C while the right side of the subject corresponds to right rail B and right rail C. A DC 10[W] motor winds each wire. Each rail is formed



(a) Perspective view



(b) Plan

Fig. 7. Construct image of rails.

by combining circular arcs with straight lines to keep the direction of the tensile force vertical to the major axial leg direction, independent of change in the joint angle. Rail A, rails B and rails C differ in shape.

Each wire is attached to a belt fitted to a leg, so force can be applied to the leg by drawing the belt. The spot to which the belt is fitted is determined with reference to how to hold the leg in training manually described in 3.1. The following 3 spots are chosen:

- rail A: on the trunk side approx. 0.1[m] from the ankle
- rails B: on the trunk side approx. 0.1[m] from the knee
- rails C: on the peripheral side approx. 0.1[m] from the knee

In system operation, before the start of training, the position of each winding mechanism and the length of each wire are adjusted individually to fit the leg properly. A motion pattern (a target path) is then selected. Body-dimensional parameters (the length of the thigh and the lower leg) and motion parameters (starting angle, finishing angle, angular velocity, and the number of repetitions) are input numerically. Target values with time about the joint angle are obtained from given parameters, and the position of each winding mechanism and the length of each wire are geometrically calculated. A condition imposed is that the tensile direction of the wire be perpendicular to the major axis of the leg to uniquely determine the position of the winding mechanism and the length of the wire. The position and length thus calculated are taken as the target values for PTP control. The sampling cycle is 0.1[s].

Motion patterns can variably be set, but the following two patterns are used:

- knee flexion and extension in prone position
- hip flexion and extension in supine position

For safety, the following measures are taken. Each rail and winding mechanism has limit switches to restrict the range of motions. When the tensile force of each wire exceeds a certain percentage of body weight, the system stops automatically; a load cell detects tensile force at a certain place on the wire. When a PC key is pressed during training motion, it is programmed to halt operation. An emergency switch within the subject's immediate reach operates when pressed to turn off the system.

4. Experiments

4.1. Experiment on Knee Flexion and Extension

This section details experiments on training motions conducted with a test dummy. Knee flexion and extension experiment and hip flexion and extention experiment are conducted separately.

In the knee experiment, the extended knee is taken as 0[deg] and the direction of flexion is taken as positive. Three reciprocating motions at a knee flexion angle ranging from 20[deg] to 50[deg] are taken as one target motion, and the angular velocity is assumed to be 1[deg/sec]. The right leg of the dummy in prone position is used as the target of motion. Only wire A is used in this experiment. Of all wires used, that connected to the winding mechanism on rail A is called wire A; the same applies to wires connected to rails B and C.

The test dummy was developed by the former Agency of Industrial Science and Technology for testing medical equipment. It is 1.649[m] tall and weighs 48.2[kg]. The thigh is 0.402[m] long and the lower leg is 0.358[m] long; one leg weighs 9.7[kg]. The dummy is placed on the bed with its right leg parallel to the central axis of the bed (just under rail A) and with the rotational center of its hip set at the center of the bed.

We used a goniometer to measure the joint angle.

Figure 8 shows changes in angle and tensile force with time. Dotted lines represent the predicted values simulated in Section 3.2. Solid lines represent actual values measured in the experiment. The figure shows that---

(1) Knee flexion angle: Angles measured at the knee are generally larger than simulated angles, presumably because the goniometer was attached to the position determined visually and a seam on the dummy was used as a supplementary mark to determine a goniometer-attachment point. The seam did not agree with the major axis of the leg, forming an offset of about 20[deg].

