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# Effects of Vibration Rolling on Ankle Range of Motion and Ankle Muscle Stiffness in Stroke Patients: A Randomized Crossover Study

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Background: Vibration stimulation has emerged as a treatment tool to help reduce spasticity during physical therapy. Spasticity includes problems of reduced range of motion (ROM) and stiffness. However, the benefits of vibration rolling (VR) on interventions for stroke patients are unclear.
Objectives: This study aimed to investigate the effect of VR intervention on the ankle ROM and ankle stiffness in stroke patients.
Design: A randomized crossover study.
Methods: Seven stroke patients completed two test sessions (one VR and one non-VR [NVR]) in a randomized order, with 48 hours of rest between each session. Participants completed intervention and its measurements on the same day. The measurements included ankle dorsiflexion and plantarflexion ROM and stiffness of ankle muscles, including the tibialis anterior, medial, and lateral gastrocnemius muscle.
Results: After VR, ankle dorsiflexion ROM, lateral gastrocnemius stiffness, and medial gastrocnemius stiffness improved significantly (all $P<.05$). After NVR, only the lateral gastrocnemius stiffness improved significantly ($P<.05$). Furthermore, in the cases of changed values for ankle dorsiflexion ROM and lateral gastrocnemius stiffness were compared within groups, VR showed a more significant difference than NVR ($P<.05$)
Conclusion: VR improved ankle ROM and muscle stiffness. Therefore, we suggest that practitioners need to consider VR as an intervention to improve dorsiflexion ROM and gastrocnemius stiffness in stroke patients.

Keywords: *Stroke; Vibration rolling; Ankle; Range of motion; Stiffness*

## INTRODUCTION

Stroke is caused by cerebral infarction and cerebral hemorrhage.[1] Stroke may result in several problems including poor balance and gait, spasticity, weakness, and contractures, as well as sensory and cognitive impairments, all of which require much effort in terms of patient care.[2,3] Among these problems, spasticity results in worse motor function, greater pain and stiffness, and reduced range of motion (ROM) of joints.[4,5] Spasticity can be defined as a sensorimotor disorder related to some level of involuntary muscle activation, and it is a consequence of upper motor neuron syndrome.[6,7] Physical therapy intervention, such as static stretching,[8] transcutaneous electric nerve stimulation,[9] extracorporeal shock wave therapy,[10] electromyography biofeedback,[11] and vibratory stimulation,[12] can be used to treat post-stroke spasticity. However, among the various treatment methods, most vibration stimulation studies have been whole-body vibration studies,[12-14] and local vibration studies are lacking.

Among the various local vibration tools, vibration rolling (VR) is a combination of foam roller and vibration function. VR has been reported to improve lower extremity of ROM, flexibility, pain, strength, proprioception, balance, and muscle tone in adults.[15-17] Recently, VR has been reported to improve athletic performance in athletes.[18] These effects are necessary not only for adults or athletes but also for stroke patients. Despite this, VR intervention has not yet been studied in stroke patients.

Therefore, the purpose of this study was to investigate the effect of VR intervention on the ROM and stiffness of the ankle joint in stroke patients and to present the VR as one of the treatments and exercise methods of possible intervention for stroke patients.

## SUBJECTS AND METHODS

### Subjects

The study was approved by the Institutional Review Board of Nambu University (IRB: 1041478-2020-HR-031). Eight stroke patients participated; however, one patient in poor condition was removed during the study. Therefore, seven patients (sex male/female: 6/1; paralyzed side left/right: 3/4; age: 71.43±9.64 years, body mass: 67.00±9.47 kg, height: 170.71±6.52 cm; onset period: 12.57±3.10 month; mini mental state examination, MMSE: 24.86±.90 score; modified Ashworth scale, MAS: 1.21±.27 grade) completed the study. The inclusion criteria were a diagnosis of stroke over 6 months ago, ability to move ankles without assistance, and ankle MAS below Grade 2. The exclusion criteria were as follows: cardiovascular or respiratory disease, orthopedic diseases in the legs, vision or hearing disabilities, and skin diseases of the feet. All participants were informed of the benefits and risks of this study, and written informed consent was obtained from all participants.

