ABSTRACT: Decomposition-based quantitative electromyography (DQEMG) allows for the collection of motor unit potentials (MUPs) over a broad range of force levels. Given the size principle of motor unit recruitment, it may be necessary to control for force when using DQEMG for the purpose of deriving a motor unit number estimate (MUNE). Therefore, this study was performed to examine the effect of force on the physiological characteristics of concentric needle- and surface-detected MUPs and the subsequent impact on MUNEs obtained from the first dorsal interosseous (FDI) muscle sampled using DQEMG. Maximum M waves were elicited in 10 subjects with supramaximal stimulation of the ulnar nerve at the wrist. Intramuscular and surface-detected EMG signals were collected simultaneously during 30-s voluntary isometric contractions performed at specific percentages of maximal voluntary contraction (MVC). Decomposition algorithms were used to identify needle-detected MUPs and their individual MU firing times. These MU firing times were used as triggers to extract their corresponding surface-detected MUPs (S-MUPs) using spike-triggered averaging. A mean S-MUP was then calculated, the size of which was divided into the maximum M-wave size to derive a MUNE. Increased levels of contraction had a significant effect on needle- and surface-detected MUP size, firing rate, and MUNE. These results suggest that force level is an important factor to consider when performing quantitative EMG, including MUNEs with this method.

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DECOMPOSITION-BASED QUANTITATIVE ELECTROMYOGRAPHY: EFFECT OF FORCE ON MOTOR UNIT POTENTIALS AND MOTOR UNIT NUMBER ESTIMATES

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Quantitative electromyography (QEMG) provides information pertaining to the physiological characteristics of motor units (MUs) in health and provides insight into the underlying pathophysiology in neuromuscular disease.[21,26,29] One type of QEMG analysis, introduced by Buchthal and colleagues, analyzed the first few needle-detected motor unit potentials (MUPs) recorded during low-level voluntary contractions.[4–7] This technique, in addition to others that utilize amplitude-based triggering windows and template matching,[29] is limited to sampling from the lowest-threshold MUs due to an inability to identify individual MUPs within more complex interference patterns associated with higher-intensity contractions. Furthermore, due to the tedious nature of data acquisition and analysis, the application of such techniques to a clinical setting is limited.

Advances in technology have allowed for the development of new techniques of quantitatively assessing an electromyographic (EMG) signal. These tech-

Abbreviations: ANOVA, one-way analysis of variance; AP, adductor pollicis; DE-STA, decomposition-enhanced spike-triggered averaging; DQEMG, decomposition-based quantitative electromyography; EMG, electromyography; FDI, first dorsal interosseous; HSD, honestly significant difference; MU, motor unit; MUNE, motor unit number estimation; MUP, motor unit potential; MVC, maximal voluntary contraction; QEMG, quantitative electromyography; RMS, root mean square; S-MUP, surface motor unit potential; STA, spike-triggered averaging

Key words: electromyography; force; motor unit; quantitative electromyography; size principle

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niques either partially or completely decompose an EMG signal into its constituent MUP trains through the application of shape or temporal-based classification methods.[29]

We have developed a new QEMG technique, decomposition-based quantitative electromyography (DQEMG), that provides quantitative information pertaining to the size and complexity of both needle- and surface-detected motor unit potentials.[12] Advantages of DQEMG include the speed and efficiency with which MUP samples are obtained as well as the ability to classify MUPs detected during higher-intensity contractions.[3,12] Based on the size principle of MU recruitment,[15] the capability to sample the MUPs of higher-threshold MUs has raised questions regarding the impact of the level of force on the size-related parameters of needle- and surface-detected MUPs. Previous studies employing various QEMG techniques have examined this contractile level effect in both needle- and surface-detected MUPs, and have shown that as the level of force increased, an increase occurred in MUP size.[8,9,13,18]

Recently, a component of DQEMG, decomposition-enhanced spike-triggered averaging (DE-STA), was shown to be a valid and reliable method of obtaining motor unit number estimates (MUNEs) from intrinsic hand muscles.[3] Of particular interest in that study was the weak relationship observed between lower levels of voluntary muscle contraction [10 ± 5% of the maximal voluntary contraction root mean square (MVC-RMS) value] and the size of the needle- and surface-detected MUPs. The absence of this contractile level effect coupled with an inability to demonstrate the size principle of MU recruitment prompted the need for further investigation. Thus, the purpose of this study was to examine the effects of specific percentages of voluntary contractile force on the size of needle- and surface-detected MUPs sampled with DQEMG from the first dorsal interosseous (FDI) muscle. Additionally, the effect of force on first dorsal interosseous/adductor pollicis (FDI/AP) MUNEs derived using DE-STA was examined. We also sought to examine the relationship between force and the magnitude of the surface-detected EMG signal in order to determine whether it could be used as an indicator of force.