By reference to a relative angular change -- the difference between maximum and minimum values -- the amount of angular change corresponds to 70 to 85% of

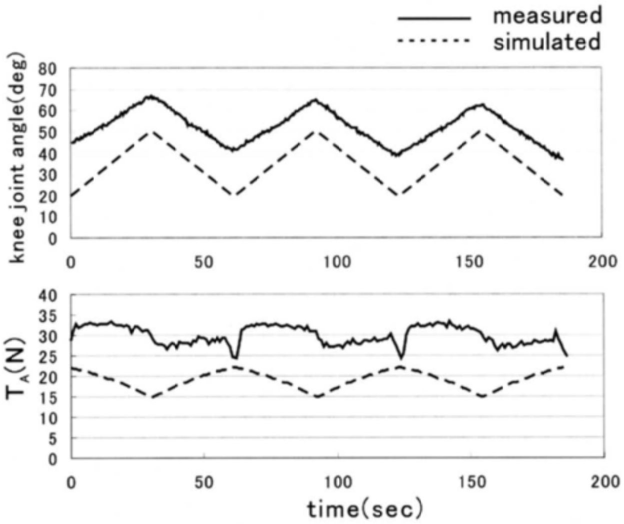


Fig. 8. Simulated and measured value of knee flexion · and extension.

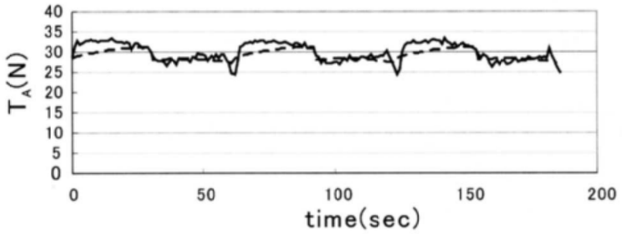


Fig. 9. Simulated and measured value of tensile force on the assumption of resistance force of knee.

the amount of target change. Displacement motion patterns are reproducible.

(2) Tensile force of wires: A specific pattern is seen in changes in tensile force. Measured tensile force is generally larger than those predicted in simulation. Predicted tensile force registers the maximum when the knee is fully extended, but measured tensile force sharply declines, presumably because resistance force is generated by elasticity in the outermost layer at the knee of the dummy. It is assumed in a 2-D model that torque is produced at the knee via a nonlinear torsion spring with different spring constants in flexion and extension directions. It is then possible (**Fig.9**) to reproduce discontinuous behavior similar to that observed in measurement.

As repetitive motions are reproducible, it seems possible to reproduce motions needed in leg training.

4.2. Experiment in Hip Flexion and Extension

We conducted an additional experiment on hip flexion and extension, with the motions intended:

The extended hip is taken as 0[deg] and the direction of flexion is taken as positive. A target angle θ_t is set at each 5[deg] from 30[deg] to 50[deg], and two reciprocating motions are conducted from 0[deg] to each θ_t. The angular velocity is assumed to be 1[deg/s]. The right leg of the dummy placed in supine position is used as the target of motion. Three wires, i.e., wire A and the two wires B on the left and right sides are used for moving

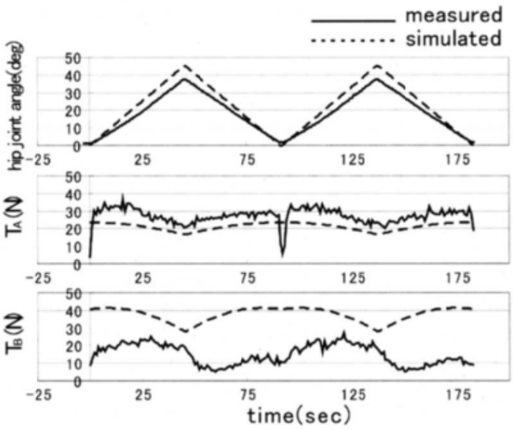


Fig. 10. Simulated and measured value of hip flexion and extension.

