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Changes in Surface Electromyography during Physiotherapy as Influenced by Therapists' Length of Experience

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ABSTRACT

Background: In Japan, the experience level of physiotherapists is often used to measure proficiency, regardless of other factors such as training quality. This approach cannot establish standards for quality and consistency among physiotherapists. This study aims to lay the foundation for standardizing education and evaluating employee performance in physiotherapy.

Methods: The participants were 14 physiotherapists. Participants were tasked with performing specific physiotherapy skills related to weight-shifting, range of motion exercise, muscle strengthening exercise, and manual muscle testing. Electromyographic (EMG) activity in the participants' upper and lower extremities was measured while they performed the designated physiotherapy skills. Correlational statistical analysis was employed to determine whether therapists' length of experience affected EMG activity during these tasks.

Results: The study found correlations between therapists' length of experience and EMG activity in specific muscles. The length of experience correlated strongly with brachioradialis activation in muscle strengthening exercises (MS-ex) of elbow flexion ($r = 0.779$), moderately with extensor carpi radialis in MS-ex of knee extension ($r = 0.581$), and manual muscle testing of hip abduction testing ($r = 0.550$), but negatively with gastrocnemius in range-of-motion exercises of hip flexion exercises ($r = -0.670$).

Conclusion: Experienced therapists excelled at applying resistance optimally during trunk movements while stabilizing peripheral parts and maintaining effective positions, showing enhanced gastrocnemius muscle activity when required. These findings suggest that experience plays a significant role in the proficiency of physiotherapists and should be considered in efforts to standardize education and evaluate performance in the field.

Keywords: Physiotherapy, Education, Skill, Experience, Electromyography.

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INTRODUCTION

The Japanese Physical Therapy Association (JPTA) conducts a lifelong learning system to improve the quality of physiotherapists (therapists), elevate professional standards in this specialized field, and encourage the continuation of voluntary learning among therapists. This system has been revised in 2022 to enhance the professional quality of therapists to the public. The features of the system can be summarized into 3 points: First, therapists who join the association become "registered therapists" after completing the first and second-semester training to foster "generalists" with the ability to manage a variety of disabilities, considering the first 5 years after graduation as a compulsory post-graduate education period. Second, members who have become "registered therapists" are encouraged to continue self-improvement by renewing their membership every 5 years. Third, on the foundation of "registered therapists," "certified therapists," and "specialized therapists" with higher expertise are fostered as "specialists" with more specialized clinical skills. The JPTA has made these changes to its system to ensure the quality of therapists. However, few therapists continue lifelong learning and obtain these certifications. Of a total membership of 139,556, there are 62,917 registered therapists, 14,974 certified therapists, and 1,697 specialized therapists [1].

Regarding quality assurance, it is necessary to standardize and train basic physiotherapy skills even among certified and specialized therapists, rather than simply encouraging them to attend training sessions and accumulate years of experience. Still, the JPTA's current lifelong learning system lacks this. Standardizing skills requires differentiating between "experienced" and "novice" therapists based on their basic physiotherapy skill levels and approaches. The purpose of this study was to provide a basis for the standardization in education and evaluation.

In terms of skills, experienced therapists teach them to clinically inexperienced therapists and such education is based on the individual therapists' experience. Similarly, although general skills should be taught equally at school, this is also based on experience. Thus, physiotherapy education depends on the staff's views at each facility. In physiotherapy education, it is vital to differentiate experienced and novice therapists, but first, a definition of "experienced" is necessary. As previously mentioned, experienced and novice therapists tend to be differentiated by the length of experience, which is not standardized (5 years of practice) [2].

Additionally, in Japan's public insurance system, experienced and novice therapists perform physiotherapy at the same rate, making it challenging to foster therapists' motivation for self-improvement. These factors are barriers to ensuring the minimum quality of physiotherapy services, and, therefore, the objective evaluation of teaching methods in undergraduate education and physiotherapy skills before and after education are crucial.

Basic physiotherapy encompasses range-of-motion (ROM) exercises [3], manual muscle testing (MMT) [4], muscle strengthening exercises (MS-ex) [5], weight-bearing [6], and weight shifting (WS) [7]. These basic skills are considered the main components of quality in physiotherapy, and their standardization may be essential.

In therapists' training and post-graduate education, objectively evaluating and teaching physiotherapy skills is meaningful. As a preliminary step, this study aimed to analyze and clarify the characteristics of physiotherapy skills based on therapists' length of experience.

