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Technical note

Automatic suspension device for gait training

J. KAWAMURA*, T. IDE**, S. HAYASHI*, H. ONO*** and T. HONDA*

*Department of Physical Medicine and Rehabilitation, Osaka Rosai Hospital, Osaka, Japan
**Department of Orthopaedic Surgery, Yamanashi Medical College, Yamanashi, Japan
***Horikawa Hospital, Kyoto City, Japan

Abstract

The automatic suspension device (REHABOT) suspends the patient's body in a standing position allowing the patient to walk around the circular handrail without forward propulsion. Reduction of body weight is accurately maintained automatically while safely supporting the patient.

The device was used for 23 patients with orthopaedic disorders or central nervous system disorders who were chosen because of their initial difficulties with gait training in parallel bars.

Its advantages are that (1) it may be used for patients with open wounds or cardiac problems, or patients using prostheses or orthoses, (2) preparation and walking practice are simpler both for patients and staff than the therapeutic pool and walking trolley, (3) running costs are lower than the therapeutic pool. Its drawbacks are that the initial cost is relatively high, only one patient can be trained at a time, and the effect of warm water is missing.

The automatic suspension device will become one of the new and fundamental pieces of equipment for gait training, especially for hospitals where there are many elderly patients and also severely and multiple disabled persons.

Introduction

The automatic suspension device named REHABOT was developed as a piece of equipment for gait training by Dr. Ide at the Department of Orthopaedic Surgery, Yamanashi Medical College with the cooperation of Japan EM Co., Ltd. and is presently supplied by the Sumire Medical Corp. (Ide and Nakajima, 1986; Ide *et al.*, 1993).

The device has been used for gait training at the Department of Physical Medicine and Rehabilitation, Osaka Rosai Hospital since 1988.

This paper introduces the structure and function of the device and reports some clinical experiences at the Osaka Rosai Hospital.

Structure and function of the device

Basically, the device consists of a central shaft, a suspending arm containing a control section, and a sling. The suspending arm which extends horizontally from the central shaft is able to rotate 360° in the horizontal direction and 30° vertically both upward and downward. Presently, two kinds of slings are available which are mounted at the end of the arm. One of the slings is attached under the patient's axilla and trunk with a safety belt placed around the patient's chest-wall (under-arm sling) (Fig. 1). The other sling is similar to the harness of a parachute and is able to lift the patient strongly and comfortably, even supporting more than two-thirds of bodyweight (parachute sling) (Farrimond, 1989).

Compressed air is used as the power source for the suspending force. The patient is suspended in a standing position and is able to walk around the circular handrail with reduction of the body weight and without the aid of forward propulsion.

Four kinds of sensors are installed to detect the load, the air pressure, the height of the suspending arm, and the rate of rotation. As changes occur in the load, a load-cell sensor which is installed between the end of the arm

All correspondence to be addressed to Dr. Jiro Kawamura, Department of Physical Medicine and Rehabilitation, Osaka Rosai Hospital, 1179-3, Nagasone-cho, Sakai City, Osaka 591, Japan.

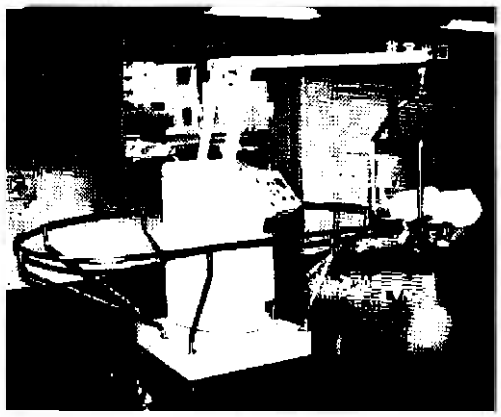

Fig. 1. Automatic suspension device (REHABOT).

and the sling perceives them and controls the suspending force with a microprocessor. Once the suspending force has been set, it will automatically be maintained by these sensors and a microprocessor. The patient is prevented from falling down by an emergency locking system of the lifting arm which is activated immediately after detection of any sudden change in load or height of the arm (Fig. 2).

