Increases of accuracy about examination of temporomandibular disorders

（顎関節症検査における精度向上に関する検討）

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Ⅰ. Abstract

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Ⅰ. Abstract

[Objective]

The aims of the present study were twofold: first, to compare awake bruxism events between subjective and objective evaluations using a questionnaire survey and a modified portable electromyography (EMG) device, and to examine correlations between sleep quality and awake bruxism, and second to estimate the effects of clinical experience and visual feedback on the accuracy of palpation in standardized settings.

[Materials and methods]

Research 1: The Epworth Sleepiness Scale (ESS), Pittsburgh Sleep Quality Index (PSQI), and awareness of awake bruxism as clarified via interviews were conducted on 34 participants as subjective evaluations. The EMG device was used to record left temporal muscle activity for 6.5 h (from 09:00 to 15:30) and the number of awake bruxism episodes per hour. The participants were then classified into "bruxer" and "non-bruxer" groups based on the number of awake bruxism episodes.

Research 2: Thirty-two dentists (age 35 ± 11 years) classified as either specialists (n=16) or generalists (n=16) participated in this experiment. All dentists were instructed to target force levels of 500-gf or 1000-gf, as determined on an electronic scale using either standardized palpometers or manual palpation (MP). All dentists participated in four different tests: MP, MP with visual feedback (MPVF), palpometer (PAL), and PAL with visual feedback (PALVF). Actual force values for each type of palpation from 0-2, 2-5, and 0-5 seconds were analyzed by calculating target force level.

[Result]

Research 1: The mean number of awake bruxism episodes per hour was 33.6 ± 21.4, and 23% of the participants who reported having no awareness of awake bruxism in the

interviews were defined as "bruxers" in the objective evaluations. In the bruxer group, positive correlations were found between the number of awake bruxism episodes and both ESS and PSQI scores.

Research 2: The relative differences during 2-5 and 0-5 seconds with 1000 gf were significantly lower for generalists than for specialists (P < 0.05). In generalists and specialists, the coefficients of variation and the relative differences during 2–5 seconds were significantly lower for PAL and PALVF than for MP (P < 0.05).

[Conclusion]

These findings suggest that objective measurements using a portable EMG device can increase the diagnostic accuracy for awake bruxism, and that sleep quality is a major risk factor for awake bruxism, and the use of a palpometer, but not clinical experience with palpation of masticatory muscles, increases the accuracy of palpation, and ≥ 2 seconds of palpation with a palpometer is optimal for masticatory muscles.

Ⅱ. Introduction

Awake bruxism, defined as the occurrence of masticatory muscle activity during wakefulness characterized by repetitive or sustained tooth contact and/or bracing or thrusting of the mandible, is not a movement disorder experienced by otherwise healthy individuals. Although it is important for dental clinicians to diagnose and manage awake bruxism, the mechanisms underlying awake bruxism in the unconscious state have not yet been elucidated. Some studies have investigated the prevalence of awake bruxism using questionnaires and real-time self-reports about awake bruxism via a smartphone application. Bracci et al. conducted a questionnaire survey to investigate the prevalence of awake bruxism and found that the prevalence of self-reported awake bruxism was as

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high as 30% across populations [1]. Using a real-time self-report smartphone application, Stanisic et al. reported a significant difference in the frequency of awake bruxism between young adults and parents, and a moderate correlation between awake bruxism and stress [2]. However, because "possible" awake bruxism is based on self-reports and "probable" awake bruxism is based on self-reports plus clinical inspections [3], it is important to investigate masticatory muscle activity during the daytime to clarify the grading of "definite" awake bruxism and gain a better understanding of awake bruxism behavior.

To this end, some studies have attempted to measure awake bruxism using a portable electromyography (EMG) device as a means of objective evaluation [4-7]. Although these previous studies have mainly investigated masticatory muscle activity during daytime as an objective variable, they have not compared subjective and objective evaluations of awake bruxism in the same participants. To improve the diagnosis of awake bruxism and the clinical significance of the use of a portable EMG device for its assessment, it is essential to investigate the correlations between subjective and objective evaluations in the same participants.

The pathomechanism of sleep bruxism has also been gradually clarified according to the development of a portable EMG device that can measure masticatory muscle activity. Sato et al. objectively demonstrated a correlation between awake and sleep bruxism [5]. Ohlmann et al. investigated the associations between "definite" sleep bruxism, chronic stress, and sleep quality, and reported finding no significant correlation between sleep bruxism and self-reported stress or sleep quality [8]. Together, these conclusions imply significant associations between "definite" awake bruxism, chronic stress, and sleep quality. Although Stanisic et al. suggested the presence of a moderate

positive correlation between "possible" awake bruxism and stress, no studies have investigated the correlation between "definite" awake bruxism and sleep quality to date. Therefore, to gain a better understanding of awake bruxism, it may be important to clarify the correlation between "definite" awake bruxism and sleep quality. The final aim of Research 1 was to clarify the pathomechanism of awake bruxism to establish both a management plan and a set of diagnostic criteria for awake bruxism as a form of patho-bruxism [9].

Myofascial pain in the jaw muscles due to temporomandibular disorders (TMD) is a frequent symptom in the general population, with a prevalence ranging from 21.5% to 51.8% [10–13]. Furthermore, women show a greater prevalence than do men [14–16]. Manual palpation of masticatory structures is an important part of the clinical examination and in the diagnostic process of TMD and orofacial pain. In the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD), palpation of the masticatory muscles is defined as a palpation procedure with a duration of approximately 2 seconds if a diagnosis of myalgia is to be provided, and of approximately 5 seconds for a diagnosis of any type of myalgia (local myalgia, myofascial pain with spreading, or myofascial referred pain) [17]. The evaluation of muscle pain by palpation is therefore a pivotal part of the clinical examination in patients with myalgia. Masuda et al. [18,19] have reported that standardized palpation of the masseter and temporalis muscles can evoke referred pain and sensations. The degree of pain elicited by palpation is determined by several factors, with the intensity of pressure exerted by the observer as likely the most important [20].

However, the fact that manual palpation forces cannot be measured, and thereby standardized within and between observers, is potentially a serious problem

[20,21]. In addition, many confounding factors (e.g., patient bias, examiner expectancies, instructions, training, psychological state) can influence the outcomes of manual palpation [22]. Some studies have investigated the reliability of several algometers to evaluate their utility in the clinical setting [21,23–28]. However, sophisticated types of pressure algometers are associated with disadvantages in terms of cost and practical handling of the instrument (e.g., power supply, size) [21]. Futarmal et al. [21] described a new palpometer that demonstrated low test–retest variability and provided a more accurate and reproducible pressure stimulus compared with manual palpation. Kothari et al. [29] also investigated the effects of handedness, force levels, target surface hardness, and palpation duration using the new palpometer.

However, those previous studies only compared palpation between manual palpation and palpation with the new palpometer; one of the studies also investigated the effects of calibration using the palpometer in manual palpation immediately before performing the procedure, but none have investigated the effects of training with the use of visual feedback in each phase with the new palpometer immediately before performing the procedure. To improve the reliability and repeatability of palpation, training with the use of visual feedback could be a method which can help to solve this problem. Furthermore, it is low cost, easy and may provide important benefits. If training of standardized palpation provided immediately before the procedure affects its variability and accuracy, then training before palpation of the masticatory muscles should be recommended. In addition, if palpation of the masticatory muscles using the new palpometer can reduce variability and increase the accuracy, then the use of palpometers should be recommended regardless of clinical experiences. However, to our knowledge, no studies have investigated the effects of clinical experience and visual

feedback on palpation of the masticatory muscles with or without a palpometer. The hypotheses of Research 2 were that the accuracy of palpation depends on clinical experience with palpation, and that a lack of clinical experience can be compensated for by the use of a quantitative and standardized palpometer.

Given this background, the aims of the present study were twofold: first, to compare awake bruxism events between subjective and objective evaluations using a questionnaire survey and a modified portable electromyography (EMG) device, and to examine correlations between sleep quality and awake bruxism. Second to estimate the effects of training on visual feedback to increase the accuracy of palpation, and to investigate the effects of clinical experience on palpation of the masticatory muscles.

Ⅲ. Materials and methods

Research 1: Analysis of definite awake bruxism using a portable electromyography device

This study consisted of two experiments. Ten healthy volunteers (6 men, mean age ± standard deviation [SD], 31 ± 4 years; 4 women, mean age ± SD, 28 ± 3 years) with no abnormal stomatognathic function participated in the first experiment, while 34 healthy volunteers (19 men, mean age ± SD, 27 ± 3 years; 15 women, mean age ± SD, 28 ± 3 years) with no abnormal stomatognathic function participated in the second experiment. The exclusion criteria for both experiments were as follows: pregnancy, any mental disorder, and medication use (analgesics, antidepressants, or hypnotics) within 48 h of the investigation. All participants provided informed consent before the study began, and all study protocols were approved by the ethics committee of Nihon University School of Dentistry at Matsudo (EC 18-024). This study was conducted in

accordance with the guidelines of the Declaration of Helsinki.