### Study Procedures

This study was a crossover study. Assessments performed by each participant were assessed in a physical therapy room at the Department of Rehabilitation Medicine, Suwan Medical Center. Prior to the assessment, participants received instruction on how to perform VR and non-VR (NVR) exercises. During this orientation, participants were familiarized with the procedures, assessment tools, and VR equipment of the study. One day after the orientation session, each participant completed two exercise/assessment sessions in a randomized order, with 48 h of rest between each session. Before the assessment session, each participant completed general physical therapy and rehabilitation exercises. Participants rested before the assessment session. Each exercise/assessment session was conducted in the afternoon. An assessor prepared randomly shuffled sticks (A stick: VR; and B stick: NVR) and sealed each stick in an opaque envelope. Each participant looked for an envelope and opened the envelope to identify the exercise of assignment. The identified exercise was performed first, and the other exercise was performed two days later. The paretic leg of the participants was assessed using ROM of ankle dorsiflexion and plantarflexion, muscle stiffness of the tibial anterior muscle, and medial and lateral gastrocnemius muscles. After the completion of the pre-test assessments, each participant performed the intervention. Each intervention was performed in three sessions for 1 minute per session, and a 30-second rest was taken between each session. Immediately after the intervention, post-test assessments were conducted in the same order as pre-test measures. Participants completed the intervention and its measurements on the same day. One participant in the poor condition was lost to follow-up for the second session. A flowchart of the experimental design is shown in Figure 1.

### Outcome Measures

#### Ankle ROM

The ROM of the ankle was measured using a plastic goniometer. The angle of ankle dorsiflexion in the prone position with 90° of knee flexion was measured. The angle of ankle plantarflexion in the supine position and the ankles outside the bed were measured. The axis of the plastic goniometer was placed on the lateral malleolus. The fixed arm was placed parallel to the line connecting the fibular head, and the moving arm was placed parallel to the line connecting the metatarsal bone of the fifth toe.[19] The measurements were performed by a physical therapist who was blinded to the measured values. The measurer told the recorder when the measurement was complete. The recorder visually confirmed and recorded the measured value. The data used the average of the two measured values. The plastic goniometer showed high interrater reliability (ICC=.87) and intrarater reliability (ICC=.91).[19]

#### Ankle Muscle Stiffness

The stiffness of the ankle muscles of the tibialis anterior, lateral and medial gastrocnemius muscles was measured using the myotonPro (Myoton AS, Tallinn, Estonia). The stiffness of the tibialis anterior in the supine position was measured.[20] The stiffness of the lateral and medial gastrocnemius muscle was measured with the patient in the prone position and with feet hanging over the end of the bed.[21] The