Clinical experiences

Patients

There were 1,793 patients who received medical rehabilitation at the Department of Physical Medicine and Rehabilitation of the Osaka Rosai Hospital from August 1988 to April 1991, of which 1,030 patients received gait training because of orthopaedic or central nervous system disorders. The device was used for 23 patients who were chosen from 1,030 patients because of their difficulties with gait training in parallel bars. There were 12 female and 11 male patients ranging in age from 15 to 79 years (mean age 54 years).

Sixteen patients had orthopaedic disorders, of which 4 patients had bilateral surgery simultaneously (total knee replacement or high tibial osteotomy), 9 patients unilateral surgery (femoral head replacement, total hip replacement, or total knee replacement) with previous disorders (osteoarthritis of hip or knee joint, trans-femoral amputation or hemiparesis on the contralateral side, or rheumatoid arthritis), 2 patients juvenile rheumatoid arthritis with severe osteoporosis of the spine, and one patient was a bilateral trans-femoral amputee. Of these 16 patients, 8 were able to initiate gait training both in the therapeutic pool and with the automatic suspension device, but the other 8 patients were not able to initiate gait training in the therapeutic pool because of percutaneous fixation after high tibial osteotomy (3 patients), use of a lower limb prosthesis (2 patients), use of a spinal orthosis for severe osteoporosis (2 patients), hemiparesis on the contralateral side (1 patient).

Seven patients had central nervous system disorders, and of these 2 patients had hemiparesis with other difficulties (knee contracture or obesity) and 5 patients incomplete quadriplegia. Furthermore, one patient of the latter 5 patients had also cardiac insufficiency. None of them was able to undertake pool therapy.

Gait training using the robotic device was started after completion of a tilting table routine

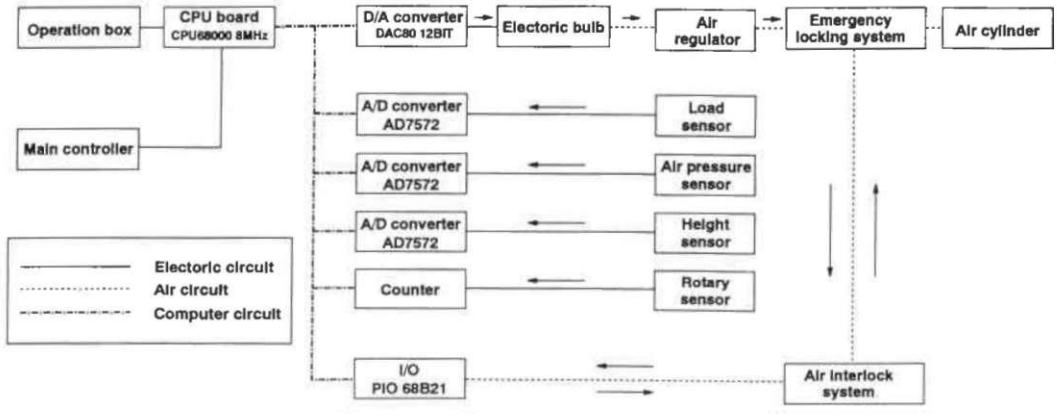

Fig. 2. Block diagram of the automatic suspension device.

and ended when the patients were able to shift to parallel bars. Before starting walking practice with the device, the physical therapists fastened the sling (under-arm sling or parachute sling) on the patient, who kept his clothes on and sat on a chair or a wheelchair. The therapist then set the lifting force of the control unit to assist the patient to stand. It required 2 to 3 minutes for the preparation. Patients walked around the outside of the circular handrail with manual support from the therapists in the initial stages and later by themselves. The handrail is about 10 metres in circumference. The patients circled once to several times (10-100m) depending on their condition. Gait training using the device was carried out once a day, 5 days a week. The under-arm sling was mainly used in cases of orthopaedic disorders who required load reduction of less than two-thirds of bodyweight. The parachute sling was used in cases where greater reduction of load, more than two thirds of bodyweight, was required. In cases of central nervous system disorders, the parachute sling was mainly used because of difficulties encountered with such patients managing the under-arm sling.