The sample size was calculated using G*Power 3.1 (Heinrich-Heine-Universität Düsseldorf, Germany). The alpha value (α, probability of making a type I error) and power (1-β, the probability of not making a type II error) were set as 0.05 and 0.80, respectively. The effect size in this study was set as a medium effect of 0.25 according to Cohen. [30]. Accordingly, a sample size of 24 participants was required.

1. First experiment

Evaluation of a modified portable EMG device compared with a stationary surface EMG device

Ten participants joined this experiment. All participants were seated on a comfortable chair without head support with the trunk in an erect posture and the head in its natural position. Motor tasks consisted of (1) swinging the neck 90° to the left and right and swinging the neck to the maximum possible vertical range of motion, (2) opening and closing eye movements, (3) opening and closing jaw movements, (4) 10 tooth tapping movements, and (5) clenching the jaw twice at 100% maximum voluntary contraction for 3 s [31-36]. Each motor task was performed continuously for 10 s with a 5-s rest period.

Figure 1 shows the modified portable EMG device (Fig. 1). This device was a modified version of an existing portable EMG device (Butler GrindCare; Sunstar Suisse SA, Etoy, Switzerland. Modification of the device was carried out by Sunstar Inc., Japan), which enabled recording of the whole wave during wakefulness from a single channel to detect temporalis muscle activity. The EMG signal was bandpass-filtered after sampling at 2 kHz. Baseline EMG amplitudes were calculated from 80 signal points immediately before 2.5 s on a preset point. In this experiment, the electrodes were randomly placed

at the left or right anterior temporalis muscles to provide the same information as EMG recording from the masseter muscles [37,38]. EMG activity using stationary surface EMG signals were recorded from the opposite side of the temporalis muscles according to the placement of the customized portable EMG device. Bipolar disposable surface electrodes (NM319Y; Nihon Kohden, Tokyo, Japan) were placed on the most prominent part of the muscles, perpendicular to the main direction of the muscle fibers in the superficial portion of the anterior portion of the temporalis muscles. The interelectrode distance was about 10 mm. The EMG signals were amplified (2,000 times; PL3508 Power Lab 8/35, Bio Research Center, Nagoya, Japan), 20-1,000 Hz signal-filtered using a processor box (National Instruments, Austin, USA), A/D converted with sample frequency of 512 Hz, and stored in a personal computer. For all measurements, EMG activity during each task was initially quantified by calculating the root mean square (RMS) EMG amplitude in each 3-s period from each EMG channel.

2. Second experiment

Comparison of awake bruxism events between subjective and objective evaluations and correlations between sleep quality and awake bruxism events

Thirty-four participants were included in the main experiment. Before the main measurements, all participants were assessed using the Epworth Sleepiness Scale (ESS) and the Pittsburgh Sleep Quality Index (PSQI). In addition, as a subjective evaluation, all participants were asked about their awareness of awake bruxism via interviews. For the main measurements, left temporal muscle activity was recorded for a total of 6.5 h (from 09:00 to 15:30) using the same modified portable EMG device as that used in the first experiment. The lunch period (from 12:00 to 12:30) was excluded from the data analysis. In the data analysis, awake bruxism was defined as an episode when

the EMG amplitude was greater than 3 times the standard deviation calculated from the baseline the EMG amplitudes and the EMG amplitudes must be ≥ 0.25 s in duration according to Dreyer et al., as assessed using the modified portable EMG device [39]. In addition, the number of awake bruxism episodes per hour was counted and recorded by the modified portable EMG device. A total of 25 awake bruxism episodes per hour was defined as the threshold of habituation for awake bruxism (to determine if the participant is a "bruxer" or "non-bruxer") according to polysomnographic diagnostic cut-off criteria for sleep bruxism [40]. The coefficient of determination between the number of awake bruxism episodes and ESS or PSQI scores was calculated for all participants.

All data are presented as the mean and SD. The Friedman test was used to compare RMS-EMG amplitudes between the modified portable EMG device and the stationary surface EMG device in each motor task. Spearman's rank correlation coefficient was used to analyze the association between the number of awake bruxism episodes and ESS and PSQI scores. The Mann-Whitney U test was used to compare the number of awake bruxism episodes between the "bruxer" and "non-bruxer" groups. Values of $P < 0.05$ were considered significant. All analyses were performed using the SigmaPlot 14.5 package (Systat Software, San Jose, USA).

Research 2: Effect of clinical experience and training with visual feedback on standardized palpation outcomes – potential implications for assessment of jaw muscle sensitivity

The study participants were 32 healthy dentists (22 men, 10 women; mean age: 35 ± 11 years) classified as either specialists or generalists. The specialist group comprised 16 dentists working as specialists in orofacial pain and certified in clinical

DC/TMD (mean clinical experience: 18 ± 11 years), and the generalist group comprised 16 healthy dentists working as general dentists (mean clinical experience: 2 ± 1 years). This study was approved by the Institutional Ethics Committee (No. EC15-021), and conducted in accordance with the guidelines of the Declaration of Helsinki.

Experimental Procedure

In this experiment, a quantitative palpometer (Palpeter; Sunstar Swiss SA, Etoy, Switzerland) was used for standardized palpation [21]. The quantitative palpometer consisted of a 10-mm diameter circular metal stamp coated in rubber and a stainless steel spring. The spring was in contact with the circular metal stamp, which was in contact with the surface of the structure to be palpated. At the other end of the cylinder was a hole through which the end of the tapered stamp could be pushed out. The examiner felt the tapered end against the finger, corresponding to the pressure force. In this study, two types of quantitative palpometers were used (pressure force: 500 gf and 1000 gf).

In each experiment, the participants were told that the target force level should be 500 gf or 1000 gf, which was tested on an electronic scale (EJ-3000; A&D, Tokyo, Japan) using palpation with the quantitative palpometer or manual palpation. The electronic scale sampled data at 4 Hz and stored the results for off-line analysis.

All participants participated in four different tests: manual palpation (MP), manual palpation with visual feedback (MPVF), palpometer (PAL), and palpometer with visual feedback (PALVF). One experiment consisted of two phases (training and measurement) and two target force levels (500 gf and 1000 gf). During each phase, the participants alternately performed 5 seconds of rest and 5 seconds of palpation, for a total of 95 seconds. All participants thus performed the training and measurement phases

using target force levels of 500 gf and 1000 gf, respectively, in one test. The order of target force levels was randomized to avoid sequence effects (Fig. 2). In MP, the participants performed 10 manual palpations at 500 gf and 1000 gf on the electronic scale using the right index finger during the training and measurement phases. In MPVF, the participants performed 10 manual palpations of 500 gf and 1000 gf on electronic scales using the right index finger with visual feedback during the training phase. Visual feedback at the target force level via the electronic scale was displayed to the participant on a monitor only in the training phase. The participants performed 10 manual palpations at 500 gf and 1000 gf using the electronic scale with the right index finger during the measurement phase. In PAL, the participants performed 10 palpations at 500 gf and 1000 gf using the quantitative palpometer on the electronic scale during the training and measurement phases. In PALVF, the participants performed 10 palpations at 500 gf and 1000 gf using a quantitative palpometer on the electronic scale with visual feedback during the training phase. Visual feedback at the target force level via the electronic scale was displayed to the participant on a monitor only in the training phase. The participants performed 10 palpations at 500 gf and 1000 gf using the quantitative palpometer on electronic scales during the measurement phase. The interval between each experiment was set to 3 minutes.

For the data analysis, first, actual force values from 0 to 2 seconds (0–2 seconds) in each palpation were quantified by calculating the target force level from all participants. Second, actual force values from 2 to 5 seconds (2–5 seconds) in each palpation were quantified by calculating the target force level from all participants. Third, actual force values from 0 to 5 seconds (0–5 seconds) in each palpation was quantified by calculating the target force level from all participants. Fourth, variability at each target

force level and in each palpation was determined as the coefficient of variation (CV) of the actual force values at 0–2, 2–5, and 0–5 seconds. Fifth, to evaluate the accuracy of the performance, the relative difference between the actual force values at 0–2, 2–5, and 0–5 seconds, and the target force level was calculated from the actual force value at each palpation in each phase.

All data are presented as the mean and standard deviation (SD). The Shapiro–Wilk test did not confirm the normality of clinical experience, actual force values, variability, or relative differences. The Mann–Whitney U test was used to compare clinical experience, actual force values, variability, and relative differences between specialists and generalists. The Kruskal–Wallis test was used to compare actual force values, variability, and relative differences between MP, MPVF, PAL, and PALVF in multiple comparisons (Bonferroni correction). Values of $P < 0.05$ were considered significant.

