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The Correlation between Power Error and Velocity Error according to the Condition and Frequency of Self-Controlled Feedback during Knee Extension

This study examined the correlation between power error (PE) and velocity error (VE) according to the condition and frequency of self-controlled feedback (SCF) during knee extension. One hundred participants were randomly assigned to 30% SCF, 70% SCF, 30% yoked feedback (YF), 70% YF and control group, respectively. The SCF group was provided with feedback when they requested it, whereas the YF group did not influence the feedback schedule. Participants in the control group were not given any visual feedback during the experiment. The isotonic, isometric, and isokinetic dynamometer (PRIMUS RS, BTE, USA) was used to measure the power and velocity error during knee extension. The collected data was analyzed using a Pearson test and SPSS 21.0. The correlation between PE and VE according to the condition and frequency of feedback on each phase during knee extension was significant. Both PE and VE were significantly higher when the feedback was provided with high frequency, passive, and no feedback. Our study suggests that application of SCF can help to improve the proprioception of the healthy person while reducing errors through low frequency and active feedback.

Key words: *Power error, Velocity error, Self-controlled feedback.*

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INTRODUCTION

Augmented feedback is additional information about motor skill performance that supplements a participant's own sensory feedback [1]. Provision of concurrent augmented feedback during practice of a new motor skill can improve learning of that skill [2]. Effective motor learning is mainly dependent on feedback conditions and frequency during acquisition phase [3]. The types of feedback were classified as frequency [4], average [5], bandwidth [6], faded [7], and summary [8, 9] feedback according to the method of providing. However, these methods do not lead to active participation of learners, which is important in learning by providing only passive feedback to learners. self-controlled feedback (SCF), self-determination, and self-regulation have been attempted to solve these problems [10].

SCF is a type of feedback that is provided by the learners themselves at the desired time during the acquisition phase [11]. On the other hand, the SCF group was provided with feedback when they requested it (active feedback), whereas the YF group had no influence on the feedback schedule. YF group received feedback at the same trial with SCF group regardless of whether YF group wanted it or not (passive feedback) [11, 12]. The effects of SCF have typically been assessed by comparing the performances of self-controlled groups to yoked groups that could not control feedback delivery, but instead received feedback each time the matched participant of the self-control group requested feedback [12, 13]. SCF was more effective when the learner could make a decision about receiving feedback after the trial than yoked feedback (YF) [13, 14]. SCF can improve task learning in children with developmental coordination disorder [15]. SCF can be used in physiotherapy programs related to children with spastic hemiplegic cerebral palsy to improve their motor skills and independence movements [16]. Self-controlled practice in persons with Parkinson's disease was more motivated to maintain the balance,were less nervous,

and less concerned about their body movements relative to yoked participants [17]. On the other hand, SCF did not show positive results in improving the performance of the average 15.8 year old female soccer players [12] or performing the golf putting tasks of the average 68 years old [18].

In the studies related to the frequency of feedback, Silva et al.[19] reported the benefit of subjective error estimation in association with high frequency (100%) of extrinsic feedback in children's motor learning of the basketball free shooting pattern. Reduced feedback during practice has been shown to be detrimental to movement accuracy in children but not in young adults [20]. On the other hand, the group which received 50% feedback performed better than the other groups (0% and 100%) in the retention phase and scored higher for throwing a dart [21]. When the feedback frequency was controlled (100% or 33% feedback) for motor skill learning and the data indicate that a reduced feedback frequency only enhanced the learning of observers [22].

Human movements require accuracy and coordination to move without errors [1]. In exercise therapy, most therapists are treating to recognize angles and velocities of movement by stimulating proprioception for the patients [30]. Proprioception refers to perception of position, motion, and vibration collected by the proprioceptors from muscles, tendons, and joints [31]. In this study, we used power error (PE) and velocity error (VE) as the dependent variables to measure the proprioceptive accuracy of knee extension. Most of the studies related to feedback have examined examiner-controlled feedback, but studies on the efficiency of the SCF and frequency feedback are lacking [4,-9]. Especially, the study of SCF's effect to recognize proprioception based on motion of joints is very lacking. Therefore, the purpose of the present study was to examine the correlation between PE and VE according to the condition and frequency of SCF during knee extension.