Results

The average period of use of the device was 5 weeks for all patients, 3 weeks for orthopaedic disorders and 9 weeks for central nervous system disorders. The average period of total gait training (from the beginning to the end of gait training) was 16 weeks for all patients, 12 weeks for orthopaedic disorders and 26 weeks for central nervous system disorders (Table 1).

The levels of walking ability at the end of gait training for all patients were independent walking without any kind of walking aid in 1 patient, with a cane in 15 patients, with the walker in 4 patients, and in parallel bars in 2 patients. One patient could not shift to the parallel bars until the end of gait training. Although 14 patients with orthopaedic disorders (88%) reached the levels of walking of using the cane, or in one case independent walking, 5 cases of central nervous system disorders (71%) remained at a level of ability of using a walker or lower (Table 2).

Table 1. Average period of gait training

Patients	Period using the device (weeks)	Period of total gait training (weeks)
All*	5±4	16±11
Orthopaedic**	3±1	12±7
CNS***	9±6	26±13

*All: all patients.
**Orthopaedic: patients with orthopaedic disorders.
***CNS: patients with central nervous system disorders.

Table 2: Final levels of walking reached

Final levels	Patient	
	Orthopaedic*	CNS**
REHABOT	0	1
Parallel bars	0	2
Walker	2	2
Cane	13	2
Independent	1	0

*Orthopaedic: patients with orthopaedic disorders.
**CNS: patients with central nervous system disorders.

The following three patients, all of whom were not able to initiate gait training in a therapeutic pool, were typical cases where the device was very useful.

Case 1: A 69-year female. The patient simultaneously had a high tibial osteotomy with percutaneous fixation, bilaterally. After a tilting table routine for 2 weeks, she started gait training 4 weeks after surgery using the parachute sling with load reduction of two-thirds body weight (Fig. 3). One week later, the sling was changed to the under-arm type and load reduction was decreased to one-third of bodyweight. She used the device for 2 weeks, after which time she was able to walk with full weight bearing and shifted to parallel bars. Finally, 10 weeks after starting gait training, she could walk with a T cane.

Case 2: A 25-year male. The patient lost his right lower limb at trans-femoral level due to an industrial accident 4 years ago and started using a trans-femoral prosthesis. Five years after the accident, he suffered from a vascular necrosis of the left femoral head. He received replacement of the left femoral head at the Orthopaedic Department of the Osaka Rosai Hospital. He started a tilting table routine 3 weeks after surgery and gait training 5 weeks after surgery with half reduction of body load using the

Fig. 3. A patient using the parachure sling: high tibial osteotomy with percutaneous fixation bilaterally and simultaneously.

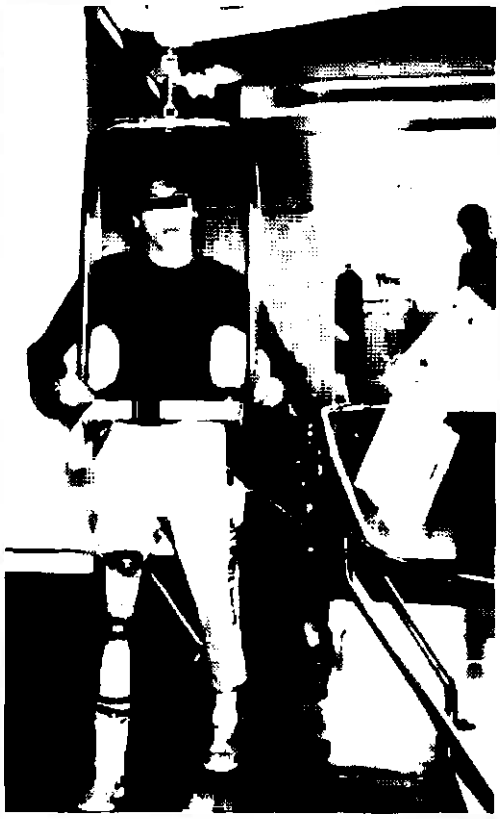

Fig. 4. A right trans-femoral amputee using under-arm sling: left femoral head replacement.

under-arm sling (Fig. 4). After using the device for 2 weeks, he could walk with full weight bearing on the left lower limb, and was then shifted to parallel bars. The period of total gait training was 10 weeks. Finally, he could walk with a trans-femoral prosthesis and a crutch.