Ⅳ. Results

Research 1: Analysis of definite awake bruxism using a portable electromyography device

1. First experiment

Evaluation of the modified portable EMG device compared with the stationary surface EMG device

Figure 3 shows a comparison of typical EMG waveforms between the modified portable EMG device and the stationary surface EMG device in each motor task (Fig. 3). No significant differences in RMS-EMG amplitudes were observed between the two devices in any motor task.

2. Second experiment

Comparison of awake bruxism events between the subjective and objective evaluations and correlations between sleep quality and awake bruxism events

The mean number of awake bruxism events per hour among all participants was 33.6 ± 21.4. Table 1 shows subjective and objective evaluations using a questionnaire survey and a modified portable EMG device. Figure 4 shows a comparison of the number of awake bruxism events per hour between the bruxer group and non-bruxer group (Fig. 4). Significant differences in the number of awake bruxism events per hour were observed between the bruxer and non-bruxer groups (P < 0.001). The results indicated that 20 participants (11 men and 9 women; 58.8%) were diagnosed as awake bruxers, and 14 participants (8 men and 6 women; 41.2%) were diagnosed as non-bruxers. Regarding awareness of awake bruxism as queried in the interviews, 16 (47.1%) and 18 participants (52.9%) reported being aware and unaware of awake bruxism, respectively. Although four participants reported awareness of awake bruxism in the interviews, they were diagnosed as non-bruxers based on the modified portable EMG device as an objective evaluation. Although eight participants reported being unaware of awake bruxism in the interviews, they were diagnosed as bruxers based on the modified portable EMG device as an objective evaluation.

The median and interquartile range of ESS and PSQI scores in the bruxer group were 6.3 ± 2.3 and 5.7 ± 1.9, respectively, whereas those in the non-bruxer group were 4.3 ± 2.7 and 4.3 ± 1.1, respectively. In the bruxer group, positive correlations were found between awake bruxism episodes and both ESS ($r = 0.496$) and PSQI scores ($r = 0.418$) (Fig. 5A and 5B, respectively).

Research 2: Effect of clinical experience and training with visual feedback on standardized palpation outcomes – potential implications for assessment of jaw muscle sensitivity

1. **Clinical experience**

The mean ± SD clinical experience of the specialists was 18 ± 11 years and that of the generalists was 2 ± 1 years (P < 0.05).

2. **Actual force values**

Actual force values during 0–2 seconds with 500 gf of target force was significantly higher for specialists than for generalists in PAL (P < 0.05). Among the specialists, the actual force values during 0–2 seconds with 500 gf were significantly lower in PALVF than in MP and MPVF (P < 0.05). For the generalists, the actual force values during 0–2 seconds with 500 gf were significantly lower in PALVF than in MPVF (P < 0.05) (Fig. 6A). Amongst both specialists and generalists, the actual force values during 2–5, 0-5 seconds with 500 gf were significantly lower in PALVF than in MP and MPVF (P < 0.05) (Fig. 6B, C). The actual force values during 0–2, 0-5 seconds with 1000 gf of target force were significantly higher for specialists than for generalists in MP and MPVF (P < 0.05) (Fig. 6D, F). The actual force values during 2–5 seconds with 1000 gf of target force were significantly higher for specialists than for generalists in MPVF (P < 0.05) (Fig. 6E). Amongst the specialists, the actual force values during 0–2, 2–5 and 0-5 seconds with 1000 gf were significantly lower in PALVF than in MP and MPVF (P < 0.05). For the specialists, the actual force values during 0–2, 2–5 and 0-5 seconds with 1000 gf were significantly lower in PAL than in MP (P < 0.05) (Fig. 6D, E, F).

The actual force values during 0.75 and 1 seconds with 500 gf of target force were significantly higher for specialists than for generalists in PAL (P < 0.05) (Fig. 7C).

The actual force values during 0.25 to 2 and 5 seconds with 1000 gf of target force were significantly higher for specialists than for generalists in MP (P < 0.05) (Fig. 8A). The actual force values during 1 to 1.25 seconds and 1.75 to 5 seconds with 1000 gf of target force were significantly higher for specialists than for generalists in MP (P < 0.05) (Fig. 8B).

3. Variability and Relative differences

The CV during 2–5 seconds with 500 gf of target force was significantly higher for generalists than for specialists in MPVF (P < 0.05). Among the specialists, the CV during 2–5 seconds with 500 gf of target force was significantly lower in PAL and PALVF than in MP (P < 0.05). The CV of generalists in PAL and PALVF was significantly lower than that of generalists in MP and MPVF during 2–5 seconds with 500 gf of target force (P < 0.05) (Fig. 9B). No significant differences in CVs were found between PAL, PALVF, and MP, MPVF during 0–2 and 0-5 seconds.

The relative difference during 0–2 seconds with 500 gf of target force was significantly higher for generalists than for specialists in PAL (P < 0.05). The relative differences for specialists were significantly lower in MPVF, PAL and PALVF than in MP during 0–2 seconds with 500 gf of target force (P < 0.05) (Fig. 10A). Among the specialists, the relative difference during 2–5 seconds with 500 gf was significantly lower in PALVF than in MP and MPVF (P < 0.05). For the specialists, the relative differences during 2–5 seconds with 500 gf was significantly lower in PAL than in MP (P < 0.05). The relative differences for generalists in both PAL and PALVF were significantly lower than those for generalists in MP and MPVF during 2–5 seconds with 500 gf of target force (P < 0.05) (Fig. 10B). The relative differences for specialists were significantly lower in PAL and PALVF than in MP during 0–5 seconds with 500 gf of target force (P < 0.05). Among

the generalists, the relative differences during 0–5 seconds with 500 gf were significantly lower in PAL and PALVF than in MP ($P < 0.05$). For the generalists, the relative differences during 0–5 seconds with 500 gf were significantly lower in PAL than in MPVF ($P < 0.05$) (Fig. 10C). The relative difference during 2–5 and 0-5 seconds with 1000 gf of target force was significantly higher for specialists than for generalists in MPVF ($P < 0.05$) (Fig. 10E, F). Among the specialists, the relative difference during 2–5 seconds with 1000 gf was significantly lower in PALVF than in MP and MPVF ($P < 0.05$). For the specialists, relative differences during 2–5 seconds with 1000 gf were significantly lower in PAL than in MP ($P < 0.05$). The relative differences for generalists were significantly lower in PAL and PALVF than in MP during 2–5 seconds with 1000 gf of target force ($P < 0.05$) (Fig. 10E). The relative differences for both specialists and generalists were significantly lower in PAL and PALVF than in MP during 0–5 seconds with 1000 gf of target force ($P < 0.05$). The relative differences for generalists were significantly lower in MPVF, than in MP during 0–5 seconds with 1000 gf of target force ($P < 0.05$) (Fig. 10F).

Ⅴ. Discussion

Research 1: Analysis of definite awake bruxism using a portable electromyography device

This study evaluated masticatory muscle activity using a modified portable EMG device compared with a stationary surface EMG device, as well as the number of awake bruxism events between subjective and objective evaluations from the same participants using questionnaires and portable EMG device signals, and investigated correlations between sleep quality and awake bruxism. The main findings in this study were as follows: (1) no significant differences in RMS-EMG amplitudes were observed between

the modified portable EMG device and the stationary surface EMG device in each motor task; (2) the mean number of awake bruxism episodes per hour in all participants was 33.6 ± 21.4; (3) although 23% of the participants (8/34) reported having no awareness of awake bruxism in the interviews, they were diagnosed as bruxers in the objective evaluations; and (4) in the bruxer group, positive correlations were found between the number of awake bruxism episodes and both ESS and PSQI scores.

This study evaluated temporal muscle activity using a modified portable EMG device compared with a stationary surface EMG device to assess awake bruxism. Prasad et al. also evaluated potentials from a portable EMG device compared with a stationary surface EMG device [42]. Because the present study focused on temporal muscle activity during the daytime, the motor task was set as not only jaw, but also body movements. No significant differences in RMS-EMG amplitudes were found between the customized portable EMG device and the stationary surface EMG device in each motor task, which suggests that movement artifacts were not detected as awake bruxism events in the EMG waveforms when using the modified portable EMG device.

Previous studies have also investigated bruxism events during wakefulness using a portable EMG device [6,7,42]. Prasad et al. measured masseter muscle activity over 8 h and reported a mean of about 45 awake bruxism episodes per hour [42], which is similar to the present results. However, Yamaguchi et al. also measured masseter muscle activity during the daytime, and reported that the mean number of awake bruxism episodes per hour was around 200 [6]. As setting up a portable EMG device may lead to differences in the number of awake bruxism episodes, further studies are needed to standardize measurements. In addition, the present study defined 25 awake bruxism episodes per hour as the threshold for habituation of awake bruxism according to

previously reported polysomnographic diagnostic cut-off criteria for sleep bruxism [40];

however, the optimal threshold for habituation of awake bruxism remains unclear. In

clinical settings, targeting management of awake bruxism is necessary for heavy awake

bruxers or patho-bruxism [9], and will be essential in making the gold standard of the

threshold for awake bruxism.