SUBJECTS AND METHODS

Subjects

The participants of this study were 100 healthy persons aged 21.08±1.22 years (Mean±SD) with an average height and weight of 167.27±3.89 cm and 66.30±5.08 kg, respectively. The participants consisted of 51 men and 49 women. None of the participants had problems with their musculoskeletal, nervous, or cardiovascular systems, and they were able to complete knee extension according to the instructions given by the researcher. Before participating in this research, all the participants were given an explanation about the content and the procedures of the experiment. The participants voluntarily participated in this research, and signed an informed consent form. This study was approved by the Institutional Ethics Committee of Namseoul University (No. NSUIRB-201812-001). 100 participants were randomly selected and randomly assigned to 30% SCF (n=20), 70% SCF (n=20), 30% YF (n=20), 70% YF (n=20) and control group (n=20), respectively.

Study Design and Sequences

The isotonic, isometric, and isokinetic dynamometer (PRIMUS RS, BTE, USA) was used to measure the power and velocity error during knee extension. The PRIMUS RS includes one main body, computer and monitor, evaluation chairs, various attachments for field work evaluation, and basic sports tools. The intraclass correlation coefficients (ICCs) for reliability of PRIMUS RS is .95-.99 [23].

The tests were conducted with non-dominant legs to investigate the proprioception according to frequency of SCF during knee extension. The non-dominant leg was selected as the opposite leg of the ball when performing the task of kicking the ball [24]. When the participant sits on the chair of the Primus RS, the frontal axis of the knee joint of the non-dominant leg is adjusted to coincide with the axis of rotation of the dynamometer, and the small lever is adjusted to parallel with the lower leg of participant. During the measurement, the chest, thighs, and ankle were fixed using a fixing pad so that the compensation movement did not occur and the participant was asked to hold the corners of the chair with both hands [25]. The target speed and power were measured in 3 times at the maximum speed and maximum power of the participant and then 35% of the average value was applied [26]. After giving the target power and target speed to the participants with the experimental posture, the participants performed knee extension of 10 times per block. The interval between blocks was set to 5 minutes.
PE (Wt: absolute value) = target power − performed power VE (m/sec: absolute value) = target velocity − performed velocity.

Acquisition Phase

In the acquisition phase to investigate the practice effect of proprioception, 4 blocks were performed with 10 times per block. At any time during the acquisition

phase, the SCF group was provided with feedback when they requested it, whereas YF group received feedback at the same trial with SCF group regardless of whether YF group wanted it or not. Participants in the SCF group were informed that they had to control their feedback frequency, and would not receive feedback unless they requested it (active feedback). The 30% SCF group received visual feedback 3 times out of 10 times, while the 70% SCF group received visual feedback 7 times out of 10 times [27]. Participants in the 30% YF group paired with 30% SCF group, 70% YF group paired with 70% SCF group received visual feedback on the monitor at the same trial with SCF group regardless of whether YF group wanted it or not (passive feedback). Participants in the control group were not given any visual feedback during the experiment.

Retention Phase

In the immediate retention phase after 30 minutes of acquisition trials to investigate the short-term learning effects and in the delayed retention phase after 24 hours of acquisition trials to investigate the long-term learning effects, 2 blocks were performed with 10 times per block without any visual feedback, respectively. All subjects were treated the same method without any feedback in the retention phase

Statistical Analysis

All the measured data were processed by the program of IBM SPSS Statistics version 21.0. The Kolmogorov- Smirnov test was conducted in order to analyze the normal distribution of the measured data. A descriptive statistics was used to examine the PE and VE according to the condition and frequency of feedback on each phase during knee extension A Pearson's correlation test was used to examine the correlation between PE and VE according to the condition and frequency of feedback on each phase during knee extension. The level of significance was set at α=.05.

RESULTS

The power error and velocity error according to the condition and frequency of feedback on each phase during knee extension

The mean and standard deviation of the PE and VE according to the condition and frequency of feedback on each phase during knee extension are presented in Table 1. In the acquisition phase, both PE and VE showed similar results. The error of the 30% SCF group and 30% YF group decreased compared to the

Table 1. The power error and velocity error according to the condition and frequency of feedback on each phase during knee extension