MATERIALS AND METHODS

Subjects. Ten healthy subjects, aged 22–50 years (29 ± 9 years), volunteered to take part in the study. All gave informed consent and the study was approved by our institutional review board.

Force Measurement. Subjects were seated comfortably with their left arm pronated and placed in a custom-made device during data collection. The thumb was stabilized with a metal brace at 90° extension and the lateral three digits separated from the second digit with a divider in order to isolate the action of the FDI muscle. A Velcro strap placed just proximal to the wrist joint line secured the forearm and hand position. The isometric abduction force exerted by the FDI was measured in Newtons (N) with a digital force gauge (Shimpo FGV-20X; Electromatic Equipment Co., Cedarhurst, New York) that was anchored to the device and aligned with the proximal interphalangeal joint of the second digit.

EMG Data Collection. The DQEMG and DE-STA method and associated algorithms as described in detail elsewhere were used.[12] EMG signals were acquired using DQEMG software on the Neuroscan Comperio (Neuroscan Medical Systems, El Paso, Texas). Intramuscular signals were recorded with a commercially available, disposable concentric needle electrode (Model N53153; Teca Corp., Hawthorne, New York) with a band pass of 10 Hz to 10 kHz, while surface signals were recorded with a band pass of 5 Hz to 5 kHz using self-adhering electrodes (Kendall-LTP, Chicopee, Massachusetts) cut in strips that measured 1 cm by 3 cm. A full-size electrode (3 cm by 2 cm) placed on the posterior aspect of the distal forearm served as a ground.

The active surface electrode was positioned over the motor point of the FDI muscle with the reference surface electrode positioned over the second metacarpophalangeal joint. All surface-electrode positions were further reinforced with the use of strips of surgical tape to reduce movement during the studies.

Experimental Protocol. The maximum M wave was elicited with supramaximal stimulation of the ulnar nerve at the wrist. Markers indicating negative onset, negative peak, negative-peak duration, and positive peak were automatically positioned. Following a visual check of the markers (and manual adjustments if required), size-related parameters of the M wave including negative-peak area, negative-peak amplitude, and peak-to-peak amplitude were automatically calculated. Surface motor unit potential (S-MUP) size distributions reported in the results have been expressed as a percentage of the M wave.

Subjects were then placed in the force device and performed a series of two MVCs for 3 s, with a 10-s rest period between contractions. Visual and auditory feedback was provided in the form of the EMG

Table 1. Mean contraction and surface-detected motor unit potential values (values in parentheses indicate range)

Force (% of MVC)	Number of MUs	Number of contractions	Firing rate (Hz)	ID rate (%)	Mean S-MUP negative peak Amplitude (μV)	Mean S-MUP negative peak Area (μV.ms)
Threshold	17 ± 5 (8–26)	4 ± 1 (3–7)	10.8 ± 2.2 (6.0–19.0)	72.6 ± 18.5 (25.4–97.5)	50.1 ± 34.7 (4.5–173.3)	351 ± 354.6 (86.8–3163.2)
10	26 ± 9 (11–42)	4 ± 1 (2–5)	12.2 ± 2.7 (6.8–18.4)	69.9 ± 19.6 (19.3–98.4)	107.4 ± 91.3 (13.6–521.9)	437.1 ± 401.2 (71.3–3507.6)
20	24 ± 8 (12–36)	4 ± 1 (3–4)	14.0 ± 3.1 (7.0–21.8)	65.4 ± 18.9 (13.4–97.8)	110.7 ± 63.9 (22.4–348.3)	522 ± 500 (84.9–3261.7)
30	17 ± 10 (5–32)	4 ± 1 (2–5)	14.8 ± 3.3 (8.4–24.3)	61.3 ± 20.8 (15.2–99.4)	201.8 ± 118.5 (45.4–749.7)	663.8 ± 701 (115.7–7398.2)
40	17 ± 9 (7–29)	3 ± 1 (2–4)	16.5 ± 3.8 (8.5–37.7)	59.7 ± 18.2 (15–92.6)	224.7 ± 127.8 (52.5–686.9)	748.5 ± 705.6 (100.8–6508.8)
50	15 ± 11 (3–37)	3 ± 1 (2–4)	16.4 ± 3.7 (8.4–26.1)	61.1 ± 17.5 (17.1–98.3)	319.4 ± 193.3 (70.3–1239.6)	821.8 ± 608.9 (120.9–3907.4)

