Ability to categorize end-feel joint movement according to years of clinical experience: an experiment with an end-feel simulator

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Abstract. [Purpose] Discrimination between end-feel types is difficult, and years of clinical experience is considered a factor for improving the accuracy of the discrimination. The present study investigated whether the accuracy of classification of end-feel types improves with the increase in years of clinical experience. [Participants and Methods] In total, 44 therapists (range of years of clinical experience: 1–26 years) and 13 students were included. The participants identified the type of end feel simulated by our newly developed simulator. The proportion of correct answers of the therapists was compared with that of the students. For the therapists, years of clinical experience and their awareness of end feel were examined, and their relationships with the ability to classify end-feel types were analyzed. [Results] The therapists showed a higher ability to identify end-feel type than the students. The ability of the therapists improved according to their years of clinical experience. The cutoff values for years of clinical experience to improve the ability for identifying bone-to-bone, muscular, and tissue approximations were 15, 6, and 15, respectively. The therapists who were always conscious about end feel were associated with a higher ability to classify end-feel types. [Conclusion] Our present study demonstrated that the ability to classify end feel improves with the increase in years of clinical experience.

Key words: End-feel, End-feel simulator, End-feel classification ability

INTRODUCTION

For physical and occupational therapists, a limited range of motion (ROM) in patients is a significant impairment that affects efforts at rehabilitation. Limited ROM is associated with multiple factors for which different methods of treatment are applied; therefore, the reason for limited ROM must be identified. This is determined according to several criteria, including end-feel (EF), range of joint motion, change in ROM according to the degree of stretch in multi-joint muscles and pain. In addition, medical history, imaging, and palpation are used as reference. EF is perceived by the examiner as a sense of resistance at the end of passive joint movement. Therapists frequently refer to EF in clinical practice because it points to the etiology of limited ROM and is convenient since it requires no equipment. Among the physical findings, EF has been found most reliable by therapists, supported by the results of an investigation by the Osaka Physical Therapist Association in 1993 that reported 37.4% of 488 physical therapists from 145 facilities in Osaka prefecture responded that EF was most important for identifying the factor(s) of limited ROM1).

The concept of EF was first introduced by Cyriax, a British orthopedist, in 1982. In his book2), EF was described in detail...
and was reported as a set of helpful criteria for the diagnosis of limited ROM. To date, Cyriax’s classification of EF has been modified several times\textsuperscript{3, 4}. Though there are some differences among studies, the most frequently used EF classification in Japan is shown in Table 1.

Despite its advantages, there can be limitations when applying EF criteria in clinical practice. The greatest limitation is that the EF type is determined subjectively by the examiner. Only a few studies have tried to simulate EF using a specialized device and software\textsuperscript{5}, however, the studies were not successful. As a result, assessment of EF type is still determined subjectively by clinicians. Therefore, a therapist’s amount of clinical experience is considered a factor related to the accuracy of EF diagnosis.

To improve the ability to discriminate EF type, we developed a device that simulates EF in human joints, called an EF simulator (Fig. 1\textsuperscript{6, 7}). The simulator consists of a spring, a servomotor, and a stopper mechanism made of rigid plastic which generates many types of reactive forces. In this study, we investigated the correlation between years of clinical experience and improvement in the ability to discriminate EF types as well as the correlation between awareness of EF types and time to acquire the ability to discriminate EF types in a clinical setting.

**PARTICIPANTS AND METHODS**

Participants were 44 therapists serving in hospitals in Osaka Prefecture, Japan, consisting of 42 physical therapists and 2 occupational therapists (gender: 31 male, 13 female; mean age (years) ± standard deviation: 29.1 ± 7.6 [range (years): 22–53]; mean years of clinical experience ± standard deviation: 7.2 ± 7.1 [range: 1–26]). Final-year physical therapy students (from Morinomiya University of Medical Sciences) without clinical training were recruited for comparison (gender: male=7, female=6; mean age (years) ± SD: 21.2 ± 0.4; range (years): 21–22). These students were aware of EF but had no clinical exposure to assessing the different types.

Prior to the start of the clinical study, the participants answered a questionnaire about awareness of EF as follows: always conscious, conscious, sometimes conscious, unconscious and don’t know. Based on Cyriax’s classification of EF, participants

| Table 1. End-feel with pathologic limitation of joint range of motion |
|---|
| **End-feel** | **Perceived resistance** | **Simulation** |
| Bone-to-bone | Bony impingement, bony braking | ✓ |
| Muscle spasm | Abrupt occurrence of stiff and spastic resistance | none |
| Capsular | Resistance during gum twisting | none |
| Muscular | Increased elasticity caused by muscular tone | ✓ |
| Tissue approximation | Strong resistance caused by tendon and connective tissue | ✓ |
| Empty | No feeling of resistance with non-constant range of joint motion limited by pain | none |

Check mark indicates the end-feel presented by the EF simulator in this experiment.

