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The effects of the 4-weeks visual biofeedback training in individuals with hyperextended knee

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[Abstract]

This study aims to investigate the effects of 4 weeks visual biofeedback training on the knee joint angle and muscle activities of lower extremity. The participants in this study were 15 volunteers with hyperextended knee. To improve the hyperextended knee, visual biofeedback training was used during 4 weeks. The training is an exercise to maintain the balance between the anterior weight bearing and posterior weight bearing of the plantar foot. The knee joint angle significantly increased and the muscle activity of tibialis anterior was significantly decreased after visual biofeedback training. It was confirmed that visual biofeedback training of correcting hyperextended knee through the information on the plantar pressure distribution has a therapeutic effect.

▸ **Key words**: Visual biofeedback training, hyperextended knee, plantar pressure, weight bearing, tibialis anterior

[요 약]

본 연구의 목적은 4주 동안의 시각 바이오피드백 훈련이 무릎관절 각도와 하지 근활성도에 미치는 영향을 조사하는 것이다. 15명의 과도한 무릎 젖힘을 가진 자원자가 본 연구에 참가하였다. 과도한 무릎 젖힘을 향상시키기 위해 4주 동안의 시각 바이오피드백 훈련을 사용하였다. 이 훈련은 발바닥의 앞 체중부하와 뒤 체중부하 사이의 균형을 유지하는 운동이다. 시각 바이오피드백 훈련 후, 무릎 관절 각도는 유의하게 증가하였으며, 앞정강근의 근전도는 유의하게 감소하였다. 본 연구의 결과를 통해 발바닥 압력 분산의 정보를 이용한 시각 바이오피드백 훈련은 과도한 무릎 젖힘에 대하여 치료효과가 있음을 확인하였다.

▸ **주제어**: 시각 바이오피드백 훈련, 과도한 무릎 젖힘, 발바닥 압력, 체중 부하, 앞정강근

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I. Introduction

The hyperextended knee refers to an extension that exceeds 10 degrees from the neutral of the knee joint, and there are various causes, but the wrong posture has the greatest effect [1]. Individuals with hyperextended knee have increased pressure on the anterior structures of the knee, and posterior structures of the knees have overstretch [2]. Therefore, the hyperextended knee causes extensive damage to the surrounding soft tissue as well as damage to the knee joint [3-4]. Damage to the musculoskeletal system caused by an abnormal hyperextended knee leads to impairment of somatosensory sensation and impairment of the ability to control the body [5-6]. In particular, biomechanics and balance ability are affected by changes in the distribution of weight due to hyperextended knee. Compared with the plantar pressure distribution in a normal alignment state, hyperextended knee shifts the mechanical axis so that the weight is mainly supported only toward the heel [7].

Although various therapeutic methods such as taping, brace, stretching, and muscle strength are applied, most of them have only short-term effects, and long-term treatment effects such as continuous improvement of knee alignment have not been shown [8-12]. To have a lasting therapeutic effect, it is not simply to treat a specific area, but the integrated control ability of the body system is required, and we call this motor control or movement control [13]. As the method recently used in clinical practice for motor control, a visual biofeedback training has been used to provide information on the body position in real time, and accordingly, to allow patients to recover their body control ability [14]. It facilitates the acquisition of skilled motor performance and to contributes to generalized or transferable learning [15-16]. Visual biofeedback is a therapeutic technique that can be used during movement training, offering patient visual information on the joint position or posture [17-18].

However, there is still insufficient research on visual biofeedback for treating hyperextended knee. This study aims to investigate the effects of 4 weeks visual biofeedback training on the knee joint angle and muscle activities of lower extremity. In addition, the existing method for providing information on the position of the knee has inconvenient points such as having to take off clothes or attach specific equipment to the knee joint. To solve such an inconvenient problem and to easily correct the alignment of the knee joint of individuals with hyperextended knee, we tried to find out the therapeutic effect using a real-time visual biofeedback-training technique for the plantar pressure distribution.

II. Preliminaries

The hyperextended knee causes extensive damage to the musculoskeletal system. Although various studies have been conducted on techniques for improving hyperextended knee, studies on the effectiveness of long-term interventions are insufficient. Therefore, this study aims to investigate the effects of long-term intervention on the knee joint angle and muscle activities of lower extremity.

III. Research design

1. Research Subjects and Data collection

The participants in this study were 15 volunteers (mean age: 23.80±2.08 years old; height: 166.07±8.36 cm; weight: 61.87±10.76 kg). Participants were included if they had no previous history of knee, ankle, or hip surgery. In addition, individuals with an knee joint angle of 175 degrees or less were recruited as participants when the examiner extended the volunteer's knee in the long sitting. Informed consent was obtained from all participants.