In parallel, recent studies investigating subjective measurements of awake

bruxism using questionnaires have reported a prevalence of self-reported awake

bruxism of around 30% [1]. In a systematic review [43], the prevalence rates of "possible"

awake bruxism were reported to be 32.08% and 16.16% in convenience and population-

based samples, respectively. On the other hand, in the present study, although the

prevalence of self-reported awake bruxism was around 35% in interviews, this result

could have been affected by differences in the format or presentation of the questions

during the interviews. However, 23% of the participants (8/34 participants) in the present

study reported having no awareness of awake bruxism in the interviews, and were

diagnosed as bruxers according to the objective evaluations. In addition, 12% of the

participants (4/34 participants) in the present study reported having awareness of awake

bruxism in the interviews, and were diagnosed as non-bruxers according to the objective

evaluations. These results suggest that objective measurements using a portable EMG

device could improve the diagnostic accuracy for awake bruxism.

As sleep bruxism has been reported to be related to micro-arousal [44], some

studies have identified a correlation between sleep bruxism and sleep quality [8,45]. The

present study also revealed positive correlations between the number of awake bruxism

episodes and both ESS and PSQI scores. These findings suggest that sleep quality is a

major risk factor for awake bruxism. In addition, Sato et al. investigated the effects of

EMG biofeedback during sleep on improving awake bruxism events [5], and Saito-Murakami et al. reported that EMG biofeedback targeting tonic EMG events during the daytime can be an effective method for regulating phasic EMG events during sleep [46]. Although these studies suggest an interrelation between awake and sleep bruxism, further studies are needed to investigate the effects of improved sleep quality on the number of awake bruxism events.

In conclusion, the results of the present study suggest that objective measurements using a portable EMG device may increase the diagnostic accuracy for awake bruxism, and that sleep quality is a major risk factor for awake bruxism.

Research 2: Effect of clinical experience and training with visual feedback on standardized palpation outcomes – potential implications for assessment of jaw muscle sensitivity

The results of the present study found for the first time that a quantitative palpometer plays a valuable role in palpation to negate clinical experience in terms of palpating masticatory muscles, and palpation using the quantitative palpometer reduced the variability of the results compared to that using visual feedback.

In comparisons of palpation between specialists and generalists, the actual force values during 0–2 and 0-5 seconds with 1000 gf of target force were significantly higher for specialists than for generalists in MP and MPVF. The actual force values during 2–5 seconds with 1000 gf of target force were significantly higher in MPVF for specialists than for generalists ($P < 0.05$). Our results may suggest that the clinical experience affects the intensity of palpation for the masseter muscle. However, the relative differences were recognized between specialists and generalists in some situations. The

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relative difference in generalists were significantly lower than the specialists during 2-5, 0-5 seconds in MPVF with 1000gf. Moreover, the relative difference was higher in specialists than the generalists in most cases on MP and MPVF. This shows that in some situations generalists has higher accuracy on palpation compared to specialists. As international guidelines for palpation for the masseter muscle were not available prior to the release of DC/TMD, clinicians have performed palpation for patients according to their own rules. Such experience may have contributed to the significant differences found between specialists and generalists. To expand the DC/TMD, it is necessary for not only generalists, but also specialists, to check the actual force applied compared with the target force.

Our results revealed that in generalists, the CVs of PAL and PALVF during 2–5 seconds with 500 gf were significantly lower than those of MP and MPVF during 2–5 seconds. In specialists, the CVs of PAL and PALVF during 2–5 seconds with 500 gf were significantly lower than those of MP during 2–5 seconds; no significant differences in CVs were found between PAL, PALVF, and MP, MPVF during 0–2 and 0-5 seconds. Futarmal et al. [21] also evaluated the CVs of palpation, reporting values for manual palpation and palpation with a palpometer of 12.6% and 5.0%–5.6%, respectively, this showed the effect of using the palpometer to reduce the variability. In addition, the CVs for 2 seconds of palpation were significantly higher than those for 5 and 10 seconds (P < 0.001), but no clear difference was seen between 5- and 10-second palpations (P = 0.564) [21,29]. The present results suggest that the duration of palpation with a palpometer may need to be at least 2–5 seconds to reduce the variability of palpation.

Our results also indicated that the relative differences in PAL and PALVF were significantly lower than those in MP in most cases, which suggests that the actual force

was close to the target force in both PAL and PALVF. These results suggest that palpation using palpometer is more accurate than manual palpation. Especially, the relative differences in PAL and PALVF during 2–5 seconds were significantly lower than that in MP, indicating the high accuracy of palpation. This point may provide evidence that the duration of palpation with a palpometer may need to be at least 2–5 seconds to secure the accuracy of palpation, as mentioned above. The duration of manual palpation in DC/TMD is set to 2 seconds [17]. Our previous study indicated that the duration of palpation stimuli for the masseter muscle was associated with a diagnosis of muscle pain related to referred pain in the orofacial area [41]. As 2 seconds of actual target force in palpation of the masseter muscle was applied in the DC/TMD procedure according to our present results, clinicians may miss masseter muscle pain in clinical situations.

From the results of the multiple comparison under each condition, no significant differences were found between PAL and PALVF indicating that visual feedback does not further enhance the accuracy of palpation provided a standardized palpometer is used. However relative difference in MPVF during 0-2 seconds with 500 gf for specialists and during 0-5 seconds with 1000 gf for generalists were significantly lower than MP (Fig. 10A, F). From this point of view, in some situations training with visual feedback seemed to increase the accuracy of palpation. Nevertheless, the present results may need to be extended before final recommendations can be suggested.

The present study did have several limitations. First, the sample size was relatively small because it is difficult to recruit orofacial pain specialists with DC/TMD certification in Japan. Furthermore, the study was not designed to test for gender differences which in clinical trials have been shown to be an important factor for pressure pain thresholds. Finally, although the present study compared the accuracy of palpation

between those with and without clinical experience in treating orofacial pain, having a clinical career as a dentist may also affect the accuracy of palpation. Further studies are needed to investigate the effects of a clinical career as a dentist on the palpation of the masticatory muscles to establish standardized palpation.

Second, one of the factors influencing palpation also depends on the surface palpated, that is, if the palpated surface is hard (bony surface—zygomatic arch, mastoid process, etc.), or if the palpated surface is overlying bony tissue (e.g. the temporalis muscle), or if the palpated surface is softer (masseter muscle, lateral pterygoid site, etc.). Measurements were conducted only on a hard surface in the present study, therefore the results of the experiment that simulates palpation on an electronic scale may not be reproduced on the actual patient's face. Further studies are needed to investigate the influence of the surface palpated to establish standardized palpation.

In conclusion, our results suggest that clinical experience treating orofacial pain affects actual force values, but not the accuracy of palpation. The use of a palpometer is desirable regardless of the amount of clinical experience. In addition, the relative difference observed during 2–5 seconds of palpation using a palpometer suggests that ≥ 2 seconds of palpation with a palpometer is optimal for the masseter and temporalis muscles.

VI. Conclusion

These results suggest that objective measurements using a portable EMG device can increase the diagnostic accuracy for awake bruxism, and that sleep quality is a major risk factor for awake bruxism, and the use of a palpometer, but not clinical experience with palpation of masticatory muscles, increases the accuracy of palpation,

and ≥ 2 seconds of palpation with a palpometer is optimal for masticatory muscles.

VII. References

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Ⅷ. Table and Figures

Table Subjective and objective evaluations using a questionnaire survey and a customized portable electromyography (EMG) device.