Fig. 1. End-feel simulator.
Simulation of end-feel occurs when applying pressure to the press pad. The reactive force adjusts according to the settings of the end-feel modulator.
tried to identify the type of EF simulated by the device. The types of EF were limited to bone-to-bone, muscular, and tissue approximation because muscle spasm and empty feel, which show inconsistent ROM, are easily identified and need no practice. In addition, capsular feel is always considered part of tissue approximation in clinical practice and the same treatment approach is provided to both types of EF. Therefore, the capsular feel was also excluded from the EF examination. During EF discrimination using the simulator, participants were asked to press a skin-like pad attached to the arm of the device in the same way as they do for patients with limited ROM (Fig. 2). The participants could repeat the procedure until they decided on an EF type. All participants were blinded to the EF types presented in the trial session. Each type of EF was randomly presented 3 times. Next, they rated the probability of the EF type by making a score in each of 3 categories (i.e. bone-to-bone, muscle, tissue approximation) on a scale of 1 to 5 (from improbable to most probable) where the category with the highest score was recognized as the EF type of the trial. When 2 or more categories were scored as “most probable,” the trial was considered undetermined. For each participant, the proportion of correct answers (PCA) for each EF type was calculated with the formula: PCA=(number of correct answers / 3).

For analyses, PCA was compared between bone-to-bone and a combination of muscle and tissue approximation because bone-to-bone indicates quite clear EFs with a complete stop of the arm movement in contrast to the ambiguity shown by muscle and tissue approximation which is effected by elastic force. Thus, for the first, the capability of discrimination between bone-to-bone and the complexed EF was examined, which was followed by a comparison between muscle and tissue approximation. Based on years of clinical experience, participants were classified into 5 groups: inexperienced (students), less than 3 years, 3 to 5 years, 6 to 9 years, and 10 years and more. For each group, PCA was calculated (average PCA) and for each type of EF (individual PCA). The cutoff value for the years of clinical experience required for improvement in the ability of EF discrimination was identified by Youden’s index calculated from the ROC curve obtained by multiple logistic regression analysis. All statistical analyses were performed using software JMP14 v 14.3.0 (SAS Institute, Cary, NC, USA). Correlation between years of clinical experience and PCA was assessed by Pearson’s correlation coefficient with list-wise case deletion. Wilcoxon rank-sum test was used to assess the significance of PCA (both averaged and individual) between therapists and inexperienced participants with a significance level of 5%.

Before the study, written informed consent was obtained from all participants by giving the participants easy-to-understand documents. This research plan was approved by the ethics committee at Morinomiya University of Medical Sciences (approval number: 2018-105).

RESULTS

The PCAs of therapists, regardless of years of practice, were significantly higher than the inexperienced participants (p<0.05) (Table 2). In particular, therapists received a significantly higher PCA for discrimination between the combination and bone-to-bone than inexperienced participants (p<0.01) (Table 2). When muscular and tissue approximations were individually examined, therapists received a significantly higher PCA for tissue approximation than inexperienced participants (p<0.05) (Table 3). However, the therapists scored a higher percentage of misidentifications that the participants identified as muscular but were tissue approximation, and vice versa, than the experienced participants though the differences were not statistically significant (Table 3).

When the participants were classified into 5 groups based on years of clinical experience, the more experienced partici-
pants tended to obtain higher PCAs (Table 4). Therapists with 6–9 years of clinical experience obtained higher PCAs than the other groups according to EF type (p<0.05), except for tissue approximation in which a significant difference was shown only between less than 3 years and 3 to 5 years of clinical experience (p<0.05) (Table 4).

The correlation coefficient between years of clinical experience (including the inexperienced participants) and PCA was 0.30 (p<0.05), 0.40 (p<0.01) and 0.47 (p<0.05) for the average, bone-to-bone, and combined scores, respectively. However, the correlation was not significant for muscular (r=0.22) or tissue approximation (r=0.10) when examined individually. The number of therapists according to the level of consciousness of EF was 11 (25%), 17 (39%), and 16 (36%) for always conscious, highly conscious, and sometimes conscious, respectively (Table 5). No therapists replied unconscious or don’t know. Generally, the therapists with a higher level of consciousness of EF had higher PCA. The therapists who were always conscious of EF had higher PCA than those who were highly conscious (p<0.05).