METHODS

The participants were 14 physiotherapists; the average therapist's length of experience was 145.7 ± 98.5 (6 - 342) months. They showed no abnormality of neurological function or the musculoskeletal system. The Declaration of Helsinki carried out all study tasks. Before the experiment, all participants were informed of the purpose of the study and agreed to participate. The study was approved by the Ethical Review Committee of the Osaka University of Human Sciences (2017 - 4) and Hyogo University of Health Sciences (19043).

Physiotherapy skills were set on WS while standing, ROM-ex of shoulder and hip, MS-ex of elbow and knee, and MMT of shoulder, knee, and hip.

While standing in this study focuses on only the frontal plane form of the walking motion (with the therapist guiding from behind), it was repeated three times on a simulated patient where the speed of movement was at the discretion of the therapist (Figure 1). All participants tried the task with the same simulated patient. Then, participants guided the simulated patient using bilateral manipulation from the posterior side at the lateral part of the pelvis. Next, participants guided WS to the right without the contralateral lower extremity lifting off the floor. First, participants shifted the weight of the simulated patient in the right direction from the pelvis. Second, participants shifted their left again and back to the upright standing position, and they performed this 3 times.

ROM-ex for shoulder flexion and hip flexion, MS-ex for elbow flexion and knee extension, and MMT for shoulder abduction, hip abduction, and knee extension were performed 3 times by participants (Figure 2). In ROM-ex, MS-ex, and MMT, all participants tried to use the same simulated patient and WS.

When the participants performed these skills, surface electromyography (EMG) of their upper and lower extremities was recorded. The target muscles were the dominant side's deltoid, biceps, triceps, brachioradialis, extensor carpi radialis, flexor carpi ulnaris, tibialis anterior, and gastrocnemius. EMG was recorded using the Clinical Direct Transmission System (Noraxon). The sampling frequency was 1 kHz, and the frequency bandwidth was 10 to 500 Hz. The signal obtained was A/D converted (Analog-to-Digital Conversion) and loaded into a personal computer. EMG was recorded during the tasks, and each

performance was analyzed. The average amplitude value per second was determined because the performance time varied depending on the participants. It was divided by the average amplitude value per second of the simulated patient's resting standing position, and the relative value of integrated EMG (IEMG) was calculated. The average amplitude value of the resting standing position, the reference value used for IEMG normalization, was acquired from the most stable 5 seconds within 10 seconds on their natural standing. In addition, the visual observation of the characteristics of the EMG waveforms was also examined.

The mean and standard deviation were calculated for IEMG. Statistical analyses were performed using SPSS software version 28.0. Normality was tested using a Shapiro-Wilk test (this method tests whether the data is normally distributed). Correlational statistical analysis was used to confirm whether the length of experience changes the degree of these skills. Non-parametric Spearman's correlation coefficient was calculated to assess the relationship between each muscle's length of experience and surface EMG activity measurement. The significance level was determined at 0.05.

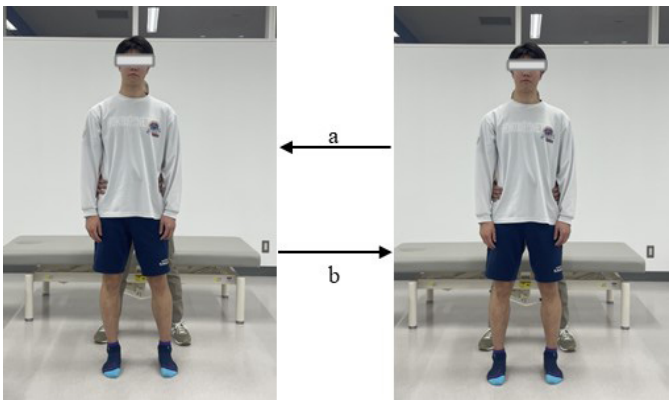


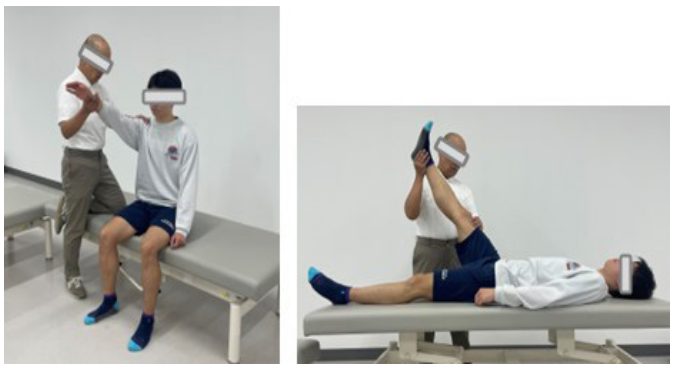
Figure 1: Weight-shifting as an essential physiotherapy skill.