	Objective evaluation		
	Bruxer	Non-Bruxer	Total
Subjective evaluation			
Bruxer	12	4	16
Non-Bruxer	8	10	18
Total	20	14	34

Fig. 1 The modified portable EMG device (Sunstar Inc., Japan) used in the present study
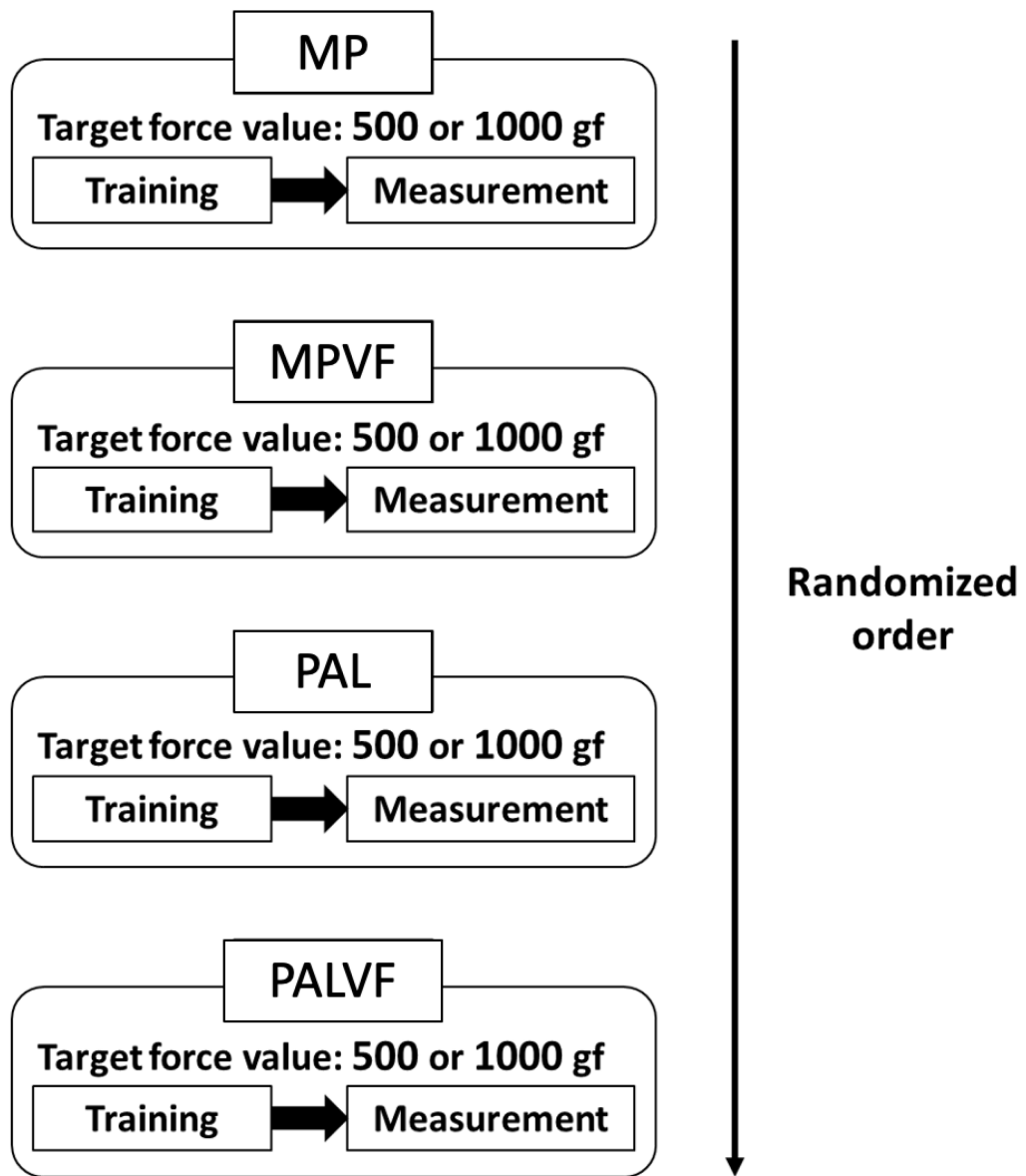
Fig. 2 Study design

MP, manual palpation; MPVF, manual palpation with visual feedback; PAL, palpometer;

PALVF, palpometer with visual feedback
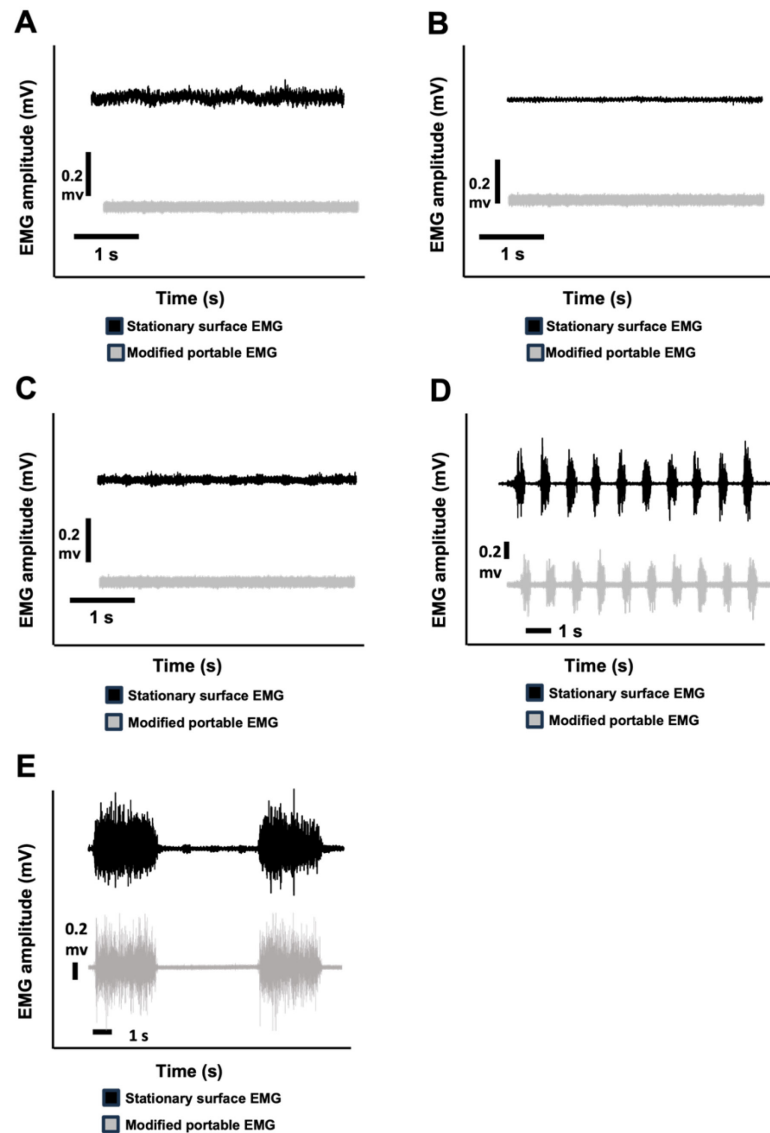
Fig. 3 Comparison of typical electromyography (EMG) waveforms between the customized portable EMG device and the stationary surface EMG device when (A) swinging the neck 90° to the left and right and swinging the neck to the maximum possible vertical range of motion, (B) during opening and closing eye movements, (C) during opening and closing jaw movements, (D) during 10 tooth tapping movements, and (E) while clenching the jaw twice at 100% maximum voluntary contraction for 3 seconds
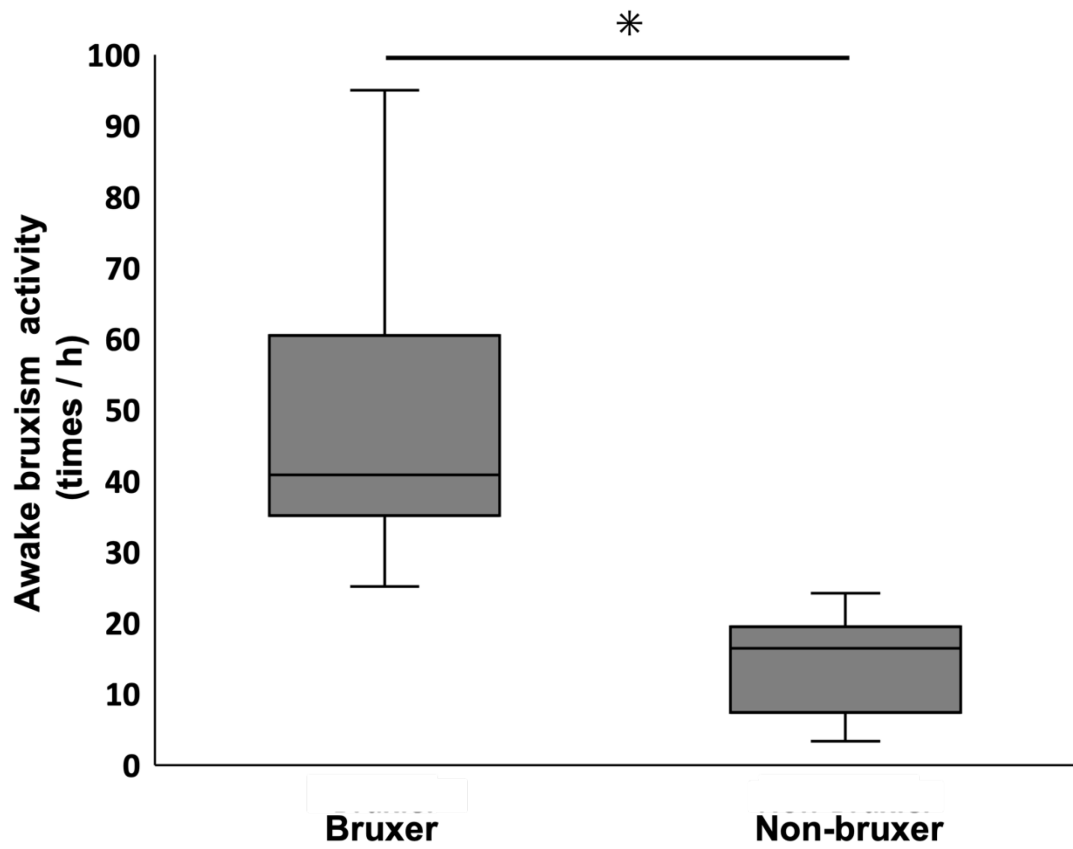
Fig. 4 Comparison of number of awake bruxism events per hour between the bruxer group and non-bruxer group