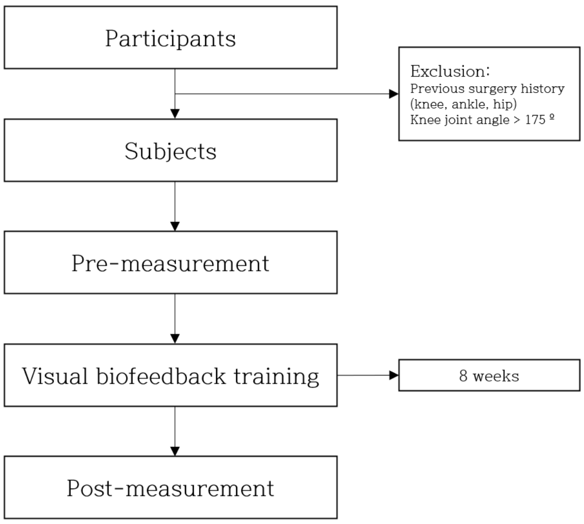

Fig. 1. Flowchart of the research

2. Research Tool

2.1 Knee joint angle

The knee joint angle of each participant was recorded using mobile phone. (Galaxy S6, Samsung Electronics, South Korea). A tripod was adjusted to the height of the knee, and then the smartphone was adjusted to the level of the knee using the height-adjustable tripod. The smartphone was placed 1 m ahead of the participant as measured using a tape measure. Before taking a photograph, three reflective surface markers (1.5cm diameter) were attached in greater trochanter, the lateral femoral epicondyle, the lateral malleolus of dominant side leg to calculate the knee joint angle [19]. The knee joint angle is measured after the participant performs a standing task while watching a video for 3 min. The knee joint angle was determined using J image software (U.S. National Institutes of Health, Maryland, USA). The angle between the two lines was automatically calculated by the Image J software. The neutral of the knee joint is 180 degree and the more the hyperextended is, the smaller the angle is measured.

2.2 Muscle activities of lower extremity

A surface electromyography system (TeleMyo DTS, Noraxon, Scottsdale, AZ, USA) was used to measure the activity of the biceps femoris, rectus femoris, gastrocnemius, and tibialis anterior using MyoResearch® XP Master Edition software (Noraxon Inc.) Filtered movement artifacts were eliminated using a 20-450 Hz digital band-pass filter (Lancosh FIR). The sample rate was set to 1,000 Hz. The root mean square was used to process electromyography signals with a moving window of 50 ms. Electromyography signals were recorded for 5 s (2-4 s used for data analysis). Two surface electrodes were positioned on each muscle. The placement location of electrode followed the Criswell [20]. The location where the electrode is attached was shaved and rubbed with alcohol to reduce skin impedance. For measuring the activity of rectus femoris, the electrodes were placed in the center of the front of the thigh surface, about 1/2 the distance between the iliac spine and knee. For measuring the activity of biceps femoris, the electrodes were placed on the lateral aspect of the thigh, about 2/3 of the distance between the back of the knee and the trochanter. For measuring the activity of the tibialis anterior, the electrodes were placed parallel to and lateral to the medial shaft of the tibia, at about 1/4 the distance between the ankle and knee. Palpate the area while the subject dorsiflexes the foot. For measuring the activity of the gastrocnemius, the electrodes were placed in the medial aspect running parallel to the muscle fibers, below the knee and within 2 cm of the midline.

The electromyography is measured after the participant performs a standing task while watching a video for 3 min. The electromyography data were normalized by calculating the root mean square of the reference voluntary isometric contraction (RVIC). To measure the RVIC, the subjects were in a comfortable standing position [21]. In addition, electromyography data are expressed as percentages of RVIC (% RVIC).

2.3 Visual biofeedback training

Visual biofeedback training was used to improve the hyperextended knee. The training is an exercise to maintain the balance between the anterior weight bearing and posterior weight bearing of the plantar foot. Smart shoe with plantar pressure measurement function (IOFIT, Salted Venture, Seoul, Korea) was used for this training. The smart shoe can measure the pressure of the plantar foot so that the anterior and posterior weight bearing can be checked in real time. Participants wear shoes that fit their size and stand comfortably in front of a screen where the plantar foot pressure of the shoe is displayed in real time (Figure 2, 3). The participant maintains a balance of approximately 50% of the ratio between the anterior and posterior pressures of the plantar foot during training. A supervisor confirms and guides maintaining balance of plantar pressure next to the participants during training. Participants visited the exercise center 3 times a week for 4 weeks and performed visual biofeedback balance training for 30 min a day.