The starting position of the simulated patient was upright. Participants shifted 'simulated patient' from upright standing to the right (a) and back to upright (b). Repeated 3 times.

RESULTS

The results of correlational statistical analysis in IEMG are shown in Table 1. For brachioradialis, the length of experience was r = 0.779 in MS-ex of elbow flexion. For extensor carpi radialis, the length of experience was r = 0.581 and r = 0.550 in MS-ex of knee extension and MMT of hip abduction, respectively. For gastrocnemius, the length of experience was r = -0.670 in ROM-ex of hip flexion. No statistical significance was demonstrated in the correlation between the length of experience and IEMG measurement for the deltoid, biceps, triceps, flexor carpi ulnaris, and tibialis anterior.

A. ROM-ex for shoulder flexion and hip flexion



B. MS-ex for elbow flexion and knee extension

C. MMT for shoulder abduction, knee extension and hip abduction

Figure 2. Typical upper and lower extremity exercise is a basic physiotherapy skill.

Figure 3 shows the raw waveforms of each muscle from surface EMG. When focusing on the brachioradialis and extensor carpi radialis, it was found that the amplitude increased and decreased during the task among therapists with longer experience. In contrast, the amplitude was negligible, with less activity among therapists with shorter experience. The raw waveform of the gastrocnemius also revealed an increase and decrease in the amplitude during the task among therapists with longer experience. In contrast, the muscle was always active among therapists with shorter experience.

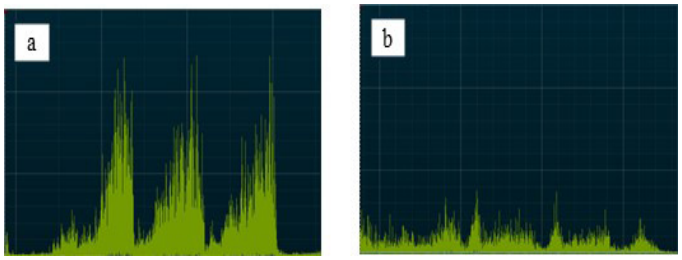
Table1. The results of correlational statistical analysis in IEMG.

	WS		ROM-ex				MS-ex				MMT					
			shoulder flexion		hip flexion		elbow flexion		knee extension		shoulder abduction		hip abduction		knee extension	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
deltoid	-0.469	0.091	-0.279	0.333	0.432	0.123	-0.218	0.454	0.238	0.413	-0.217	0.456	0.143	0.626	0.097	0.742
biceps	-0.251	0.387	0.051	0.864	0.126	0.669	-0.110	0.708	0.400	0.156	0.000	1.000	0.057	0.846	0.462	0.096
triceps	0.268	0.355	-0.226	0.437	0.255	0.380	0.416	0.139	0.396	0.161	0.044	0.881	0.262	0.366	0.213	0.464
brachioradialis	0.029	0.923	0.132	0.652	0.134	0.647	0.779	0.001	0.229	0.431	0.383	0.177	0.504	0.066	0.128	0.664
extensor carpi radialis	0.024	0.935	0.236	0.417	0.150	0.610	0.392	0.166	0.581	0.029	0.506	0.065	0.550	0.042	0.326	0.256
flexor carpi ulnaris	0.192	0.512	-0.092	0.753	0.279	0.333	0.308	0.284	0.088	0.765	0.112	0.703	0.114	0.697	0.035	0.905
tibialis anterior	-0.267	0.356	-0.164	0.576	-0.452	0.105	0.401	0.155	0.299	0.300	-0.011	0.970	-0.119	0.685	0.029	0.923
gastrocnemius	-0.465	0.094	-0.090	0.760	-0.670	0.009	-0.097	0.741	-0.412	0.143	-0.184	0.529	-0.160	0.585	-0.178	0.544

r: Spearman's correlation coefficient; p: p-value.