* P < 0.001
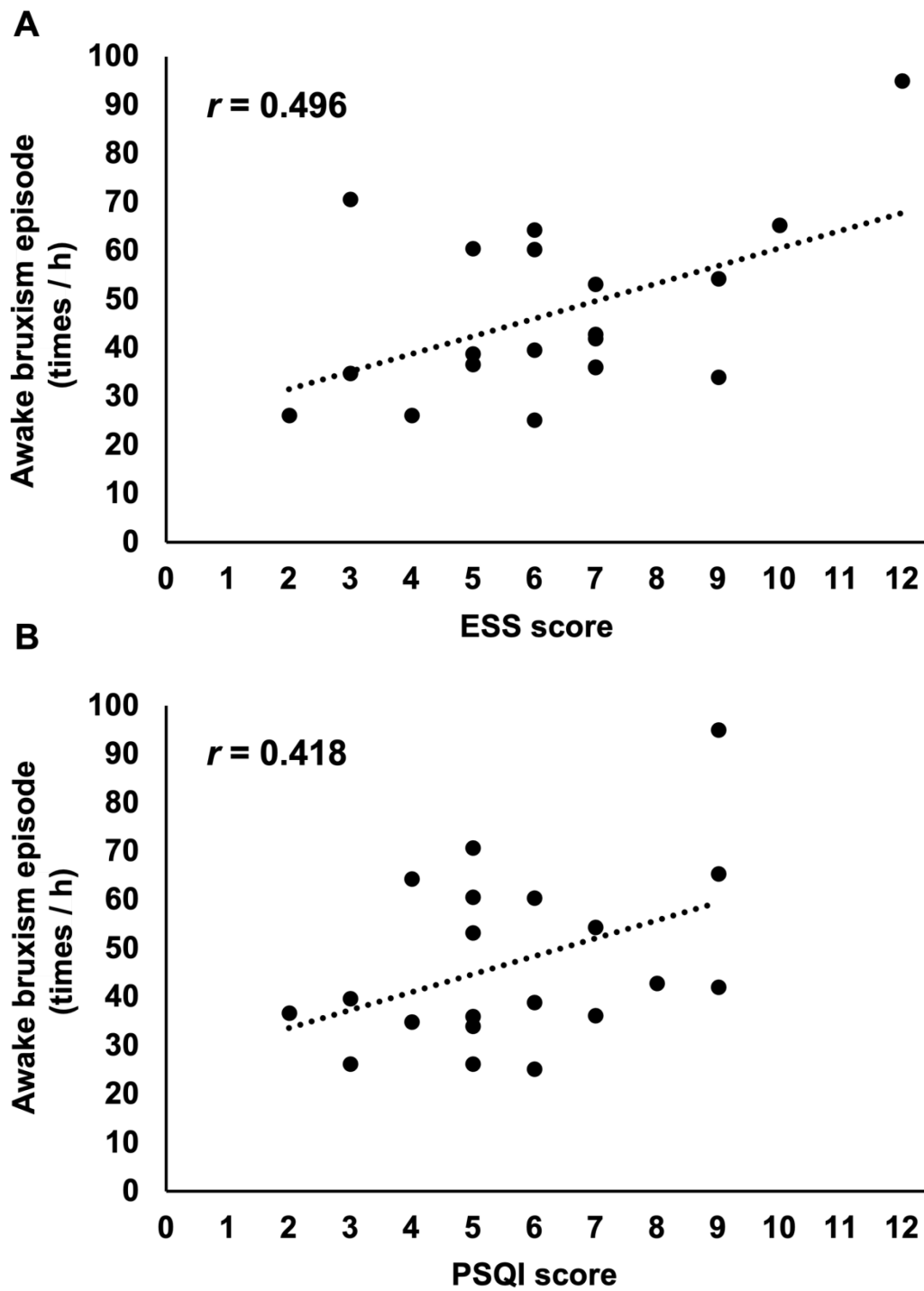
Fig. 5 Correlations between the number of awake bruxism episodes and both (A) Epworth Sleepiness Scale (ESS) and (B) Pittsburgh Sleep Quality Index (PSQI) scores
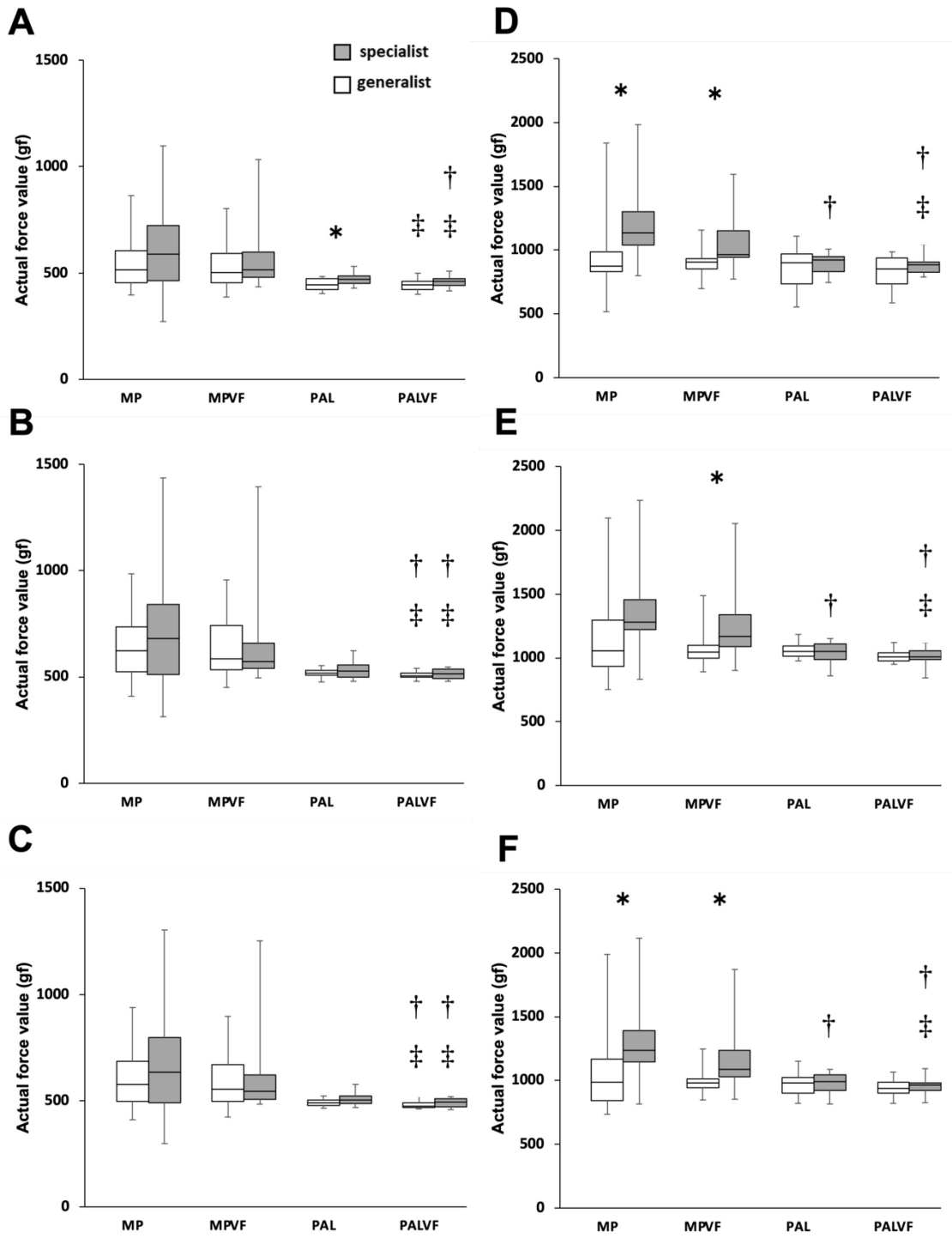
Fig. 6 Comparison of actual force values in (A) target force 500 gf 0–2 seconds, (B) target force 500 gf 2–5 seconds, (C) target force 500 gf 0–5 seconds and (D) target force 1000 gf 0–2 seconds, (E) target force 1000 gf 2–5 seconds, (F) target force 1000 gf 0–5 seconds

*: $P < 0.05$; the Mann–Whitney U test was used to compare actual force values between specialists and generalists

† and ‡: $P < 0.05$; the Kruskal–Wallis test was used to compare actual force values within participants

