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Comparative Examination of the Vibration Stimulation and Piston Technique Treatments on Muscle Tone Reduction in Children with Cerebral Palsy Who Exhibit Abnormal Muscle Tone at the Musculus Triceps Surae

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1. INTRODUCTION

Cerebral palsy (CP) is defined as "a group of developmental disorders of movement and posture that cause functional limitation or disability associated with disturbances occurring in the foetal or infant brain" [1], and is considered one of the most common causes of physical disability in children [1,2]. Several studies have reported that equinus is frequently observed in patients with CP, likely due to the influence of excessive muscle tone of the musculus triceps surae [3–5]. This abnormal muscle tone of the musculus triceps surae confines standing and walking motions and leads to incidents such as falling [6–8]. Rehabilitation techniques that have been developed to control muscle tone include stretching [9,10], transcutaneous electrical nerve stimulation [11,12], and vibration stimulation [13,14]. Vibration stimulation treatment is a device-using technique with a lower physical burden for therapists compared to other techniques and has been reported to indicate the same level of muscle tone control effect as treatments performed by hand [15]. It is also known to activate interneurons in the spinal cord by vibrating the skeletal muscle, thereby controlling the excitability of spinal motor neurons through presynaptic inhibition [16–17].

The second author of this paper has recently developed a new treatment method called the repetitive rapid transitive joint movement method [18] (hereinafter referred to as the Piston Technique), which is expected to have a muscle tone-controlling effect, and has reported its muscle tone reduction effect in the treatment of finger [18] and hip joint flexor muscles [19]. In a case of Piston Technique treatment subjecting the skeletal muscle of musculus triceps surae with abnormal muscle tone (subject muscle), the knee joint is flexed slightly, the ankle joint is held in near full extension, and bending exercises of the ankle joint are performed at a similar speed as exercises for deep and shallow flexor muscles. It is different from the vibration stimulation treatment that directly stimulates the muscle belly in the point that the subject muscle is rapidly stretched and relaxed repeatedly.

Changing the viscosity of the intercellular substance of the fascia via stretching muscle fibers to improve movement disturbance at the deep fascia is the mechanism by which this technique reduces muscle tone; notably, this technique is expected to achieve the same level of therapeutic effect as myofascial release [20]. The excitability controlling effect of spinal motor neurons by vibration waves can also be expected using this technique, such as seen in vibration stimulation treatment [18,19]. Morita et al. of Nagoya Institute of Technology developed treatment devices incorporating the Piston Technique, such as the Piston Device for Finger (the Piston Technique treatment device for finger treatment, PDF in) and the Piston Device for Foot (the Piston Technique treatment device for foot treatment, PDft). This study aimed to evaluate the effectiveness of the Piston Technique treatment using PDft in reducing abnormal muscle tone of the musculus triceps surae of children with CP exhibiting equinus. The study consisted of a comparative investigation using contracture degree and muscle stiffness levels as measurement indexes with vibration stimulation treatment as the control.

2. PARTICIPANTS AND METHODS

1) Participants

The participants were six children with CP, who were members of a group, organized by the second author of this paper, for children with CP (Table 1). The inclusion criterion was exhibiting abnormal muscle tone at the leg-joint plantar flexion muscle group on the paralyzed side (at level 2 or 3 in the Modified Ashworth Scale [MAS] score). The exclusion criteria were having pain in the lower limbs of the paralyzed side and having a history of anti-contracture drug administration, such as Botox. As per the tenants of the Declaration of Helsinki, the participants and their mothers received an in-depth explanation of the research outline both orally and in writing. Once the participants understood the research outline, their consent for research participation was obtained.

2) Methods

This study was conducted with the approval of the research ethics committees of the authors' organization (approval number: 23001). All participants received treatment using vibration stimulation (vibration stimulation treatment) and the Piston Technique (Piston Technique treatment). The measurement of the vibration stimulation and Piston Technique treatments was performed at intervals of more than one day, keeping in consideration that the effect of one treatment should not affect the measurement results of the other treatment.

Vibration stimulation treatment

The participant receiving the vibration stimulation treatment laid on the bed in the prone position with a towel inserted between the foot and the bed, and a ten-minute vibration stimulation was applied to the left Achilles tendon area after positioning the knee joint in slight flexion and the ankle joint in mid-position. Handy vibe, manufactured by Daito Electric Machine Industry Co., Ltd., was used in the vibration stimulation treatment with a setting of 76.6 Hz vibration (Fig.1), based on a study which reported that low-frequency vibration was effective in controlling muscle tone [21]. The vibration amplitude of the device was 2 mm.

b. Piston Technique treatment

The participant receiving the Piston Technique treatment laid on the bed in the face-up position with a towel inserted between the popliteal region and the bed. After positioning the knee joint in slight flexion and the ankle joint in mid-position, the therapist gently held the tip of the participant's foot on their paralyzed side, with the therapist's palm touching the participant's sole and the PDF placed on the back of the therapist's hand. Using the device's motor as the power source, a ten-minute transitive joint movement exercise was performed on the participant's ankle joint with a speed setting of five bend-and-stretch movements per second (Fig 1).

