Cause of Active Motor Function by Passive Movement

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Abstract. It is well known that active horseback riding therapy is effective for body muscle function and psychological well-being. Initially, we wanted to introduce this horseback riding therapy into Japan. But, there are practical difficulties with regard to keeping horses in our country, especially in hospitals of urban areas. Therefore, we think the only (practical) method of reproducing horseback riding conditions is the simulator. One purpose of the development of a horseback riding simulator is to make an assessment system and to establish a training system for body-balance functions. Another purpose is for the strengthening of leg and trunk muscles through active prevention of loss of balance. Consequently, the muscles are trained, and the simulator leads to the treatment of Lower Back Pain. In 1985, KIMURA developed a prototype horse back riding simulator. It was a machine, which made six movements, which reproduced the movement of a horse’s saddle. Six motors were used for the machine. The six movements were: ① pitching movement, ② roll movement, ③ twist movement, ④ movement forward and backward, ⑤ side to side movement and ⑥ vertical movement. Although individual movement was possible, the six movements were not synchronized. After the passage of ten years, we have now succeeded in the reproduction of the movement of a horse’s saddle by using a parallel mechanism and motion capture. A computer memorized a horse’s movement, and reproduces the horse’s back movement in the simulator. We could make the electro-myographical analysis of the rider.

Key words: Horseback riding exercise, Parallel mechanism, Body balance.

INTRODUCTION

In the latter half of the 20th century, the development of medical equipment hardware such as diagnostic machines, therapeutic machines, prosthesis and other medical equipment was accomplished by industrial technology.

A new problem presents itself when trying to develop an energetic and healthy senior citizen. Presently, the average family consists of 1.38 children; consequently, within the time span of the next 20 years one person in every four will be 65 years old. This results in the caring of one senior citizen by two persons, except in areas of high unemployment, because most of young persons under 20 years old are depending their parents.

In an epidemiology study, however, it was concluded that longevity could be extended by only two years. The medical community has tried all possible means to extend the life of elderly persons by treating fatal geriatric diseases, cancer, communicable and other intractable diseases. This
results in the need for assistance from industrial technology to make up new devices.

NECESSITY OF AUTOMATIC TRAINING MACHINE AS BODY FUNCTION ACTIVATOR

Physiologically, the characteristics of physical strength (muscle power, endurance and body balance) begin to decrease when the age of 60 is exceeded. This decrease in physical strength may be improved in elderly persons through continued training, effectively moving this physical boundary to the age of 70.

As a person grows older the loss of motivation will induce a decline in aggressive qualities, this decrease in function cannot be overlooked if left in its present condition.

The sixth decade of age is the most opportune time to improve the strength of the senior citizens and overcoming the considerable problem of motivation for physical strength training may be accomplished easier by any technique that encourages this endeavor.

A transitive movement (a passive movement for the person) may lead to the development of reactions that compel voluntary movement (an active movement for the person). Various mechanical candidates that utilize the technique of virtual reality (VR) rise to the top of considerations when the latest technology is surveyed.

Kimura, T (*1) thought about introducing a horse riding exercise, which was widely used in Northern Europe as rehabilitation training equipment, or for age prevention of senior citizen’s in 1971. The authors planned to develop a Horseback Riding Exercise Machine (HREM) by using VR technology, and introduced it in 1986.

WHAT IS THE HORSE-RIDING MACHINE?

The movement of the horse’s saddle accurately is divided into seven elements as follows:

a. Vertical motion.
b. The movement backward and forward.
c. Side to side movement.
d. Incline backward and forward (pitching).
e. Right and left incline (roll).
f. Right and left turn (twist).
g. Acceleration change which takes place because of movement of the horse body.

In developing the HREM, however, (g.) was overlooked as a function, as the design was for a stationary machine.

The big effect achieved in the muscle fiber by training the senior citizen is accomplished with the red muscle fiber. White muscle fiber, which is used in reflex action, becomes less effective as a person ages. From a medical viewpoint it is a significant problem to effectively train muscle fiber by using a different function of the same muscle fiber.