†: comparing MP within participants

‡: comparing MPVF within participants

MP, manual palpation; MPVF, manual palpation with visual feedback; PAL, palpometer; PALVF, palpometer with visual feedback
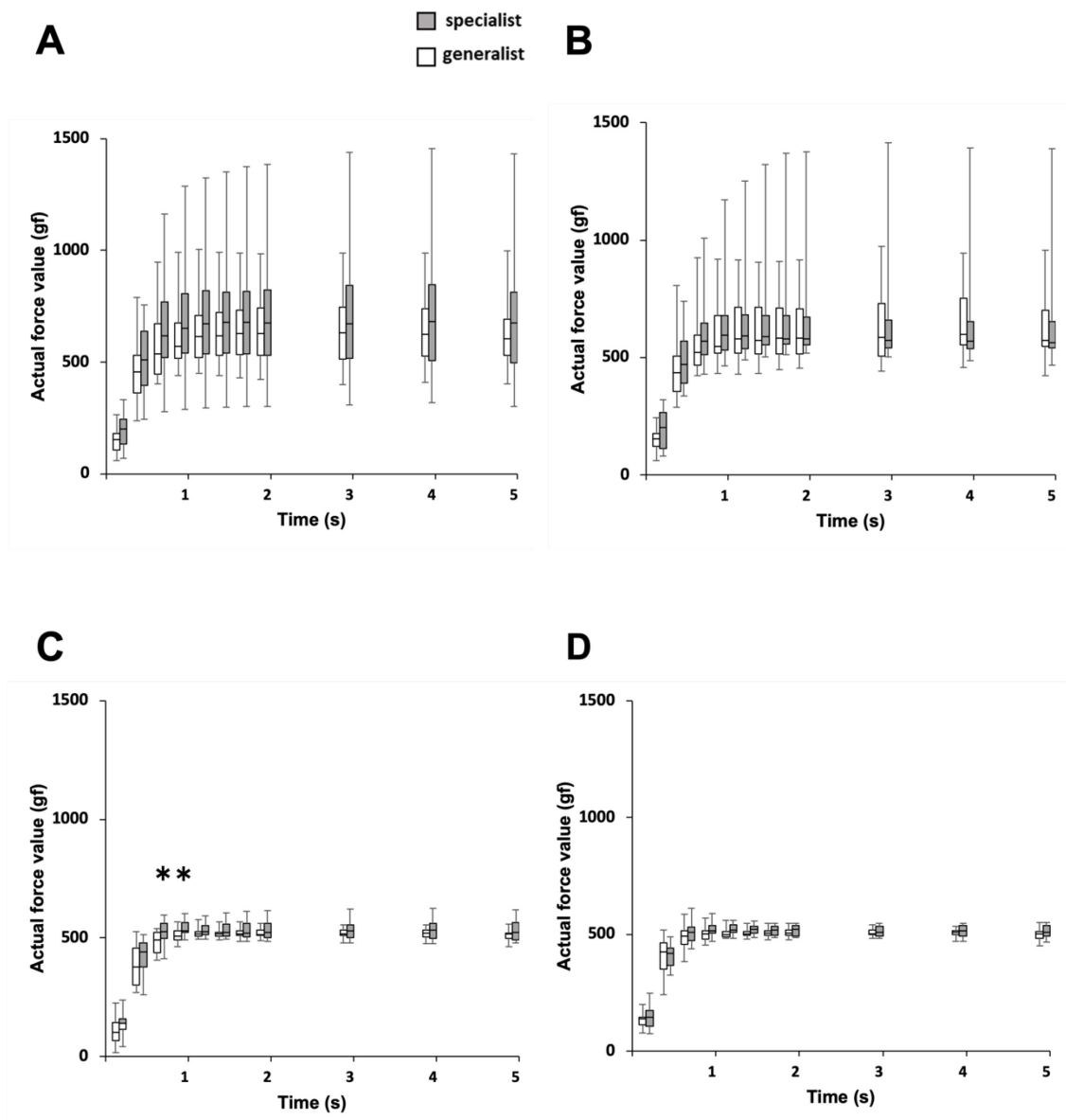
Fig. 7 Comparison of actual force values over time between specialists and generalists

with a target force of 500 gf in (A) MP, (B) MPVF, (C) PAL, (D) PALVF

*: P < 0.05; the Mann–Whitney *U* test was used to compare actual force values between

specialists and generalists

MP, manual palpation; MPVF, manual palpation with visual feedback; PAL, palpometer;

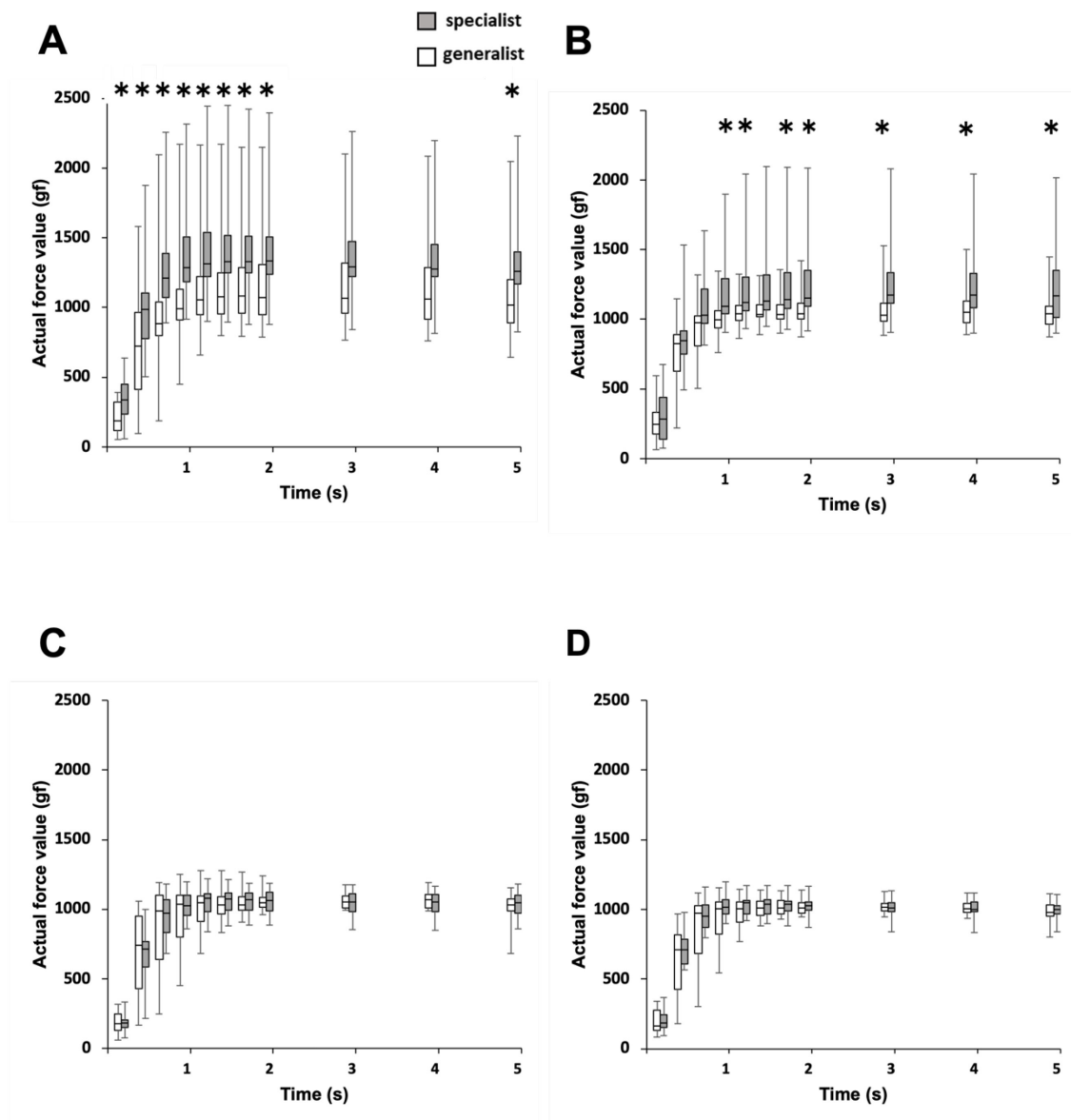PALVF, palpometer with visual feedback

Fig. 8 Comparison of actual force values over time between specialists and generalists

with a target force of 1000 gf in (A) MP, (B) MPVF, (C) PAL, (D) PALVF

*: $P < 0.05$; the Mann–Whitney U test was used to compare actual force values between