Case 3: A 73-year male. This patient fell down the stairs, sustaining a cervical cord injury with incomplete quadriplegia. After the tilting table routine for 7 weeks which took place 5 weeks after the injury, he started gait training with the device using the parachute sling, because of insufficient muscle strength and improper proprioceptive sensation of the upper and lower limbs. Reduction of load was equivalent to 10-20 kg. He continued walking practice with the device for 16 weeks, after which time he was able to walk with a walker. Finally he could move with a walker at home, although still wheelchair dependent outdoors.

Discussion

Gait training usually begins with the tilting table followed by parallel bars, walkers, and various kinds of cane (Corcoran and Peszczynski, 1984). However, there are some patients who are not able to stand in parallel bars for several reasons such as the need of restricted weight-bearing, on both limbs, insufficient muscle strength of both lower limbs, and difficulties in supporting a standing position using the upper limbs, etc.

Pool treatment has been used for such kinds of patients. However, patients having open wounds or cardiac problems and patients wearing orthoses or prostheses cannot use the pool. Some patients are afraid of the water. Furthermore, it requires substantial time and work for both patients and staff for this form of treatment, including the task of taking off and putting on clothes. The initial cost and

maintenance of a pool are very high and it involves strenuous work for the staff during the treatment (Skinner and Thompson, 1983).

The automatic suspension device enables gait training even for patients who have open wounds, percutaneous fixation, prostheses, orthoses, etc. The preparation before the walking practice with the device is simpler than for the therapeutic pool for both patients and staff. Staff costs using the device also are low. The running cost of the device is merely the cost of electricity.

Formerly, the walking trolley was used for patients with orthopaedic disorders and central nervous system disorders. However, the problems of the walking trolley were the difficulty of setting the sling and lifting the patient and the imprecise control of the reduction of load bearing. This caused patients to lose balance occasionally (Hattori and Hara, 1964; Hosokawa, 1964; Sugiyama *et al.*, 1964; Boyle, 1965).

Although the purpose of the automatic suspension device is similar to that of the walking trolley, the automatic suspension device can control the reduction of load precisely and with security. The adjustment and fitting is easier than the walking trolley and there is no chance of the patient falling down.

Walking around the circular handrail enables the patients to walk uninterruptedly and thus reduce the frequency of manual support by therapists to permit turning around. Dizziness did not occur from walking around the circular handrail because the patients could not walk swiftly. Compared with pool therapy, patients infrequently were afraid of the device. None of the patients refused to use the device. There was no accident, such as a patient falling down during training with the device.

Although patients with central nervous system disorders needed longer periods of gait training and also final levels of walking ability were lower than for patients with orthopaedic disorders, work by staff during training with the device was easier and safer in comparison with the walking trolley.

Stubbies have been used for prosthetic training often in cases of bilateral trans-femoral amputation before training with full-length articulated prostheses. Using the device, a bilateral trans-femoral amputee could begin walking practice without the help of stubbies. When gait will be achieved by combining assistive devices, such as reciprocating gait orthoses (Beckman, 1987) and functional electrical stimulation (Kralj and Bajd, 1989); or when other new technology is intended, the device could be very useful.

The number of patients trained with the device was equivalent to about 1.3% of the total number who received medical rehabilitation at the department and about 2.2% of the number of patients who received gait training during the period of the study. There were 156 patients who received pool treatment for the same period. If there were no therapeutic pool the number of patients trained by the device would have increased.

Concerning the drawbacks of the device, (1) it does not have the thermal and buoyancy effects of warm water (Walsh, 1990), (2) only one patient can be trained at a time, and (3) the frequency of its use is not high.

Conclusion

The automatic suspension device is useful for patients who are not able to initiate gait training in parallel bars, especially in cases involving difficulties of entering the therapeutic pool. Training is easier and safer and staff costs also are lower than for pool treatment and walking trolley. The running cost of the device is low.

The authors believe that the automatic suspension device will become one of the new and fundamental pieces of equipment for gait training, especially for hospitals where there are increasing numbers of elderly patients and also severely and multiply disabled persons.

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