In the horse riding therapy of Europe (photo. 1), the horse was used in training of children with mental disorders, such as cerebral palsy or patients with lower back pain or a body balance disorder. However, it is not practical to use this method of treatment directly to activate the physical functions of senior citizens in Japan, because horses cannot be bred in facilities or at hospitals in Japan and reproducing the physically large saddle size as well as the movement of the horse’s saddle would be difficult and dangerous for the senior citizen. For these reasons this therapy was not promoted in our country.

Kimura created a prototype machine, for trial purposes, that reproduced the movement of a horse’s saddle by using a mechanically driven source with six individual motors in 1985. The machine’s driving part was separate from the saddle, making the saddle movement inaccurate because the pendulum movement was mixed with the movement of the saddle. In addition, we couldn’t synchronize the six elements like horseback movement. Because unifying the saddle movement was difficult due to the lack of technology and the lack of engineering expertise of
the developers.

The authors obtained funding for further development of the HREM from the Silver Service Promotion Association (affiliated corporation of the Ministry of Health and Welfare) and awarded development to Matsushita Electric Works, Ltd. (Inc.) laboratory in 1998. Basically, the use of a parallel mechanism, as a backbone, enabled the development of the horse-riding machine to advance greatly. That is, the movement of the saddle was able to perform free movement completely, by centering on one point and moving in three axes. Furthermore, it became possible to reproduce the movement of the saddle, by studying the actual horse movement beforehand with the aid of a computer system.

Physiological evaluation of the simulation was performed not only for this use, but also for use in recreational equipment. Additionally, the usage could be expanded to a horse riding training machine and to a Balance Exercise Machine for senior citizens. The possibility of its usage has grown in the area of body muscle training and for the treatment of lumbago through posture training.

To be precise, it is not merely a “Horse simulator”, but a machine for treatment and training. In addition, during its development it was expected that it would be used as a robotic horse for health equipment (photo. 2).

**INTRODUCTION OF VIRTUAL REALITY (VR) TECHNIQUES**

Attitudinal reflex is important for the body’s function of keeping an upright posture. Attitudinal reflex consists of localization equilibrium reflection, metamere equilibrium reflection and equilibrium reflection of pan-local equilibrium reflection etc. The reflex consists of recovery reflex of the labyrinth, sight, body and the function that the cerebral cortex controls. Persons with a healthy posture maintenance function can perceive the direction of gravity. Based on this, the posture maintenance function works with the posture control mechanism and feedback sight information, and when a person sits on the saddle, they control their posture and balance by horse riding. It should be expected that when non-disabled persons use the horse riding training machine they apply sight information to maintain posture, and not only depend on equilibrium reflex and recovery reflex, but also correction by sight when training. Sight becomes necessary and indispensable for compensating for vibration from minor speeds synchronized with the vibration of the saddle and the perceived speed during progress, (to our regret, the robotic horse does not walk and it is the only function of the seven horse’s saddle movements that is not used).

In recent years many theme parks etc. have made the best use of virtual reality. We can experience VR with vibrations such as on floors, chairs and the projection of wide-angle degree views. For that, we receive an impression in which the main factor is visual sensation. The software that makes the reflex agree with perceived body motion is not easily maintained for posture. Moreover, it may be difficult to set and maintain the extending chair sitting position balance on the horse. Presently, we have not yet arrived at the stage where the actual perceptions merge with the reflexes that are capable of being generated. This would be a method of recognizing the relation from the floor to the horse with the results being displayed on a large screen. Recently, head mount display (HMD) or eye mount display (EMD) are being used for individual
equipment use. Using these it would be necessary to be possible to confirm the view of the relation from the horse to the floor through HMD or EMD. In brief, it transmits to man, peripheral scenery as information, which is sensed by sight when the balance is lost on the horse. It can be said that it would be dangerous to give no information that the balance is lost, and also that loss of this information while using HMD and EMD feedback is more hazardous.