specialists and generalists

MP, manual palpation; MPVF, manual palpation with visual feedback; PAL, palpometer;
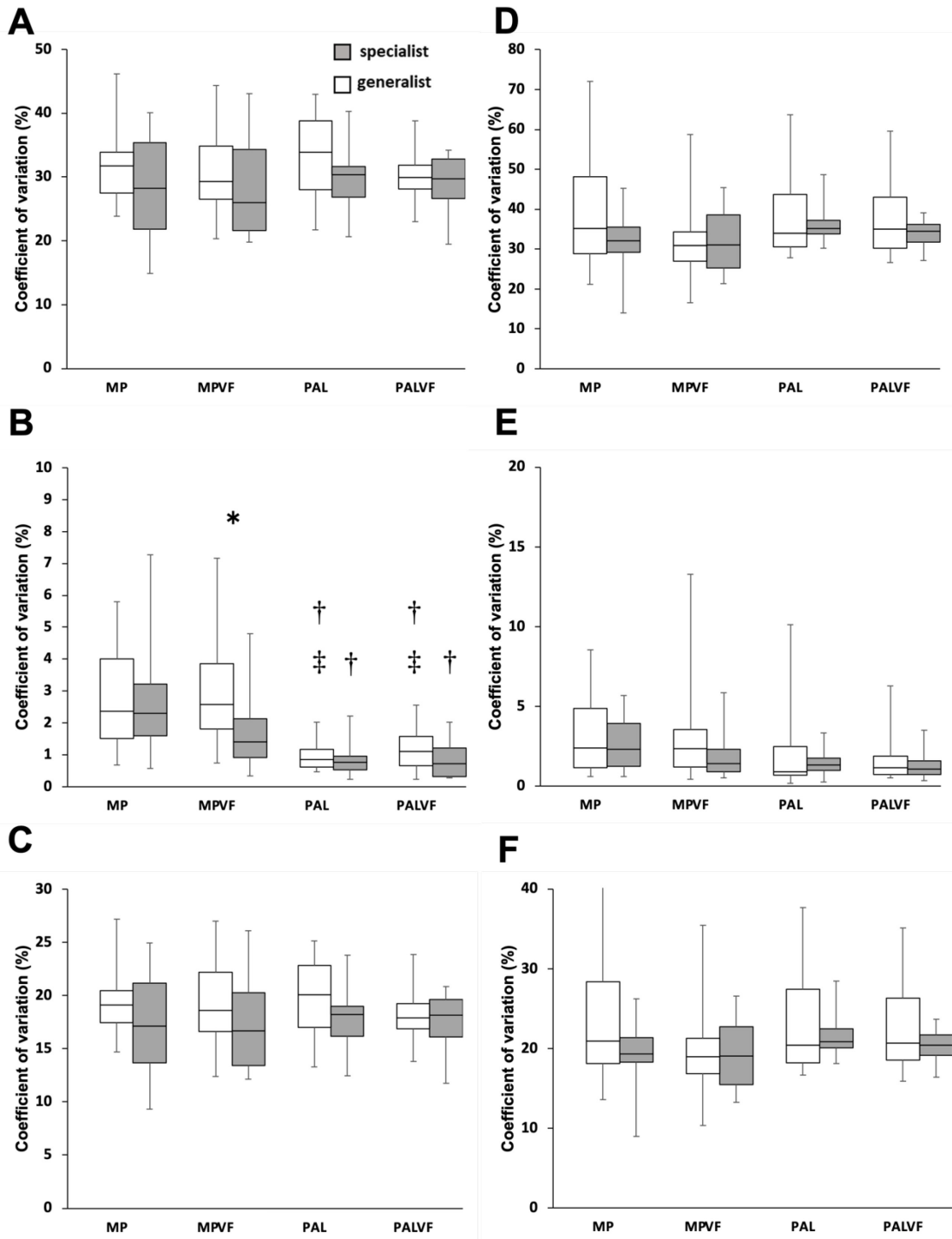
PALVF, palpometer with visual feedback

Fig. 9 Comparison of coefficient of variation in (A) target force 500 gf 0–2 seconds, (B) target force 500 gf 2–5 seconds, (C) target force 500 gf 0–5 seconds and (D) target force 1000 gf 0–2 seconds, (E) target force 1000 gf 2–5 seconds, (F) target force 1000 gf 0–5 seconds

*: $P < 0.05$; the Mann–Whitney U test was used to compare variability between specialists and generalists

† and ‡: $P < 0.05$; the Kruskal–Wallis test was used to compare variability within participants

†: comparing MP within participants

‡: comparing MPVF within participants

MP, manual palpation; MPVF, manual palpation with visual feedback; PAL, palpometer; PALVF, palpometer with visual feedback; CV, coefficient of variation
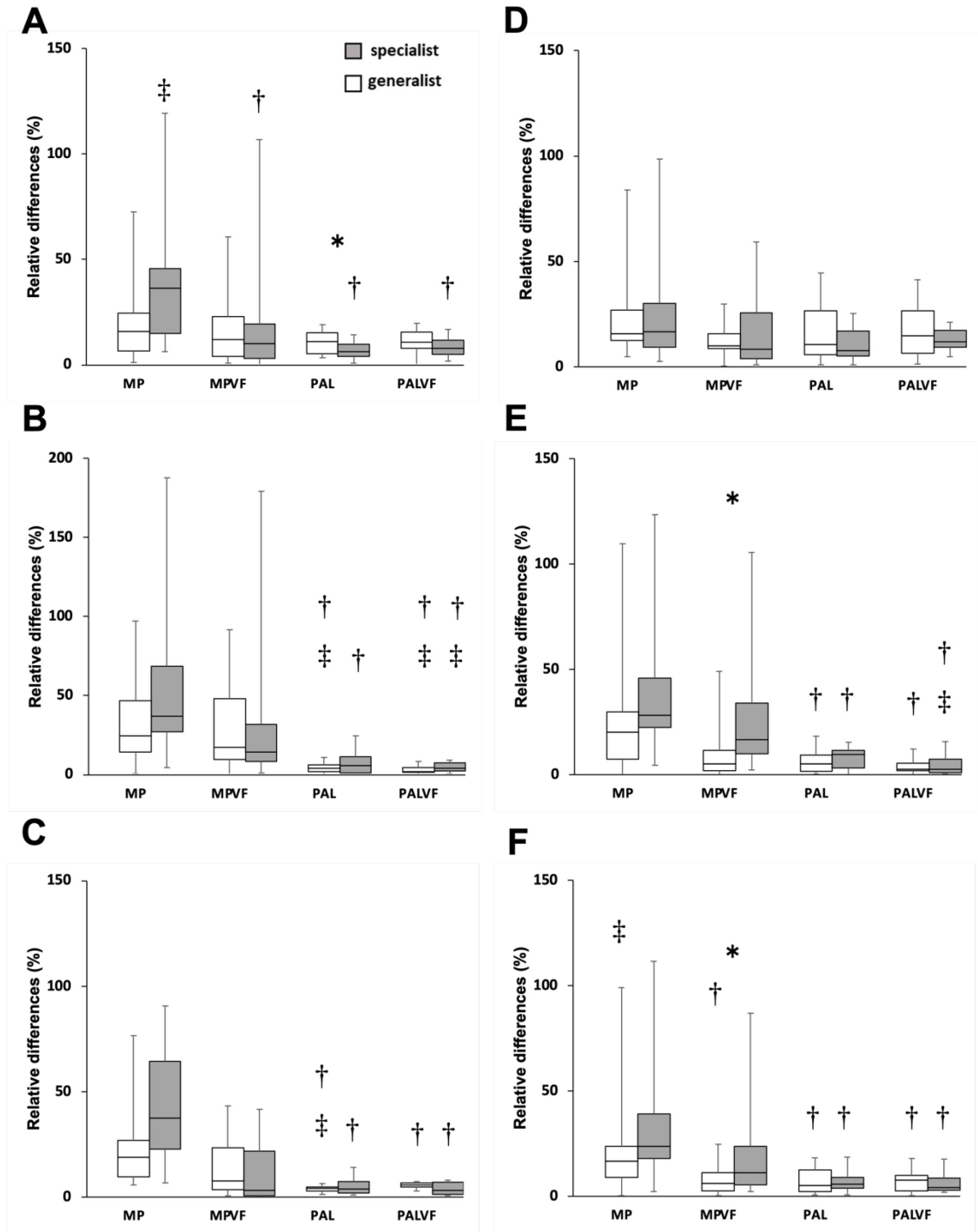
Fig. 10 Comparison of relative differences in (A) target force 500 gf 0–2 seconds, (B) target force 500 gf 2–5 seconds, (C) target force 500 gf 0–5 seconds and (D) target force 1000 gf 0–2 seconds, (E) target force 1000 gf 2–5 seconds, (F) target force 1000 gf 0–5 seconds.

*: $P < 0.05$; the Mann–Whitney *U* test was used to compare relative differences between specialists and generalists.

† and ‡: $P < 0.05$; the Kruskal–Wallis test was used to compare relative differences within participants.

†: comparing MP within participants.

‡: comparing MPVF within participants.

MP, manual palpation; MPVF, manual palpation with visual feedback; PAL, palpometer; PALVF, palpometer with visual feedback.