	Acquisition		Retention30min		Retention24hrs	
	PE (Wt)	VE (m/sec)	PE (Wt)	VE (m/sec)	PE (Wt)	VE (m/sec)
1	7.37±2.36	14.88±4.67	6.00± .96	17.69±3.06	7.64±1.16	16.12±2.82
2	11.66±5.40	23.01±8.22	8.58± .96	26.87±2.54	13.91±2.51	30.60±3.83
3	7.84±2.37	16.20±5.30	9.40±1.34	26.21±4.13	10.28±1.17	32.60±2.79
4	8.85±3.14	21.10±9.27	7.60± .93	21.37±9.05	10.53±1.38	22.40±2.71
5	29.16±2.67	95.29±12.36	28.26±4.24	96.68±12.87	28.82±1.86	91.33±14.76

PE: Power error, VE: Velocity error, 1: 30% Self-controlled feedback, 2: 70% Self-controlled feedback, 3: 30% Yoked feedback, 4: 70% Yoked feedback, 5: Control

Table 2. Correlation between power error and velocity error according to the condition and frequency of feedback on each phase during knee extension

		Acquisition		Retention30min		Retention24hrs	
		PE	VE	PE	VE	PE	VE
Frequency* Feedback (1, 2, 3, 4, 5)	r	.649**	.705**	.726**	.706**	.712**	.721**

PE : power error, VE : velocity error, 1 : 30% self-controlled feedback, 2: 70% self-controlled feedback, 3 : 30% yoked feedback, 4: 70% yoked feedback, 5: control
* p<.05, ** p<.01.

70% SCF group and 70% YF group. In the immediate retention phase, both errors for the 30% SCF group decreased compare to the 30% YF group, 70% SCF group, and control group. In the delayed retention phase, both errors for the 30% SCF group decreased compare to all groups. Both errors for the control group on all phase increased compare to all groups (Table 1).

Correlation between power error and velocity error according to the condition and frequency of feedback on each phase during knee extension

The correlation between PE and VE according to the condition and frequency of feedback on each phase during knee extension was significant ($p<.01$). Both PE and VE were significantly higher when the feedback was provided high frequency, passive, and no feedback ($p<.01$) (Table 1, 2).

DISCUSSION

The main result of this study is that both PE and VE were significantly higher when the feedback was provided high frequency, passive, and no feedback. The error for the 30% SCF group on all phase decreased compare to the 30% YF group, 70% SCF group, 70% YF group, and control group.

For the 30% SCF group, participants provided active feedback to adjust the feedback schedule by themselves at low frequency. The group which received 50% feedback performed better than the 100% feedback group in the retention phase and scored higher for throwing a dart [21]. In a study which compare task performance with 100% and 33% feedback, a reduced feedback frequency only enhanced the learning of observers [22]. Young and Schmidt [28] reported that too much feedback can interfere with learning and retention phase of tasks and participants may become dependent upon those providing feedbacks as they perform the task in a degree that intrinsic mechanisms are ignored [21, 22]. The results of this study can help to improve the proprioception of the healthy person while reducing errors through low frequency feedback.

Janelle et al. [10] reported that SCF in an active practice was more effective at increasing practice time and learning effect than yoked feedback in a passive practice. Self-controlled learning environments satisfy the basic psychological need of autonomy, and this is associated with greater self-regulated learning [10, 11, 13, 15]. "Self-regulated" describes a process of taking control of and evaluating one's own learning and behavior. Self-regulated learning emphasizes autonomy and control by the individual who monitors, directs, and regulates actions toward goals of information acquisition, expanding expertise, and self-improvement [29]. Self-regulated learners feel more responsible for improving performance, which leads to a higher motivation to practice and perform well, and thus results in more active involvement of the learner in the learning process [10, 11, 17]. As a result, PE and VE decreased in the active feedback, SCF. This is why the subjects were actively involved in the task and self-regulated as mentioned in the previous study [10, 11, 15, 17]. Therefore, if the advantages of the SCF revealed in this study is utilized well, it can be used not only for improving the proprioception of the healthy person but also for enhancing the functional performance of various patients.

A limitation of the present research is that this experiment was conducted using only healthy persons. Thus, we may not safely generalize our research results to any other patients. Also, it was difficult to completely control the amount of daily physical activity performed by the participants during the experimental period. In the future studies, we suggest that SCF should be applied to various patients and various age groups as well as healthy persons to check the efficiency of SCF.

CONCLUSION

The main result of this study is that both PE and VE were significantly higher when the feedback was provided high frequency, passive, and no feedback. The error for the 30% SCF group on all phase decreased compare to the 30% YF group, 70% SCF group, 70% YF group, and control group. In conclusion, the application of SCF can help to improve the proprioception of the healthy person while reducing errors through low frequency and active feedback.

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