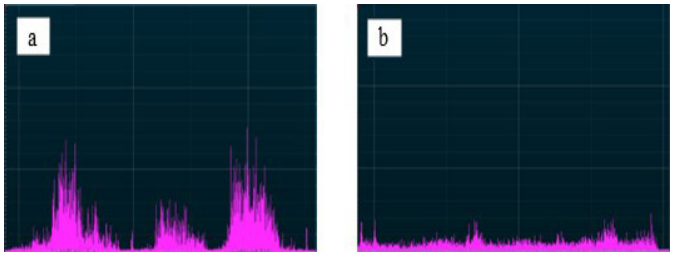
A. brachioradialis

MS-ex of elbow flexion

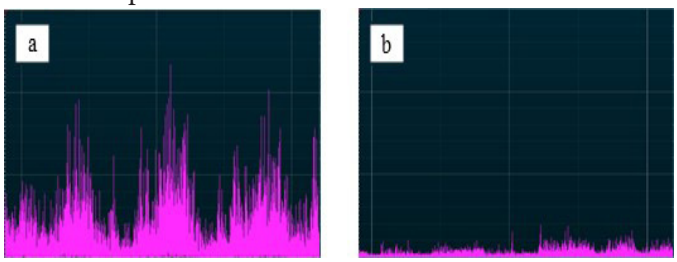


B. extensor carpi radialis

MS-ex of knee extension



MMT of hip abduction



C. gastrocnemius

ROM-ex of hip flexion

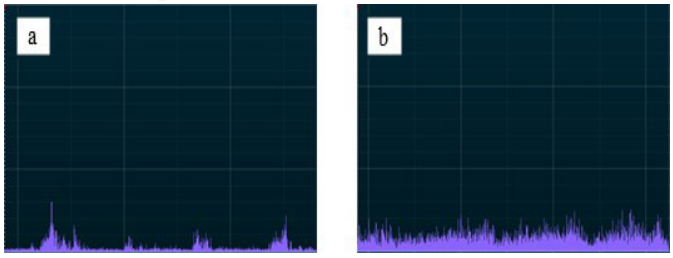


Figure3. The raw waveforms in EMG

a: therapists with longer experience, b: therapists with shorter experience

DISCUSSION

In this study, we electromyographically examined the physical movements of therapists when applying various physiotherapy skills and found that therapists' length of experience was strongly correlated with the brachioradialis, moderately correlated with the extensor carpi radialis, and negatively correlated with the gastrocnemius.

Okayama et al. (2023) showed the ratio of the center of pressure (COP) displacement and the maximum ground reaction force (GRF) of a simulated patient was examined by means of WS, which is one of the basic physiotherapy skills 8). As a result, a weak negative correlation was confirmed between the length of experience and the ratio of COP displacement. In contrast, no correlation was found between the length of experience and the maximum GRF. There were significant differences in the ratio of COP displacement and the maximum GRF during WS compared to institutions. The study participants had from 66 to 330 months of therapists' experience. They all met the minimum of 5 years (60 months) of therapists' experience as per Japan's clinical practice supervisor requirement. Therefore, it is possible that only a weak negative correlation between the length of experience and the basic physiotherapy skill was considered. However, this study supposed that the relationship between the length of experience and the basic physiotherapy skill is more pronounced because participants with less than 5 years of therapist' experience were also included.

The therapists' length of experience was significantly correlated with the brachioradialis, extensor carpi radialis, and gastrocnemius, each involved in elbow flexion, wrist dorsiflexion, and ankle plantar flexion, respectively. The positive correlations between the length of experience and the brachioradialis and extensor carpi radialis suggest that therapists with longer experience kept their elbow joint flexed and their wrist joint dorsiflexed during the task. By fixing these joints, they may have intended to increase the stability of their body and the ease of using other joints. On the other hand, the negative correlation with gastrocnemius indicates that therapists with shorter experience need to shift their weight and control ankle dorsiflexion during the task.

The following is a discussion of each of the individual muscles.

Brachioradialis

In MS-ex for elbow flexion, the therapists flexed their elbow joint and applied resistance to the patient's forearm. In this position, therapists with longer experience moved their entire body to shift their weight while applying resistance. In contrast, those with shorter experience only applied it using the elbow joint.

The raw waveforms of the brachioradialis revealed that the EMG amplitude of therapists with longer experience increased around the middle of the simulated patient's joint ROM (Figure 3 A-a). In contrast, the muscle activity of therapists with shorter experience in response to the movements was low (Figure 3 A-b).

These findings suggest that therapists with longer experience could use the trunk movement with the peripheral parts fixed and apply resistance in accordance with force development. In contrast, therapists with shorter experience mainly used the movements of the peripheral parts and applied insufficient resistance.