3) Assessment Scales for Evaluation

The degree of contracture was assessed using MAS [22]. MAS was initially developed as a contracture assessment scale called the Ashworth Scale [23] in 1964 and was improved by Bohannon et al. in 1987. It is now a globally employed contracture assessment scale. The scale aims to assess the degree of contracture in a subject's extremities by moving them transitively using the examiner's hand and evaluating the "resistance" to the movement action through a five-point ordinal scale ranging from "0 = no increase in tone" to "4 = limb rigid in flexion or extension".

A muscle stiffness measuring device (NEUTONE TDM-NA1; TRY ALL Pty Ltd., Japan) was used to measure muscle stiffness. The device pressed the participant's medial gastrocnemius muscle until the pressure handle touched the stopper. Then the gauge needle was used to measure the pressure (N), and the process was repeated five times to obtain the mean value, which was used as the data [24, 25]. Statistical processing was performed using the statistical processing software Stat View-J 5.0. The degree of contracture and muscle stiffness were used as dependent variables to analyze the efficacy of each treatment (i.e., vibration stimulation treatment and Piston Technique treatment). MAS scores and muscle stiffness measurement results were compared using Wilcoxon's signed-rank sum test. Statistical significance was set at a risk rate of less than 5%.

Results (Table 2)

The MAS results indicated that the pre-intervention mean value (standard deviation) was 3.8 (0.4) and the post-intervention mean value (standard deviation) was 2.5 (0.6) in the vibration stimulation treatment, thereby showing no significant difference. In contrast, the Piston Technique treatment results exhibited a significant difference from the pre-intervention mean value (standard deviation) of 3.8 (0.4) to the post-intervention mean value (standard deviation) of 2.0 (0.0), indicating an evident reduction of muscle tone up to the score of 2 in all participants.

The results of muscle stiffness measurements indicated that the pre-intervention mean value (standard deviation) was 30.3 (2.7) and the post-intervention mean value (standard deviation) was 25.3 (2.5) in the vibration stimulation treatment, thereby showing a significant difference. The results of the Piston Technique treatment also indicated a significant difference with pre-intervention mean value (standard deviation) scores of 30.5 (3.3) and post-intervention mean value (standard deviation) scores of 20.7 (2.5).

3. DISCUSSION

In this study, the influence of the Piston Technique treatment using PDft on the musculus triceps surae in reducing abnormal muscle tone was investigated in children with CP who exhibited equinus due to abnormal muscle tone of the musculus triceps surae. The Piston Technique was compared with vibration stimulation treatment by using the degree of contracture and muscle stiffness levels as measurement indexes. The results indicated that a reduction of muscle tone was confirmed in the Piston Technique based on MAS scores that evaluate muscle tone, whereas no evident effect was observed when vibration stimulation treatment was applied. Notably, both treatments exhibited an evident reduction in muscle stiffness after intervention.

According to Noma et al., in the immediate 30 minutes after applying the five-minute vibration stimulation to the post-stroke contracted muscle, the values of F waves, which indicate the excitability of ventral horn cells, and the F/M ratio amplitude are significantly reduced [26]. In this study, vibration stimulation treatment reduced the level of muscle stiffness but did not exhibit a reduction of muscle tone, although this method should be expected to reduce muscle tone.

A motor-driven device was used in the Piston Technique treatment in this study, and the vibration from the device could be transferred from the participant's foot to the lower limb, thereby applying a similar effect as the vibration stimulation treatment. In this sense, vibration stimulation can also influence the effects of the Piston Technique.

In this study, the participant's ankle joint was moved transitively in dorsal and planar flexion repeatedly at a speed of 5 Hz during the Piston Technique; according to a study by Pham et al., corticospinal tract excitation is significantly reduced by transitively moving the metacarpophalangeal joints of a participant's fingers rapidly at a speed of 5 Hz [27]. This supports the theory that the Piston Technique controls corticospinal tract excitation by applying rapid transitive movement to the ankle joint. Regarding the muscle stiffness reducing effect, a study by Lapole et al. reported that applying vibration to the Achilles tendon could reduce muscle stiffness of the musculus triceps surae [21]. It is possible that in this study, vibration stimulation was indirectly applied during the Piston Technique treatment; therefore, muscle stiffness of the musculus triceps surae was reduced as in the vibration stimulation treatment, in which the vibration was directly applied.

4. CONCLUSION

In this study, the effectiveness of the Piston Technique in reducing muscle tone of the musculus triceps surae in comparison with vibration stimulation treatment (control) was investigated in six children with CP, who exhibited equinus due to evident abnormal muscle tone of the musculus triceps surae. The techniques were compared using the degree of contracture and the levels of muscle stiffness as measurement indexes. The results demonstrated that the Piston Technique treatment exhibited a reduction of muscle tone whereas no effect was observed after the vibration stimulation treatment, based on MAS scores that assess muscle tone. Notably, both treatments showed a post-intervention reduction in muscle stiffness levels. In children with CP, the Piston Technique is more promising than vibration stimulation in reducing abnormal muscle tone of the musculus triceps surae.

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