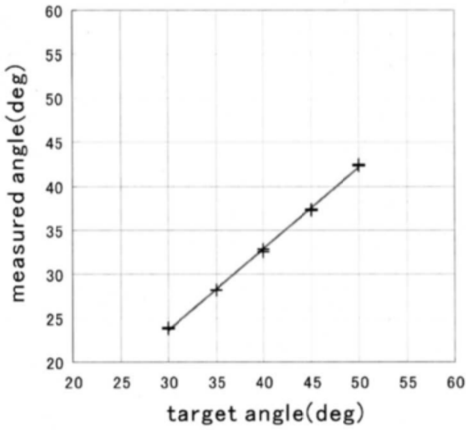
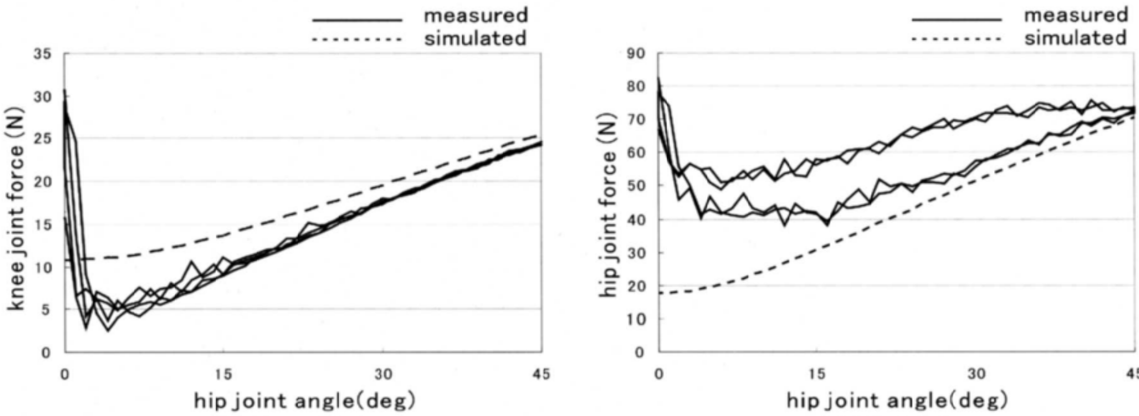


Fig. 11. Relation between simulated value and measured value of hip flexion angle.



(a) Knee joint (b) Hip joint

Fig. 12. Simulated value of knee and hip reaction.

the leg.

As in the experiment in Section 4.1, the dummy is placed with its right leg set to be parallel to the central axis of the bed and with the rotational center of its hip set to the center of the bed.

To measure the hip angle, two clinosensors (Micro Strain FAS-E), one attached to the trunk and the other to the thigh, are used to obtain information on angular difference at the hip, which is then used as the hip flexion angle.

Figure 10 shows changes in the hip flexion angle and tensile force when θ_t = 45[deg]. Dotted lines represent predicted values simulated from Section 3.2. Solid lines represent actual values measured in the experiment. T_A or the predicted tensile force of wire A is assumed equal to the tensile force T_3 of the 2-D model, and T_B or the predicted tensile force of wires B correspond to the tensile force T_1 of the 2-D model that is distributed evenly to the left and right wires.

The experiment showed that ---

(1) Hip flexion angle: **Fig.10** suggests training motions are highly accurate in repeatability, but the difference between the target and measured angular value increases with the flexion angle.

Based on the result of an experiment conducted by changing θ_t, the relationship between θ_t and the maximal value of the angle actually measured is obtained as shown in **Fig.11**. In this case, there is an error of up to approximately 7.5[deg] between θ_t and the maximum angle. As far as the result of measurement is concerned, however, the presence of linearity can be observed between the two above. This means that leg training practice with the use of wires can be realized with high reproducibility.

(2) Tensile force of wires: **Fig.10** shows that the tensile force of wire A maintains a higher value at all times than simulated values with the exception of the level in the vicinity of 0[deg] of the hip angle. The tensile force of wires B shows a lower level at all times than simulated values.

An investigation of patterns and changes in tensile force with time clarified that: for wire A, the changing pattern in simulated values is in agreement with the changing pattern in measured values with the exception of that near 0[deg] of the hip angle. For wires B, however, the former changing pattern differs from the latter changing pattern. Similar phenomena were observed even when θ_t is changed. Based on measurements, the magnitude of the reaction force at the knee and hip against the hip angle is estimated as shown in **Fig.12(a)** and **(b)**. **Fig.12(b)** suggests that the reaction force at the hip is accompanied by a hysteretic effect probably due to friction at the joint. In addition, the tensile force of wires is influenced by the aberration of the wire location on the leg side or the aberration of the position of the test dummy, necessitating further study on relations to patterns of changes in tensile force.