The cutoff value for years of clinical experience for improved discrimination between bone-to-bone, muscular, and tissue approximation was 15, 6, and 15, respectively (Fig. 3). To confirm this, the PCAs was compared between the participants with clinical experience of less than 15 years (n=38, mean PCA ± SD: 0.45 ± 0.32) and 15 or more years (n=6, mean PCA ±

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**Table 2.** Comparison of proportion of correct answers between therapists and inexperienced participants

| Therapists (n=44) | Average of all end-feel types | Bone-to-bone | Combination of muscular and tissue approximation |
|-------------------|-----------------------------|-------------|-----------------------------------------------|
| * 0.44 ± 0.17     | 0.50 ± 0.34                | * 0.72 ± 0.23 |
| Inexperienced participants (students) (n=13) | 0.32 ± 0.19 | 0.46 ± 0.25 | 0.41 ± 0.24 |

Results are shown as mean ± SD. * p<0.05, ** p<0.01.

**Table 3.** Percentage of correct answers and misidentification

| Therapists (n=44) | Muscular | Tissue approximation |
|-------------------|----------|-----------------------|
| Percentage of correct answer | Identified as tissue approximation | Percentage of correct answers | Identified as muscular |
| 0.40 ± 0.32 | 0.30 ± 0.31 | * 0.42 ± 0.31 | 0.33 ± 0.33 |
| Inexperienced participants (n=13) | 0.28 ± 0.23 | 0.21 ± 0.26 | * 0.21 ± 0.32 | 0.21 ± 0.22 |

Results are shown as mean ± SD. *<0.05.

**Table 4.** Percentage of correct answers grouped by years of clinical experience

| Years of clinical experience | Gender: Male/Female | Averaged end-feel (across 3 types) | Bone-to-bone | Combination of muscular and tissue approximation | Muscular | Tissue approximation |
|-----------------------------|---------------------|-----------------------------------|-------------|-----------------------------------------------|----------|----------------------|
| None (n=13)                 | 7/6                 | 0.32 ± 0.19                       | 0.46 ± 0.25 | ** 0.41 ± 0.24                                | 0.28 ± 0.23 | 0.21 ± 0.32          |
| Less than 3 years (n=13)    | 8/5                 | 0.44 ± 0.23                       | 0.41 ± 0.28 | 0.71 ± 0.26                                  | 0.38 ± 0.30 | * 0.38 ± 0.30        |
| 3 to 5 years (n=11)         | 7/4                 | 0.37 ± 0.10                       | 0.39 ± 0.29 | * 0.64 ± 0.21                                | 0.27 ± 0.33 | 0.45 ± 0.27          |
| 6 to 9 years (n=10)         | 6/4                 | * 0.47 ± 0.19                     | * 0.53 ± 0.42 | * 0.83 ± 0.16                                | 0.53 ± 0.23 | 0.37 ± 0.37          |
| Over 10 years (n=10)        | 10/0                | 0.50 ± 0.13                       | 0.43 ± 0.39 | 0.72 ± 0.26                                  | 0.43 ± 0.39 | 0.47 ± 0.36          |

Results are shown as mean ± SD. *<0.05, * *<0.01.

**Table 5.** Consciousness of end-feel and percentage of correct answers in therapists

| Level of consciousness concerning end-feel | Averaged end-feel (across 3 types) | Bone-to-bone | Combination of muscular and tissue approximation | Muscular | Tissue approximation |
|-------------------------------------------|------------------------------------|-------------|-----------------------------------------------|----------|----------------------|
| Always conscious (n=11)                   | * 0.54 ± 0.13                      | * 0.70 ± 0.28 | 0.83 ± 0.21                                   | 0.42 ± 0.34 | 0.48 ± 0.31          |
| Conscious (n=17)                          | 0.40 ± 0.18                        | * 0.39 ± 0.32 | 0.66 ± 0.25                                   | 0.35 ± 0.34 | 0.37 ± 0.26          |
| Sometimes conscious (n=16)                | 0.43 ± 0.18                        | 0.48 ± 0.36  | 0.71 ± 0.21                                   | 0.44 ± 0.29 | 0.42 ± 0.38          |

Results are shown as mean ± SD. *<0.05.
DISCUSSION

In this study, we investigated the relationship between years of clinical experience and the ability to discriminate EF types using EF simulator we developed. Higher PCAs were reported for those with clinical experience compared to inexperienced participants (Table 2). However, this was not the case for all EF types. In particular, the between-group difference in PCA was relatively small for bone-to-bone EF. We attribute these results to the easily identifiable bone-to-bone EF. Moreover, bone-to-bone EF is easily examined using X-ray image, thus the EF can be identified with high accuracy by less experienced participants. We presume this is the reason for the similar PCA despite the years of clinical experience.