signal as well as a display on an analog oscilloscope (model 5111A storage oscilloscope; Tektronix, Inc., Beaverton, Oregon). The peak force of these contractions was recorded as the MVC value, with subsequent contractions performed as a percentage of this MVC as outlined below. In addition, the maximal root mean square (RMS) value of the surface EMG signal, detected during the MVC, was calculated using a 1-s wide sliding window and called the MVC-RMS value. RMS values from nonmaximal contractions were calculated as the RMS of the surface EMG signal averaged over the entire contraction and expressed in millivolts and as a percentage of the MVC-RMS value.

The concentric needle electrode was then inserted into the FDI just proximal or distal to the active surface electrode. Subjects were asked to minimally contract the muscle isometrically while the needle position was adjusted in order to minimize the rise times of the MUPs of the first 2–3 recruited MUs. With the needle manually maintained in a stable position by the examiner, the subject was instructed to increase the contraction force to the desired percent of MVC. If the signal was of poor quality based on visual inspection, the needle was repositioned and the process repeated to ensure adequate signal quality. Each isometric contraction lasted for 30 s. Subjects were instructed to maintain consistent contraction intensities throughout the 30-s contraction period and were aided in doing so by the presence of a target line displayed on the oscilloscope. Each subject performed groups of contractions at threshold, which corresponded to the first 2–3 detected MUs (3%–5% of MVC), 10%, 20%, 30%, 40%, and 50% of MVC, the order of which was randomized prior to each session. To obtain 20 or more MUP trains, 2–7 contractions were required per subject at each of the force levels.

Following needle-detected signal decomposition and analysis,[27,28] the MUP trains and needle and surface-detected MUPs were reviewed with regard to their acceptability based upon two interrelated criteria. Visual checks were made to assess the variability of the instantaneous firing rate vs. time plot of each MUP train and the interdischarge interval histograms of each MUP train were examined. Those that were accepted displayed consistent firing rate plots and physiological firing rate as quantified by an associated interdischarge interval histogram that displayed a Gaussian-shaped main peak and a coefficient of variation of the interdischarge interval of less than 0.3.[14,28] Each train was required to include a minimum of 50 detected potentials that would serve as triggers for STA. The needle- and surface-detected MUP waveforms were visually checked to ensure that the onset and peak markers were accurate (and if not, they were repositioned manually). Lastly, the onset of the S-MUP waveform was required to occur within 10 ms of the needle-detected MUP waveform onset. MUP trains, and needle- and surface-detected MUPs that failed to meet all the inclusion criteria, were excluded from further data analysis. The MUNE was determined by dividing a size-related parameter of the maximum M wave (either negative-peak amplitude or area) by the corresponding size-related parameter of the mean S-MUP, determined by the data-point by data-point average of all acceptable S-MUPs aligned based on their onset.

Statistics. Mean values along with their standard deviations are presented throughout. Correlations

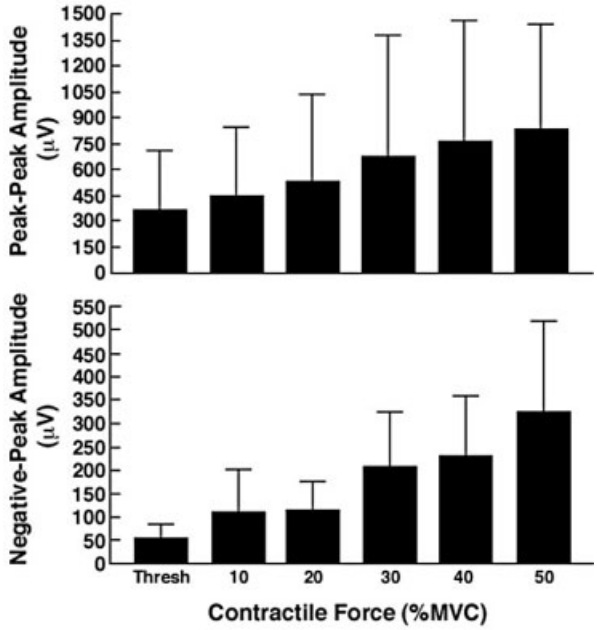

FIGURE 1. Needle- (upper graph) and surface-detected (lower graph) MUP size at specific percentages of contractile force means and standard deviations are presented.

were determined with the Pearson product moment statistic. Significant effects were determined via a within-subjects repeated-measures, one-way analysis of variance (ANOVA). Where significant effects were present, pairwise comparisons were performed with the application of the Tukey honestly significant difference (HSD) procedure.