There is an almost exact similarity in tensile force change patterns between the first and second reciprocating motions of test training. When leg rehabilitation assistance is applied to clinical training, information about tensile force-change patterns becomes useful for distinguishing normal motions from abnormal ones.

5. Conclusions

We propose leg rehabilitation assistance with parallel-wire mechanisms and designed a 2-degree-of-freedom joint training mechanism for use in knee and hip flexion and extension. We focused on setting the direction of force as uniformly as possible to the major axis of the leg to minimize the load on the leg. To realize this mechanically, curved rails and winding mechanisms designed to move on these rails were introduced.

The results of a series of preliminary experiments conducted with a test dummy proved it possible for the proposed mechanism to give training motions to the leg with high reproducibility.

We plan to introduce improvements using an experimental system for developing new assistance able to realize further precise motions and tolerant of severer clinical testing. We will also work to develop a mechanism in which the number of degrees of freedom is further increased or a measurement device designed to provide each subject with physiological characteristics or with the existing condition of recovery that also builds up psychological encouragement.

References:

1) R.B. Salter, D.F. Simmonds, B.W. Malcolm, E. J. Ramble, D. MacMichael, "The biological effect of continuous passive motion on the healing of full thickness defects in articularcartridge: An experimental investigation in the rabbit," The Journal of Bone and Joint Surgery, 62-A, pp.1232-1251, 1980.
2) T. Shimada, et al., Manual for Physical Therapy, Ishiyaku Publishers, Inc., 1996.
3) T. Ohtani, "Problems in Knee CPM Appliance and Countermeasures," Journal of the Society of Biomechanisms, 18-4, pp.211-215, 1994.
4) Sakaki T., Okada S., Okajima Y., Tanaka N., Kimura A., Uchida S., Taki M., Tomita Y. and Horiuchi T., "TEM: Therapeutic Exercise Machine for Hip and knee Joints of Spastic Patients," Proc. of Sixth International Conference on Rehabilitation Robotics, pp.183-186, 1999.
5) S. Kawamura, M. Ida, T. Wada and J. L. Wu, "Development of A Virtual Sports Machine using A Wire Drive System -A Trial of Virtual Tennis-," Proc. of the 1995 IEEE/RSJ International Conference on Intelligent Robots and Systems, pp.111-116, 1995.
6) M. Tateno, H. Tomita, S. Hatakeyama, O. Miyashita, A. Maeda, and S. Ishigami, "Development of Powered Upper-Limb Orthoses," Official Journal of the Society of Life Support Technology, Vo.5, No. 5, pp.156-164, 1993.
7) T. Shimada and T. Kaneko, Joint Motion Impairment - Evaluation, Physical Therapy and Occupational Therapy, Medical Press, 1990.
8) K. Homma, O. Fukuda, T. Koda, Y. Nagata, S. Hashino, and M. Usuba, "Development of a Leg Rehabilitation System- 1st Report," Proceedings of SOBIM 2000, pp.203-204, 2000.
9) A. Ming and T. Higuchi, "Study on Multiple Degree-of-Freedom Positioning Mechanism Using Wires (Part I) -Concept, Design and Control-," International Journal of The Japan Society for Precision Engineering, Vol.28, No.2, pp.131-138, 1994.
10) Human Engineering and Human Body Measurement Committee, Diagram of Human Body Measured Values, Ishiyaku Publishers, Inc., 1968.

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Brief Biographical History:

1986- Joined Mechanical Engineering Laboratory, AIST, MITI, Assigned to Advanced Technology Division

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2001- Joined National Institute of Advanced Industrial Science and Technology

Main Works:

- "The Influence of the Motion of Powered Ceiling Hoists on the Subjective Sense of Safety," The Japanese Journal of Ergonomics, Vol.36, No.4, 5-8, 2000.

Membership in Learned Societies:

- Japan Ergonomics Society
- The Japan Society for Precision Engineering