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Original Article

Effect of the post-learning period on the accuracy and self-efficacy of measuring the joint range of motion

Ryohei Yamamoto, RPT, PhD[1)*], Yushin Yoshizato, RPT[2)], Takaki Imai, RPT, PhD[2)], Kazunori Akizuki, RPT, PhD[3)]

[1)] *Department of Rehabilitation, Kumamoto Health Science University: 325 Izumi-machi, Kita-ku, Kumamoto-shi, Kumamoto 861-5598, Japan*
[2)] *Department of Rehabilitation, Kyushu University of Nursing and Social Welfare, Japan*
[3)] *Department of Physical Therapy, Mejiro University, Japan*

Abstract. [Purpose] To verify the effects of the differences in the post-learning period on the accuracy and self-efficacy of measuring the range of passive flexion of the knee and elbow of students. [Participants and Methods] Thirty-six physical therapy students were classified into three groups (short-term, medium-term, and long-term) based on the interval since learning to measure the range of motion. Participants were asked to self-evaluate their efficacy in appropriately measuring the range of motion for knee and elbow flexion using a 10-point Likert scale. Subsequently, the flexion range of the left knee and elbow was measured using a universal goniometer and compared to the measurements obtained using an electronic accelerometer. [Results] Absolute errors in measuring knee flexion were significantly smaller in the medium- and long-term groups than in the short-term group. No other significant main effects or correlations were observed. [Conclusion] Although the accuracy of measuring the range of motion by students improved while they were in school, it did not improve sufficiently based on the joint being assessed. Furthermore, the post-learning period did not affect a student's self-efficacy for measuring the range of motion and did not reflect its accuracy.

Key words: Range of motion measurement, Self-efficacy, Proficiency level

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INTRODUCTION

Range of motion (ROM) limitations can be attributable to various causes, including traumas such as bone fractures and the aftereffects of neurological diseases such as stroke, and such limitations can restrict activities such as daily living activities and walking. Therefore, physicians and physical therapists obtain joint ROM measurements for various purposes such as diagnosis, assessments of disease severity, and prognosis prediction. The measurement methods include visual estimation[1–3)], measurements based on radiographs[4–6)], measurements using electronic goniometers[7, 8)], and measurements using universal goniometers[9–11)] and equipment such as three-dimensional motion analysis devices[12)]. Although radiograph-based measurements are considered the gold standard, they are difficult to obtain routinely in clinical settings because of the high cost of the equipment, limited measurement locations, and radiation exposure[13)].

For ROM measurements obtained with a universal goniometer, many studies have recognized the validity of measurements performed by the same examiner within the same session on the same day[14–18)]. Furthermore, Gajdosik et al. concluded that the universal goniometer is a suitable instrument for measuring ROM[19)]. In this regard, Akizuki et al. compared the ROM measurement accuracy of physical therapy students and physical therapists with clinical experience[20)]. Consequently, they

*Corresponding author. Ryohei Yamamoto (E-mail: yamamoto.rh@kumamoto-hsu.ac.jp)

reported that the measurement error decreased as clinical experience increased, indicating that students could not perform accurate measurements. Inaccurate measurements may lead to incorrect assessments of severity and prognosis prediction, which may hinder appropriate treatment selection. Knee joint ROM is typically limited by orthopedic diseases[21], while limitations of the elbow joint ROM, which is an outcome of surgical procedures, have been reported to be a risk factor for baseball elbow[22, 23]; therefore, accurate measurement of the ROM of these two joints is essential. However, the effects of the post-learning period on ROM measurement accuracy have not been examined except for the knee joint, and are unknown for the elbow joint.

Self-efficacy is defined as the perception of one's ability to successfully perform the required actions in a particular situation[24]. Medical students with high self-efficacy have been reported to show excellent academic performance[25]. According to Bandura, increased self-efficacy for a particular behavior also increases the likelihood of that behavior, which is further reinforced by success[26]. Therefore, physical therapy students with high self-efficacy are expected to actively practice various techniques, including ROM measurement. Furthermore, people with a high sense of self-efficacy are more likely to succeed in their tasks[25]. These findings suggest that graduating physical therapy students should have high self-efficacy in addition to the ability to accurately measure ROM. However, Baaji et al. reported that although dental students are guaranteed a certain level of competence at the end of their undergraduate practice, the level of self-efficacy varies among students[27]. It is possible that the level of self-efficacy for ROM measurements, which is a basic technique, differs among physical therapy students, however, there have been no reports of self-efficacy for ROM measurements in physical therapy students to date.