RESULTS

Force, MUP Size, and Firing Rate. We sampled 1130 MUs from the FDI muscle from a total of 218 contractions collected from six different force levels, with a mean yield of 5 MUs/contraction. MUP identification rates ranged from 59.7% ± 18.2% at 40% of MVC to 72.6% ± 18.5% at threshold (Table 1). MUP size (both needle and surface detected) varied across all force levels and increased in size as the level of force increased (Fig. 1). Mean S-MUP negative-peak amplitude ranged from 50.1 ± 34.7 μV at threshold to 319.4 ± 193.3 μV at 50% of MVC (Table 1). Likewise, needle-detected MUP peak-to-peak voltage ranged from 351.0 ± 354.6 μV at threshold to 821.8 ± 608.9 μV at 50% of MVC (Table 2). Statistical analysis revealed a significant effect ($p < 0.05$) for force and MUP size (needle and surface-detected). Post hoc analysis revealed the significant differences between force levels, with needle-detected size distributions differing significantly between threshold and 40% or 50% of MVC, and 10% and 40% or 50%. All S-MUP pairwise comparisons were significant other than between threshold and 10% or 20% of MVC, 10% and 20% of MVC, and 30 and 40% of MVC. Additional needle-detected MUP characteristics including duration and numbers of turns and phases displayed no significant changes ($p > 0.05$) as the level of force increased. Needle-detected MUP duration ranged from 8.3 ± 0.9 ms at threshold to 7.4 ± 4.4 at 50% of MVC with the numbers of turns and phases ranging from 3 ± 1 and 3 ± 1 at threshold to 3 ± 1 and 4 ± 2 at 50% of MVC, respectively (Table 2).

Analysis of the relationship between needle- and surface-detected MUP amplitude revealed a weak but significant relationship ($r = 0.384$, $p < 0.01$). Despite this rather weak relationship, the distributions of needle- and surface-detected MUPs were similar and displayed a greater number of larger amplitude MUPs as force increased (Figs. 2 and 3). Mean MU firing rates increased as a function of force with values ranging from 10.8 ± 2.2 Hz at threshold to 16.4 ± 3.7 Hz at 50% of MVC (Table 1). Statistical analysis revealed a significant effect ($p < 0.05$) for force and firing rate.

Maximum M Wave and MUNE. Maximum M waves ranged in size (negative-peak amplitude) from 10.2 to 14.1 mV with a mean value of 11.7 ± 1.3 mV.

Table 2. Needle-detected motor unit potential values (values in parentheses indicate range)

Force (% of MVC)	Needle-detected MUP			
	Peak-to-peak voltage (μV)	Duration (ms)	Number of turns	Number of phases
Threshold	133.9 ± 88.7 (13.3–427.1)	8.3 ± 0.9 (1.0–21.0)	3 ± 1 (1–5)	3 ± 1 (1–7)
10	270.7 ± 195.6 (31.2–1265.4)	8.5 ± 3.5 (2.1–23.6)	3 ± 1 (0–5)	3 ± 1 (1–9)
20	290.7 ± 162.8 (52.3–895.1)	7.8 ± 4.2 (1.5–23.2)	3 ± 1 (1–5)	3 ± 2 (1–13)
30	519 ± 277 (70.2–1562.9)	8.4 ± 4.0 (1.8–20.4)	3 ± 1 (1–6)	3 ± 2 (1–9)
40	580.8 ± 322.2 (74.7–1877.9)	7.7 ± 4.3 (1.1–25.0)	3 ± 1 (1–6)	4 ± 2 (1–14)
50	789.4 ± 418.1 (168.8–2112.6)	7.4 ± 4.4 (1.7–33.2)	3 ± 1 (1–6)	4 ± 2 (1–14)