Extensor carpi radialis

In MS-ex for knee extension, the therapists kept their wrist joint dorsiflexed and applied resistance to the patient's lower leg. Among therapists with longer experience, there were fewer elbow and wrist movements, and resistance application involved trunk extension and rotation. In contrast, therapists with shorter experience used their elbow and wrist joints more extensively.

In MMT for hip abduction, the therapists kept their wrist joint dorsiflexed and applied resistance to the patient's thigh. Among therapists with longer experience, there were fewer elbow and wrist movements, and resistance application involved trunk and hip flexion. In contrast, therapists with shorter experience used their elbow and wrist joints more extensively.

The raw waveforms of the extensor carpi radialis revealed that the EMG amplitude of therapists with longer experience increased around the middle of the simulated patient's joint ROM (Figure 3 B-a). In contrast, the muscle activity of therapists with shorter experience in response to the movements was low (Figure 3 B-b).

These findings suggest that therapists with more experience could use trunk movement with the peripheral parts fixed and apply resistance in accordance with force development. In contrast, therapists with shorter experience mainly used the movements of the peripheral parts and applied insufficient resistance.

Gastrocnemius

In ROM-ex for hip flexion, the therapists moved their COG while supporting the patient's lower limb with the upper body. Therapists with longer experience stood near the patient's knee joint, whereas those with shorter experience stood near the patient's ankle joint.

The raw waveforms of the gastrocnemius revealed the EMG amplitude of therapists with longer experience increased as the patient's lower limb moved away from the therapist's body during hip flexion (Figure 3 C-a). In contrast, the muscles of therapists with shorter experience were active throughout the task (Figure 3 C-b).

These findings suggest that therapists with longer experience maintained an appropriate standing position and that their gastrocnemius was active only when they executed necessary movements. In contrast, the muscles of therapists with shorter experience were always active, as they stood far from the patient, and their COG was located forward.

In this study, there were many variations in the methods of physiotherapy skill application, as we did not specify these methods and asked the therapists to perform each skill in their usual way. The results revealed correlations between their length of experience and some physiotherapy skills. However, due to such variations, it cannot be concluded that the two factors are correlated. Considering that therapists change how they use their bodies, depending on the differences in size and environment between themselves and patients, it may be necessary to standardize the conditions for physiotherapy skill application and accurately evaluate therapists' skill levels.

Specifically, the physiotherapy skills applied in WS depend on the staff of each facility [8]. In other words, therapists' skills depend on the teaching methods of their supervisors. The above variations in the methods of physiotherapy skill application may also have resulted from the differences in the teaching methods of supervisors in educational institutions, such as universities and vocational schools, or workplaces, such as hospitals and facilities. This explains why the muscle activity level and pattern varied among therapists in the present study.

The term "tacit knowledge" comes from a scientist who said, "We can know more than we can tell" [9]. It is a type of knowledge based on personal experience and intuition that cannot be easily verbalized. We believe quantifying therapists' body movements during treatment and their effects on patients will help clarify tacit knowledge related to physiotherapy skills. Therefore, we will conduct similar experiments involving individuals supervising physiotherapy skills and promote explicit knowledge related to these skills.

CONCLUSIONS

This study examined the relationship between therapists' experience and their muscle activation patterns while applying physiotherapy skills. Specifically, therapists with longer experience displayed increased muscle activity in the brachioradialis and extensor carpi radialis, indicating a tendency to maintain joint stability in the elbow and wrist, potentially enhancing body stability. Conversely, less experienced therapists showed increased activity in gastrocnemius, suggesting a greater reliance on ankle control to adjust body balance. The findings also highlighted differences in skill application across therapists.

Experienced therapists demonstrated trunk-centric movements with fixed peripheral joints, which suggests an ability to stabilize core muscles and apply resistance appropriately. In contrast, less experienced therapists tended to rely more on peripheral joint movement, indicating a possible lack of coordination in trunk stability.

This variability in physiotherapy methods, influenced by institutional training and supervisors' teaching styles, underscores the need to standardize specific physiotherapy skill applications to ensure consistency in practice and skill assessment. Additionally, quantifying the body movements of therapists could provide valuable insights into "tacit knowledge"—the experiential and intuitive understanding that guides skilled practice. Future research involving experienced physiotherapy supervisors could further clarify the relationship between therapists' body mechanics and treatment efficacy, promoting explicit knowledge transfer to advance physiotherapy techniques.

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Credit Authorship Statement

Yumi Okayama: Methodology, Validation, Conceptualization, Resources, Data curation, Formal analysis, Writing - original draft.

Shinich Daikuya: Supervision, Project administration.

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