Thus, the purpose of this study was to examine the effects of differences in the post-learning period for ROM measurement on students' accuracy and self-efficacy for obtaining ROM measurements. The hypothesis of this study was that students who had a longer post-learning period would have more accurate ROM measurements for knee and elbow joints than those who had a shorter post-learning period. The second hypothesis was that self-efficacy for ROM measurements would vary among students regardless of measurement accuracy. Understanding the differences in student ROM measurement accuracy and self-efficacy across post-learning periods may help improve the teaching of ROM measurement to students.

PARTICIPANTS AND METHODS

The participants included 36 physical therapy students (21 males, 15 females; mean age, 20.6 ± 1.2 years). Students were recruited from various grades of the physical therapy program at university, with a distribution of 12 each in grades 2, 3, and 4. At university, the students learn ROM measurement within the second half of their first year. Therefore, the lapse of time from learning the basic techniques of ROM measurement to participation in our study was approximately 6 months for second-year students, 18 months for third-year students and 30 months for fourth-year students. The participants were further differentiated by their clinical experience, with only fourth year students having completed all their clinical education. Participants who had acquired credits for ROM measurement less than 1 year back, 1 to less than 2 years back, and ≥2 years back were assigned to the short-term (ST), medium-term (MT), and long-term (LT) groups, respectively. The participants were given a verbal description of the contents of this study and the protocol for handling the results, shown the research manual, and provided consent to participate in the study. The study protocol was approved by the Ethics Committee of Kumamoto Health Science University (approval number: 22007).

ROM measurement during flexion of the left knee joint and left elbow joint in the supine position was set as the measurement task. ROM measurements were obtained using an accelerometer and a universal goniometer. The joint angle measurements obtained using the accelerometer were considered as the reference values, and the absolute value of the difference between the reference value and the measurement obtained by the participant with the universal goniometer was defined as the measurement error. In this study, the reference ROM values for the knee and elbow joints were measured using the software ARMS (ATR-promotions, Kyoto, Japan) based on the measured values obtained by two electronic accelerometers (TSND151, AMWS020; ATR-promotions, Kyoto, Japan). The measured values obtained by the accelerometer were transferred to a personal computer via Bluetooth, and the joint angles were calculated based on the numerical values. For lower-extremity measurements, one accelerometer was attached to the lower limb at a position 5 cm from the lateral epicondyle of the femur along the line connecting the greater trochanter and the lateral epicondyle of the femur, while the other was attached 5 cm from the fibular head along the line connecting the fibular head and lateral malleolus. Similarly, for upper-extremity measurements, one accelerometer was placed 5 cm from the lateral epicondyle of the humerus along the line connecting the acromion and the lateral epicondyle of the humerus, while the other was attached 5 cm from the radial styloid process along the line connecting the radial head and the radial styloid process. These landmarks were identified by palpation. All accelerometers were secured with surgical tape, and elastic bandages were used to prevent slippage. The joint angles calculated from the accelerometer measurements and saved at a sampling frequency of 1,000 Hz were displayed on a monitor using the ARMS software to notify individuals who underwent ROM measurements of the joint angles.

Previous studies have confirmed the reliability of knee ROM measurements using accelerometers during various motions such as walking, climbing stairs, and jumping[28]. In this study, the measurement task and the mounting position of the joint goniometer were based on the method described by Akizuki et al. using an electrogoniometer[20]. For the elbow joint, the degree of agreement between the ARMS and the three-dimensional motion analysis device (VICON Nexus, Oxford, UK) were confirmed in advance by using the same settings as the measurement task. In this pre-assessment exercise, the attachment positions of the reflex markers were the acromion, the lateral epicondyle of the humerus, the radial styloid process, and the radial head, and the landmarks were identified by palpation as for the ROM measurement. Passive exercise was performed with the forearm in the supine position and the upper arm kept on the bed. After obtaining two measurements for two individuals, the accelerometer was reattached once, and the measurement was performed four times in total. Table 1 shows the results. The mean measurement error of the four trials for both individuals did not deviate greatly from the mean value and standard deviation of the trials performed before and after reattaching the accelerometer. In addition, the deviation in the trials performed for each individual was also minimal. These two individuals also underwent all ROM measurements performed in this study.

A universal goniometer with a handle length of 30 cm and angle markings in 1° increments was used in this study. The measurement landmarks for the knee joint were the greater trochanter, the lateral epicondyle of the femur, the head of the fibula, and the lateral malleolus. The angles formed by the lines connecting the greater trochanter and the lateral epicondyle of the femur and the lines connecting the fibular head and the lateral malleolus were measured by the participant in 1° increments. At the elbow joint, the angles formed by the lines joining the acromion and the lateral epicondyle of the humerus and the lines joining the radial styloid process and the radial head were also measured in the same manner as for the knee joint. The participants received no instructions for locating the landmarks by palpation, bending each joint passively, or applying the goniometer to the measurement site. As soon as the participants completed the measurement, they declared "done" and reported the measurement to the researcher. The researcher used the time recording function of the ARMS software to measure the time required to complete the measurement.