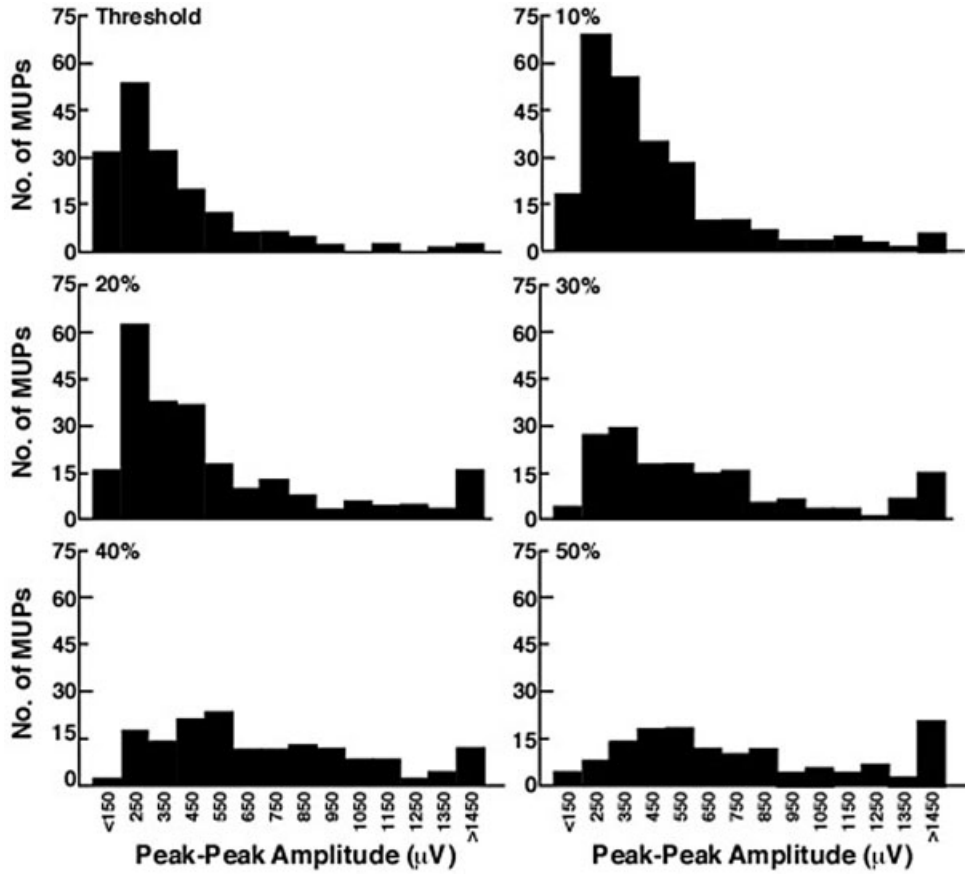

FIGURE 2. Needle-detected MUP size distribution at specific percentages of contractile force.

FDI/AP MUNE values (based on negative-peak amplitude) ranged from 282 ± 112 at threshold to 53 ± 20 at 50% of MVC. Statistical analysis demonstrated a significant effect ($p < 0.05$) for force and MUNE. Post hoc analysis showed no significant difference between 10% and 20%, 20% and 30% or 40%, and 30% to 50% of MVC. All other pairwise comparisons differed significantly ($p < 0.05$). These data are summarized in Table 3.

Force and EMG Amplitude. The mean MVC value was 28.4 ± 8.0 N with subsequent contractions ranging from 1.6 ± 1.2 N at threshold to 14.2 ± 4.0 N at 50% of MVC. The RMS of the surface-detected EMG signal was also calculated and recorded for each contraction. The mean MVC-RMS value recorded during the MVC was 0.98 + 0.25 mV. Ensuing contractions ranged from 0.04 ± 0.02 mV at threshold to 0.44 ± 0.08 mV at 50% of MVC. A strong linear relationship and positive correlation ($r = .806$, $p < 0.01$) was found between force (N) and the RMS of the surface-detected EMG signal (Fig. 4).

DISCUSSION

Our results provide clear evidence that the level of force can have a significant impact on the sizes of both needle- and surface-detected MUPs sampled with DQEMG. This contractile level effect is evident from the presence of a significant increase in the sizes of the needle- and surface-detected MUPs as force increases (Figs. 2 and 3). Coupled with this change in MUP size is an increase in MU firing rate[1,16] as well as a decrease in the magnitude of the MUNE values as force increases. This contractile level effect can be attributed to physiological factors, governed by the size principle, electrophysiological factors, as well as technical factors inherent in the algorithms used for DQEMG.