The use of HND or EMD feedback is a problem that can be examined in the future. At present, basic research is needed for the development of software, but development of such machine is possible depending on the technology available. Hoping for the super dome screen as seen in theme parks is not realistic. If possible, we want to make up a small chamber with all functions. It would be better to use the present one which brings a more realistic sense such as a pseudo sense. Now, the stage is set in which all of the possibilities are examined. When applying the simulator to training of maintenance posture, the main considerations are horse movement and view of the horse. However, if activating the mind and body of the senior citizen is purpose, it would also be necessary to offer the user information to motivate the user. It is likely to be used so that the sound, wind and smell, etc. may stimulate the senses as well as the view. The effect of the sound cannot be disregarded.

**LOSS OF MOTIVATION**

When the senior citizens lose motivation, and are caught in self-thoughts of “Annoyance” or “Cowardice”, the ability to make training interesting would be extremely limited. Even if senior citizens show lack of concern for the external world, it is said that they are interested in family (especially children or grandchildren), young men and women, food, money and rewards to some extent. The effect can be expected to stimulate a psychological trigger point, but we have no evidence.

It is thought that a lot of energetic elderly persons would want to use the HREM if it were available in recuperation facilities, hot springs, etc. even for a usage fee. It is thought, however, that a reward type of exchange may be good for the senior citizen who is losing motivation to attend health service facilities for the elderly or the home for the aged.

**EVIDENCE THAT PASSIVE MOVEMENT CAUSES ACTIVE MOVEMENT**

When we go down the stairs step by step, it is thought that we do not become tired because of the energy of position, however, almost 1/3 the energy is consumed when going up the stairs. When going down a hill, for even a person that is skilled in downhill skiing, extensive energy is consumed and a slight tiredness is felt. When doing more, beginner’s muscles will tense; using more muscle power than is necessary, and because of this, muscle fatigue becomes a problem. In the case of horse riding, in order not to fall from a horse, and to maintain posture the muscle contraction needed to maintain posture is induced. This muscle contraction has a big effect on strength training, since physiologically this muscle contraction is active muscle contraction. It is an active muscle contraction induced as a result of a passive movement, or in other words a passive movement causes an active movement.

An experienced horse rider is in a state in which a stable, static posture is maintained when horse-riding Lumbo-dorsal muscle contraction and slight abdominal muscles contraction erect the spine and the consumption of energy is minimal. However, both strongly lumbo-dorsal muscles (spinal erector muscles group) and abdominal muscles contract firmly if the horse rider is a beginner.

Table 1 shows the situation of the caro electrical discharge (electromyogram: EMG), which was originated according to the movement elements of the HREM.

When a non-disabled person is sitting on a chair, posture will be maintained by the use of muscles of turn and lower extremities with both knee joints prohibited from straddling, but being made to stretch. When sitting in a saddle both feet are fastened to the saddle of the horse by stirrups, though it is unstable to keep an upright position on horseback by using the lumbodorsal muscles and abdominal muscles. In order to induce maintenance of balanced it is considered necessary to produce a similar effect in the HREM.

**APPLICATION TO CLINICAL USE**

We did for see that passive movement by horse back induct active body movement on the saddle in order to keep body balance on the saddle. A person
and that uses the saddle, which needs to maintain posture and passively resists movement, voluntarily contracts muscles, consequentially and actively. It will be a treatment and training necessity to make an effort to maintain balance in the saddle of the simulator, contracting the muscles, so as not to fall from the horse.

It is necessary for the future aging society to avoid the situation where a healthy person retires and loses motivation, since this dependence encourages. It should be the responsibility of citizens who live in the 21st century to body function that is sufficient to live actively until death. Presently one fourth of the population is in the age group of 65 years or older. People who are 15 years old or less must be supported. Additionally, 90% or more of the people, up to the age 18 years old are also supported. Moreover, a further 50%, proceed to a college, and the reduction of the work force has serious implications for the whole of Japanese society.