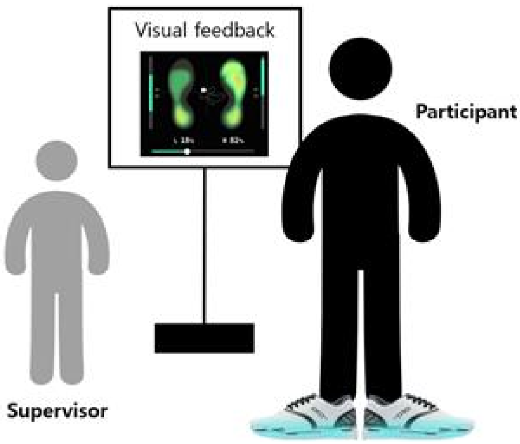

Fig. 2. Illustration of visual biofeedback training

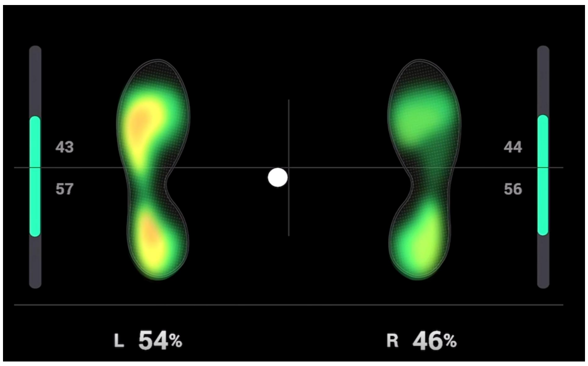

Fig. 3. Plantar foot pressure of the shoe

2.4 Data analysis method

The Shapiro-Wilk test was performed to confirm that all variables were distributed normally. If the data represent a normal distribution, perform a paired t-test; otherwise, perform a Wilcoxon signed-rank test to determine the effect of the visual biofeedback training. The significance was set at $p<0.05$. The statistical analyses were performed using SPSS version. 20 (IBM corp., Armonk, NY, USA).

IV. Results

All variables showed a normal distribution in Shapiro-Wilk test ($p>0.05$). The result for the paired t-test between pre- and post-visual biofeedback training is shown in Table 1. The knee joint angle significantly increased after visual biofeedback training ($p<0.05$). The muscle activity of tibialis anterior was significantly decreased after visual biofeedback training ($p<0.05$).

Table 1. Comparison of knee joint angle and EMG pre- and post-visual biofeedback training

	Pre-visual biofeedback training	Post-visual biofeedback training	t	p
Knee joint angle (º)	171.37 ± 3.40	174.83 ± 3.41	-4.525	0.000*
Rectus femoris (%)	6.38 ± 2.97	6.81 ± 6.20	-0.253	0.804
Biceps femoris (%)	5.84 ± 3.02	6.53 ± 3.70	-0.537	0.600
Tibialis anterior (%)	5.56 ± 2.28	4.27 ± 1.57	2.308	0.037*
Gastrocnemius (%)	7.06 ± 2.23	7.32 ± 3.17	-0.285	0.780

V. Conclusion

For individuals with hyperextended knee, restoration of normal alignment is crucial important in preventing various knee joint diseases that may occur in the future and for daily activities. Therefore, in this study, we investigated to determine how visual biofeedback training for 4-weeks affects the lower limb muscles and knee joint angle. Through the experimental results, there was a significant difference in the knee joint angle, and there was no difference in the muscle activity of the lower limb muscles, except for tibialis anterior muscle, before and after training.

Most previous studies on feedback training for hyperextended knee provided information on the position of the knee joint, and the subject performed training to maintain correct alignment based on this information [13, 22]. Unlike previous studies, this study was a training technique to correct hyperextended knee by providing information on changes in the subject's plantar pressure. The main reason for choosing this training technique is that the existing visual biofeedback training for the position of the knee joint is subject to the limitation that clothes should be removed or a certain experimental space should be provided. However, the training technique that provides information on the distribution of foot pressure in this study does not have such limitations and has the advantage of being able to correct hyperextended knee in daily life more easily. Based on the results, the results of these studies demonstrate the effectiveness of real-time biofeedback in promoting the acquisition and internalization of motor skills, improving learning and persistence. [23]. It was confirmed that the difference before and after treatment decreased by about 5 degrees. In addition, the decrease in the activity of the tibialis anterior muscle is believed to be due to the decrease in the load imposed on the muscle because the tibia, which was positioned posterior to the foot fixed on the ground, moved vertically or forward [2].

The limitations of this study are as follows. First, since training was performed only in a static state, it is considered necessary to study hyperextension occurring in a dynamic posture in the future. Second, hyperextended knee affects not only the position change of the knee joint but also the pressure distribution of the sole due to the movement of the mechanical axis. In future studies, it is considered necessary to study the changes in the plantar weight distribution due to hyperextended knee and the changes in the plantar pressure distribution during alignment correction. Third, in this study only objective data such as knee joint angle and muscle activities were measured and information on patient's feedback was not provided.

It was confirmed that visual biofeedback training of correcting hyperextended knee through the information on the plantar pressure distribution has a therapeutic effect. In addition, it is considered that this training can be applied more easily than the conventional training of correcting hyperextended knee through the position of the knee joint.

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