The results in PCA for bone-to-bone EF compared to the other EF types in the study is inconsistent with a study by Tasaka et al.7) which suggested that learning the identification of bone-to-bone EF requires more clinical exposure than the other EFs6). However, muscular and tissue approximation tended to be confused with one another in the present study (Table 3), similar to findings from Tasaka et al7).

The muscular EF was simulated by increasing the sense of softness at the end-point of the arm motion, in contrast to increasing the hardness for tissue approximation. The results showed a small difference in PCA between the two types of EF which is often the case in clinical practice as well. In the present study, the PCA for muscular EF was higher than the percentage of misidentification (e.g. muscular EF identified as tissue EF).

Tasaka et al. reported that more years of clinical experience relates to improved ability to discriminate EF types7), although no cutoff values were calculated due to the small sample size of the study. In this study, participants were classified into 5 groups based on years of clinical experience to examine the relationship with PCA (Table 4). The average of correct identification of the 3 EF types increased with years of experience, though the difference in PCAs among the groups was not significant. However, PCA for individual EF types did not show a positive correlation with years of clinical experience. The highest PCA was observed in the group with 6 to 9 years of experience, except in the case of tissue approximation. This group presumably consists of the therapists who are more familiar with clinical practice compared to the younger therapists who represent a large proportion of the workforce in Japan. The therapists with 6 to 9 years of experience may require an effort to maintain their ability to correctly identify EF types. In recent years, the use of ultrasound scanners in clinical practice can confirm correct identification. Thus, the use of EF simulators like the one we developed could be used for training on EF identification without patients and any clinical improvements in correct identification of EF types could be confirmed by ultrasound.

The relationship between the level of EF consciousness and PCA showed that the participants who were always conscious of EF had higher PCAs. Regarding the cutoff values for years of clinical experience associated with improvement in the ability to identify EF correctly, the therapists required up to 15 years for acquiring the skill of identifying tissue approximation. However, tissue approximation tended to be confused with muscular EF, which is difficult to distinguish. In contrast, correct muscular EF identification required only 6 years. Practicing the identification of muscular EF could lead to the earlier acquisition of the ability to discriminate muscular EF from tissue approximation. A training method focused on discrimination between similar EFs has not been fully established but this is an important line of inquiry.
The cutoff value of correct bone-to-bone EF identification was also 15 years. A possible reason for this is that even the less experienced therapists identified the EF correctly because of the clear EF. This result is not consistent with the relationship between the years of experience and PCA. However, the number of participants with 15 or more years of experience was small in this study and further research is required.

As the consciousness of EF was considered a possible factor that increases the rate of learning EF identification, the relationship between the participants’ self-reported level of consciousness and PCA was examined. The results showed that the participants were always or highly conscious generally had a higher rate of learning. The same tendency was indicated for tissue approximation. It could be important for the participants who had lower PCAs for bone-to-bone EF to increase consciousness of EF in daily clinical practice. Taken together, the present results suggest that the correct identification of EF types would improve with improvements in identifying muscular EF and being conscious of bone-to-bone EF. The EF simulator developed for this study could be useful for intensive training in the identification of muscular EF.

There are some limitations of the study to consider. First, the number of younger therapists was quite larger than the veteran therapists, thus, a relatively small amount of information was obtained for the experienced therapists which might affect the statistical outcomes of the analyses. The second limitation was the difference in education between the younger and the experienced clinicians and there was no way to control for these differences. Cyriax’s classification of EF has become widespread in Japan only during the last decade or two. Until then, EF classification was a dichotomy between “hard” and “soft” resistance and some of the veteran clinicians may have only been exposed to EF identification during the latter part of their careers. Therefore, further research including a cohort study is required to investigate the age-related change in the ability of therapists to identify EF.

In conclusion, improving the identification of muscular EF and being always or highly conscious of EF are key factors in increasing the reliability of EF classification. In addition, the use of a specially designed EF simulator may be effective for pre- and in-service training to improve EF classification.

Conflict of interest

The authors declare no conflict of interest.

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