During the test, the flexion angle of the left knee joint was set at 75° ± 10° and the flexion angle of the left elbow joint was set at 80° ± 10°. The individual undergoing the measurement watched the display of the monitor, and when the set angle was reached, announced that "the knee will not bend any further" and resisted the force being applied to flex the knee by the participant. As a part of the study protocol, participants first answered a questionnaire about self-efficacy. Self-efficacy was evaluated for knee and elbow joint measurements, and the participants' confidence in each passive ROM measurement was evaluated. Each item was scored on a 10-point Likert scale, with 1 indicating a lack of confidence and 10 indicating complete confidence. Many studies on self-efficacy have used the Likert scale, although the scores are not uniform, ranging from 5–10 points[29, 30]. According to Grist et al., with a high baseline self-efficacy, the room for improving self-efficacy is low[31]. Therefore, in order to increase the possibility of score dispersion, we used a 10-point Likert scale, which is also used in the falls efficacy scale[32]. Next, three measurements of the passive joint angle were performed for each joint. In addition, the measurement order of elbow joints and knee joints was adjusted to ensure that it was unified in both groups.

The primary outcome of this study was the absolute error, which was determined as the difference between the ROM measured by the accelerometer and the joint angle measured by the participant using the universal goniometer. The self-efficacy for measuring the ROM of each joint was also evaluated. First, a one-way analysis of variance (ANOVA) was performed with the absolute errors in the ROM measurements of the elbow and knee joints as the objective variable and the period after earning the credit as the explanatory variable. A post-hoc test using the Bonferroni method was performed when a significant main effect was observed, and a similar analysis was conducted for self-efficacy. Pearson's correlation analysis was also performed for absolute error and self-efficacy. All statistical analyses were performed using IBM SPSS Statistics ver. 29 (IBM Corp., Armonk, NY, USA), and the significance level was set at 5%.

RESULTS

Table 2 shows the absolute error and self-efficacy measurements for each group. The results of ANOVA indicated that the main effects of group ($F_{2, 33}$=7.262, p<0.01, η^2=0.306) were significant. In a post-hoc test using the Bonferroni method, the ST group showed significantly higher values than the MT and LT groups (ST group and MT group, p<0.01; ST group and LT group, p<0.05). No significant main effect was observed on the absolute error for the elbow joint ($F_{2, 33}$=2.071, p=0.14, η^2=0.111).

One-way ANOVA for self-efficacy in ROM measurements of the knee and elbow joints also showed no significant main effect (elbow joint: $F_{2, 33}$=0.514, p<0.60, η^2=0.111; knee joint: $F_{2, 33}$=0.062, p<0.94, η^2=0.004). Pearson's correlation analysis using the measurement error for the knee joint as the objective variable and self-efficacy of ROM measurement for the knee as the explanatory variable also showed no significant correlation (r=0.61, p<0.72). A similar analysis using the self-efficacy

Table 1. Absolute error of the left elbow joint angle measurements obtained by the 3D motion analysis device and ARMS

	Person A	Person B
Total (1st–4th) (degrees)	3.01 ± 0.52	2.51 ± 1.22
1st & 2nd trials (degrees)	3.18 ± 0.83	2.85 ± 0.03
3rd & 4th trials (degrees)	2.85 ± 0.03	1.23 ± 1.36

ARMS: Angle of Rotation Measurement Software.

Table 2. Absolute error and self-efficacy for each group

	ST group	MT group	LT group	
Absolute error (degrees)				
Elbow	8.79 ± 5.21	8.18 ± 4.73	7.84 ± 4.71	
Knee	9.44 ± 5.31	9.05 ± 5.38	8.77 ± 5.67	*
Self-efficacy				
Elbow	4.83 ± 1.34	4.92 ± 1.31	5.00 ± 1.21	
Knee	4.42 ± 1.16	4.58 ± 1.08	4.67 ± 0.98	

Mean ± SD. *p<0.05.
ST: short-term: MT: medium-term; LT: long term: SD: standard deviation.

for ROM measurement of the elbow joint and measurement error for the elbow joint also showed no significant correlation (r=−0.76, p=0.66).

DISCUSSION

This study aimed to examine the effects of differences in the post-learning period after obtaining credits for ROM measurement on the accuracy and self-efficacy of ROM measurements obtained by students. The findings of this study indicated that the measurement accuracy for left knee joint flexion differs depending on the period after learning, while the measurement accuracy for left elbow joint flexion does not differ depending on the period after learning. In addition, the findings indicated no difference in self-efficacy depending on the period after earning the credit, and self-efficacy showed no relationship with the ROM measurement accuracy of students.