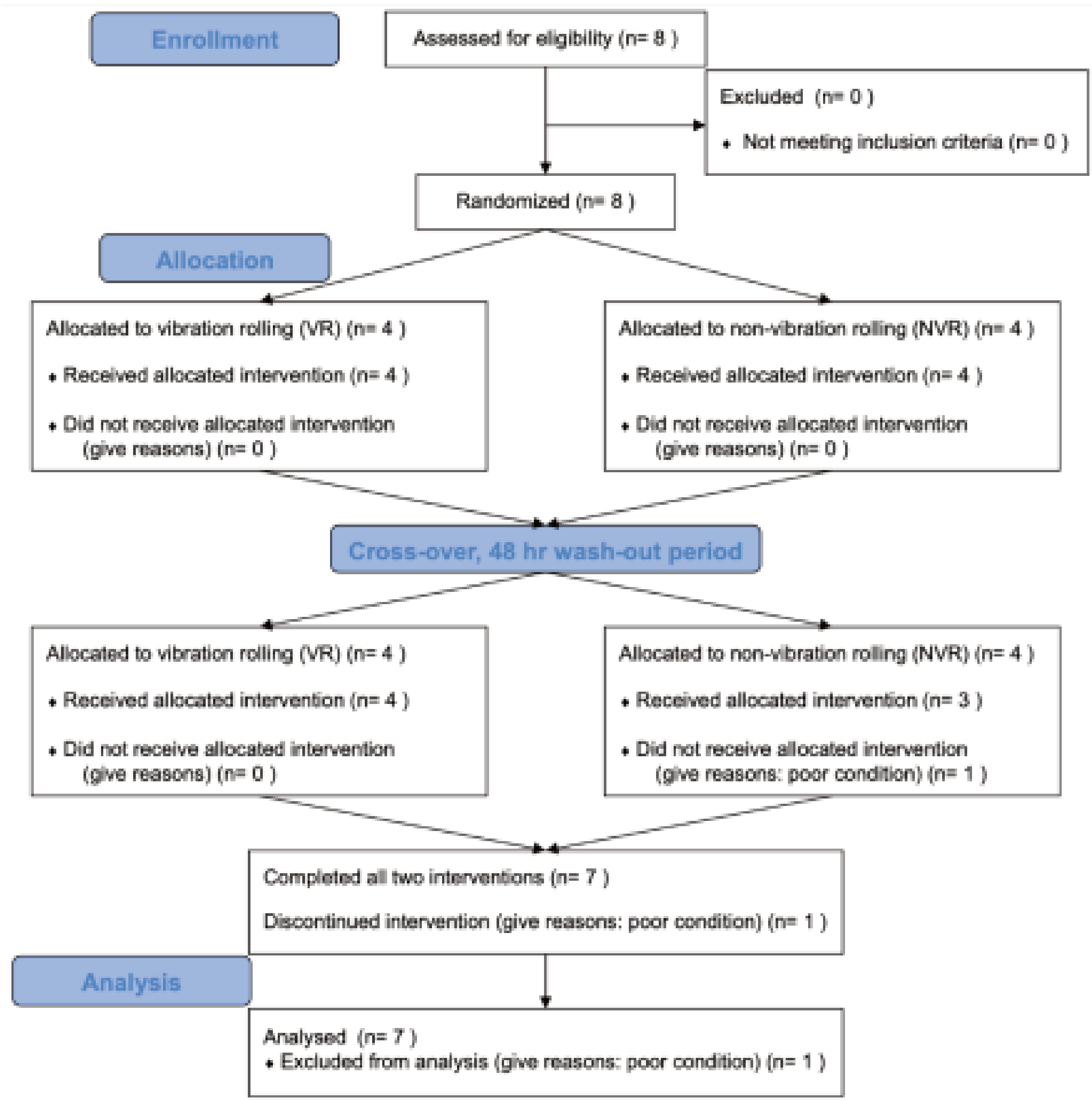


**Figure 1.** CONSORT flow diagram of the experimental design

measurements were performed by a physical therapist who was blinded to the measured values. The measurer told the recorder when the measurement was complete. The recorder visually confirmed and recorded the measured value. The data used the average of the two measured values. The myotonPro showed high interrater reliability (ICC=.93) and intrarater reliability (ICC=.95).[22,23]

## Interventions

### Vibration Rolling (VR)

Participants performed VR using a vibrating foam roller (Vyper, Hyperice, Irvine, CA, US). Participants positioned the vibrating foam roller below the gastrocnemius of their paretic side leg. The frequency of VR was 28 Hz, which has been used in many prior studies.[15,24] Thereafter, patients performed 60 s of

**Figure 2.** Vibration rolling on the ankle joint

dorsiflexion and plantarflexion of their ankle (Figure 2). The physical therapist observed and encouraged the patient to continuously move through the entire ROM. Patients engaged in 30 s of rest in between exercises. Each exercise was performed three times.

### Non-Vibration Rolling(NVR)

The exercise protocols were the same as those used for the VR exercise, except vibration (vibration button off).

### Statistical Analysis

All data analyses were performed using SPSS version 25 (Chicago, IL, USA). Data are presented as the mean±standard deviation (SD). Data were not observed statistically for normality (Shapiro-Wilk's test, $P<.05$), and a few variables were normally distributed. Therefore, nonparametric tests were used. Descriptive statistics were performed for the characteristics of the participants. A Mann-Whitney U test was performed to analyze the differences between VR and NVR by comparing the differences between pre- and post-treatment measurements. The Wilcoxon test was performed to compare pre-and post-intervention results in each group. The effect size (Cohen's d), which is the difference between the pre- and post-means divided by their common SD, was calculated and interpreted as small (d=.2), medium (d=.5), or large (d=.8) to present the magnitude of the effect.[25] The significance level (α) was considered to be $P<.05$.

## RESULTS

### Ankle ROM

For ankle dorsiflexion ROM, VR showed significant improvement in post-test measures ($P<.05$) (Table 1) when compared with pre-test measures. NVR showed no significant improvement in post-test measures ($P>.05$) (Table 1) when compared with pre-test measures. In addition, compared within groups change values, VR showed a more significant difference than NVR ($P<.05$) (Table 1).

For ankle plantar flexion ROM, all groups showed no significant improvement in post-test measures ($P>.05$) (Table 1) compared with pre-test measures. In addition, compared within groups change values, and the two groups showed no significant difference ($P>.05$) (Table 1).