The HREM developed at this time is expected to be used in the assessment and evaluation of posture and balance function, in the treatment of posture, myogenic and postural lower back pain and equilibrium functional disturbance in the near future. However, it has not yet arrived at this stage of use, as the evaluation of this exercise equipment is as yet a qualitative evaluation. Tangible evidence of efficacy will be necessary before its use as treatment equipment.

Data in support of this is being verified now, as a joint research of Kohchi Medical School, Kohchi University of Technology, Matsushita Electric Works, Ltd. and Nippon Medical School. We can use it for health keeping training machine for non-disabled. But this machine would be medical use in a near future; it is necessary to prove the function not only training but also the equipment for medical assessment. If the HREM is to be used as equipment for health improvement, its effectiveness needs to be confirmed.

**FUTURE TOPICS**

In view of the horse’s movement, it seems that almost 100% reproducibility has been achieved, although there are two different points between the simulator and a living horse.

One is that the movement of the horse walking is not simulated and the other is that the simulator horse cannot follow the man in the case where the man on the horse has lost his balance. It does not have the mechanism, which catches the center of gravity movement of the rider. This is similar to the case where the mother who is carrying her baby on her back is able to keep her balance compensating for the baby’s movement. Training in horse riding therapy moves according to the instruction of the therapist who takes the reins and always senses the

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<th>Table 1. Basic data in chair sitting position</th>
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<td>Pitching (change 5°)</td>
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<td>Horizontal back and forward (5 cm)</td>
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<td>Twist (change 5°)</td>
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T7 (seventh thoracic vertebra part) L3 (third lumbar vertebra part). + (electrical discharge of never less than 100 µV). Amplitude increase when chair frame is gripped. We set 60 times per minute of the machine vibration.
movement of gravity of the equestrian. It is extremely desirable to provide this function in equilibrium function training equipment.

On the other hand, if a simulated horse is used as health improvement equipment, it may not need the movement of all six elements in all directions, as in the actual horse. The simulation need only activate muscle training and the balance function is promoted synthetically.

CONCLUSION

Recently, horse riding therapy, which was developed in Europe and America, has been introduced as recreational therapy or animal therapy for mentally disordered children in the club system in our country. In most instances it is not performed as a medical treatment but as recreational therapy.

We paid attention to the physical function of horse riding therapy, analyzed it scientifically and physiologically, proved its utility, planned treatment, rehabilitation training, and motivational strategies for mind and body as a health improvement recreation. As a result of that research, we started the development of the horse simulator, as an equipment for horse-riding training and improving maintenance of balance. It is usually impractical to use actual horses for treatment or exercise in Japan. This is the reason why we are eager to develop a horse simulator. We used the parallel mechanism into HREM in order to move all directions and three dimensions. We could confirm the HREM for it could reappear the living horse’s movement. In order to reproduce the living horse's movement, we used computer assisted motion capture. This HREM is simulated by racing horse. And we are now at the experimental stage. So we can’t have evidence. The movement that we chime is suitable for the physical training.

A preliminary experiment has established that the myo-electrical discharge while sitting in the saddle of the simulator was almost similar to the electrical discharge when in the sitting position on a chair, not leaning against the backrest of the chair. The myo-electrical discharge of lumbodorsal and abdominal muscles suggest that horse riding therapy with the simulator would be effective.

The simulator’s usefulness as healthy exercise equipment is proven and we are convinced of its value as equipment for the assessment, evaluation and training of horse riding.

We will report, when genuine horse movement is accomplished.

The groups, which are taking part in the research and the development, are shown below. National rehabilitation center (until 1998.10.1. Five another physical therapist (PT)). Nippon Medical School, Department of Health Services Administration (After 1998, 10.2.). Matsushita Electric Works, Ltd. Laboratory. Kohchi Medical School, Department of Rehabilitation (after 1998.10.). Kohchi University of Technology. Department of Intelligent Mechanical Systems (after 1999.1.).

REFERENCES