Akizuki et al. reported that the post-learning period affects the ROM measurement accuracy of the knee joint[20], and similar results were obtained for ROM measurement of the knee joint in this study. On the other hand, the post-learning period had no effect on the measured values of the elbow joint, showing a different trend from that of the knee joint. For ROM measurements, Chapleau et al. reported that ROM measurements for the elbow joint by a physician or physical therapist using a universal goniometer differed by up to 10° from measurements using radiographic imaging, making accurate measurements difficult[33]. Similarly, Peters et al. reported that joint angles of knee joints measured by a universal goniometer by physicians and physical therapists were significantly different from those measured using X-ray images[34]. Thus, ROM measurements of elbow joint and knee joint flexion can be considered to be difficult tasks. In skill acquisition, the amount of practice has been reported to be important for both accuracy and consistency of performance[35, 36]. Because the period after learning was short in the ST group and the amount of training was limited, it is predicted that the measurement accuracy for the elbow and knee joints was low. On the other hand, the MT and LT groups had a longer post-learning period than the ST group, and although they had opportunities to practice, a difference in measurement accuracy compared to the ST group was only observed for the knee joint. Therefore, we predicted that the LT and MT groups practiced enough to improve the measurement accuracy of the knee joint, but that the amount of practice for the elbow joint was insufficient. After learning techniques through lectures, students choose their method and content of practice outside of class time. Therefore, the amount of practice for measuring the knee joint may have been greater than that for the elbow joint; consequently, the measurement accuracy of only the knee joint improved over the period after earning the credit. Of the participants in this study, only the LT group had the experience of performing ROM measurements on patients in clinical education. However, in the LT group, there was no difference in the measurement accuracy of elbow joints and knee joints compared to the MT group, who had no such experience. Clinical practice may develop clinical thinking and practical skills, but since students do not only perform ROM measurements, it is difficult to gain experience of enough measurements to improve measurement accuracy. Moreover, in clinical practice, there is often no way to know whether the values measured by students are correct, and it is possible that this did not work effectively to improve measurement accuracy.

Next, for self-efficacy, in this study, self-confidence in performing ROM measurements of elbow and knee joints accurately was confirmed using a 10-point Likert scale. The results showed no relationship between the student's self-efficacy and ROM measurement accuracy. In addition, no difference in self-efficacy dependent on the period after learning was observed. A previous study on self-efficacy in other medical-related matters targeting medical students also showed no difference in self-efficacy by grade, and the results were similar to this study[37]. One of the reasons why self-efficacy of ROM measurement differs among students is that students cannot practice while confirming the accuracy of ROM measurement. Students cannot know the difference between their measurements and the actual ROM during practice unless they use equipment such as an electronic goniometer or a 3D motion analysis device. This kind of information about the results of one's implementation is called feedback and is an important factor in skill acquisition. Akizuki et al. reported that feedback obtained using electronic goniometer measurements in knee joint ROM measurement improved the measurement accuracy of students and enabled them to acquire skills[38]. Furthermore, Aoki et al. reported that medical students' self-efficacy increased after feedback[39].

These findings suggest that feedback may improve the accuracy of ROM measurements and have a positive effect on self-efficacy. However, the effects on skill acquisition and self-efficacy have been reported to differ depending on the method of giving feedback[40], so the method should be selected carefully.

This study had several limitations. First, the results are valid only for ROM measurements of knee and elbow flexion with a universal goniometer. Notably, the differences in the results between the measurements for elbow and knee joint flexion in this study may apply to the results obtained in other joints as well. Next, the self-efficacy scale used in this study consisted of one item each for the elbow and knee joints. Some self-efficacy scales consist of multiple question items, while others use a Likert scale to evaluate a single item, as in this study. The development of a more accurate scale for judging the self-efficacy of physical therapy students will help clarify the students' motivation and learning status. Finally, the study participants were students of one university in Japan. Differences in content such as curricula and clinical training may also have influenced the differences in measurement accuracy and self-efficacy. Future studies at multiple schools and targeting other joints may further clarify the effects of the post-learning period on self-efficacy and ROM measurement accuracy.

Although the accuracy of knee joint measurement improved after earning the credit for ROM measurement techniques, the accuracy of elbow joint measurements did not differ among grades. Moreover, the effect of the post-learning period varied depending on the joint to be measured, and the differences in duration did not affect students' self-efficacy. These findings highlight the need for teaching and practice methods that promote skill acquisition while increasing students' self-efficacy.

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Conflict of interest

The authors have no conflicts of interest to declare.

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