**Table 1.** Outcomes for foam rolling with or without vibration

| Variable | | Intervention | Pre | Post | Change | Effect size | Z (*P*) |
|---|---|---|---|---|---|---|---|
| Range of Motion | Dorsiflexion (degrees) | VR | 8.86 ± 7.128 | 11.29 ± 7.296 | 2.43 ± .535[†] | .92 | −2.428 (.015)[*] |
| | | NVR | 8.43 ± 6.106 | 9.29 ± 6.824 | 0.86 ± 1.464 | .49 | −1.298 (.194) |
| | Plantarflexion (degrees) | VR | 68.57 ± 7.277 | 68.29 ± 7.566 | −.29 ± 1.976 | .13 | −.343 (.732) |
| | | NVR | 67.71 ± 5.823 | 66.57 ± 5.159 | −1.14 ± 1.864 | .52 | −1.382 (.167) |
| Stiffness | Tibialis anterior (N/m) | VR | 480.79 ± 81.238 | 488.00 ± 84.421 | 7.21 ± 9.987 | .51 | −1.352 (.176) |
| | | NVR | 424.64 ± 94.385 | 437.07 ± 102.782 | 12.43 ± 19.497 | .57 | −1.521 (.128) |
| | Lateral gastrocnemius (N/m) | VR | 349.36 ± 82.633 | 326.64 ± 87.015 | −22.71 ± 12.216[†] | .90 | −2.371 (.018)[*] |
| | | NVR | 337.86 ± 102.785 | 359.57 ± 94.156 | 21.71 ± 19.190 | .83 | −2.197 (.028)[*] |
| | Medial gastrocnemius (N/m) | VR | 349.79 ± 47.708 | 333.29 ± 42.168 | −16.50 ± 11.683 | .83 | −2.197 (.028)[*] |
| | | NVR | 343.93 ± 79.200 | 348.57 ± 92.175 | 4.64 ± 37.162 | .19 | −.507 (.612) |

[*]$P<.05$: Significant difference compared with the pretest results, [†]$P<.05$: Significant difference compared with NVR
VR: vibration rolling, NVR: non-vibration rolling

### Ankle Muscle Stiffness

For tibialis anterior stiffness, all groups showed no significant improvement in post-test measures ($P>.05$) (Table 1) compared with pre-test measures. In addition, compared within groups change values, and the two groups showed no significant difference ($P>.05$) (Table 1).

For lateral gastrocnemius stiffness, all groups showed significant improvement in post-test measures ($P<.05$) (Table 1) compared with pre-test measures. In addition, compared within groups change values, VR showed a more significant difference than NVR ($P<.05$) (Table 1).

For medial gastrocnemius stiffness, VR showed significant improvement in post-test measures ($P<.05$) (Table 1) compared with pre-test measures. NVR showed no significant improvement in post-test measures ($P>.05$) (Table 1) compared with pre-test measures. In addition, compared within groups change values, and the two groups showed no significant difference ($P>.05$) (Table 1).

## DISCUSSION

This is the first study to investigate the immediate effects of VR combined with dynamic muscle contraction as an intervention to improve ankle ROM and ankle stiffness in stroke patients. In terms of the effects on ankle ROM, VR significantly improved ankle dorsiflexion ROM. In addition, the amount of change in angle for dorsiflexion ROM was greatly improved after VR. These results are supported by those of previous studies in which VR increased ankle ROM.[24,26] This effective result is thought to be the result of vibration stimulation leading to an increase in blood flow and temperature, which could provoke ROM improvements.[27]

Next, our study revealed that VR significantly decreases lateral and medial gastrocnemius stiffness. These results were similar to those of previous studies in which VR decreased ankle stiffness in athletes.18 However, as stroke patients experience upper motor neuron syndrome, spasticity occurs as a clinical characteristic of movement disorder. Spasticity can increase muscle stiffness due to exacerbation of stretch reflexes.[28] The stretch reflexes increase in proportion to the speed of movement.[29] This study is thought to suppress the stretch reflex, and the stiffness did not increase because the dynamic movement was slowly maintained during exercise. Additionally, it is thought that the stiffness was improved because the vibration caused a change in the viscoelastic properties of the muscle and increased stretch tolerance.[30,31]

Finally, NVR showed that improvements in stiffness of the lateral gastrocnemius muscle were significant. This is thought to be because the lateral gastrocnemius muscle receives direct stimulation because the hip joint external rotation occurs when the stroke patient is in a supine position. However, VR showed that improvements in stiffness of the lateral and medial gastrocnemius muscles were significant. This result is thought to have a vibration effect on the surrounding muscles as well.

This study had several limitations. First, the number of participants in the study was small. Second, only one vibration frequency was used. The effects of other vibration frequencies could not be confirmed. Third, the patient's ankle movement speed and frequency within the intervention time were different. In the future, follow-up studies should be conducted to compensate for these limitations.

## CONCLUSION

The findings suggest that VR intervention for stroke patients can significantly improve dorsiflexion ROM and gastrocnemius stiffness. Therefore, we suggest that practitioners consider VR as an intervention to increase dorsiflexion ROM and gastrocnemius stiffness in stroke patients.

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