Our results, in keeping with the size principle,[15] revealed a relationship between force and electrophysiological correlates of MU size, needle-detected MUP amplitude, and surface-detected MUP amplitude. However, the present results indicate that larger needle-detected MUPs were not necessarily indicative of larger MUs or S-MUPs.[3]

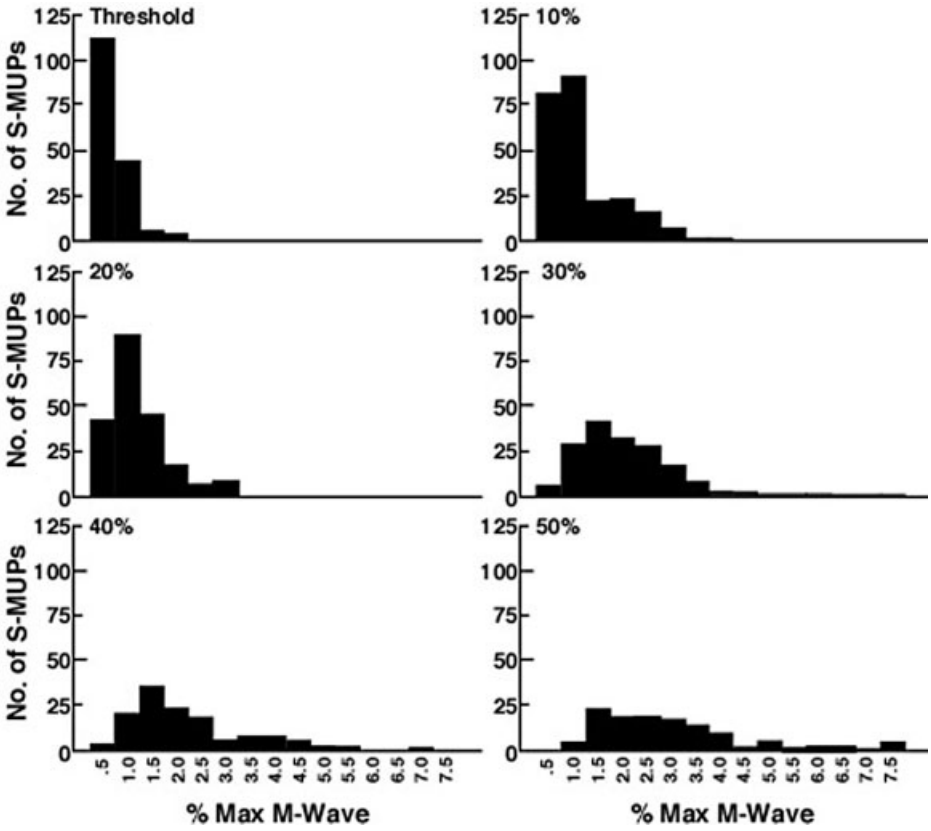

FIGURE 3. S-MUP size distribution at specific percentages of contractile force.

This is likely due to the different detection characteristics of the needle and surface electrodes. Concentric needle-detected MUP amplitude is dependent on the position of the needle detection surface relative to the few closest muscle fibers of a given MU and therefore is strongly affected by the contribution of a small number of muscle fibers.[20] Conversely, surface electrodes have a larger detection surface relative to the needle electrode, which increases the probability that a larger number of muscle fibers are equidistant from the electrode. For a specific electrode configuration, S-MUP size increases with the number of muscle fibers in the MU and decreases as the average distance between the detection surface and the fibers of the MU increases. Therefore, S-MUP size may be a more accurate reflection of actual MU size.[24,25]

Although it is expected that a greater number of larger amplitude MUPs will be sampled during higher-force levels, the size distributions in our study also demonstrate a failure to sample lower-amplitude MUPs during higher-force contractions, as evident in Figures 2 and 3 and particularly Figure 5, which illustrates data from two representative subjects. This shift in MUP size, which has been observed in similar studies[3,8,9] and is inherent in all clinically viable decomposition techniques, is likely due to technical

Table 3. Summary of M-wave and MUNE values (values in parentheses indicate range).

		MUNE at specific percentage of force (%MVC)					
	M wave	Threshold	10	20	30	40	50
Negative-peak amplitude (mV)	11.7 ± 1.3 (10.2–14.1)	282 ± 112 (101–469)	196 ± 118 (62–458)	140 ± 49 (56–211)	91 ± 52 (45–227)	67 ± 23 (30–103)	53 ± 20 (29–100)
Negative-peak area (mV.ms)	28.2 ± 5.1 (21.2–35.3)	238 ± 90 (99–383)	157 ± 84 (64–353)	108 ± 34 (62–177)	70 ± 25 (46–126)	55 ± 27 (31–122)	42 ± 20 (23–88)

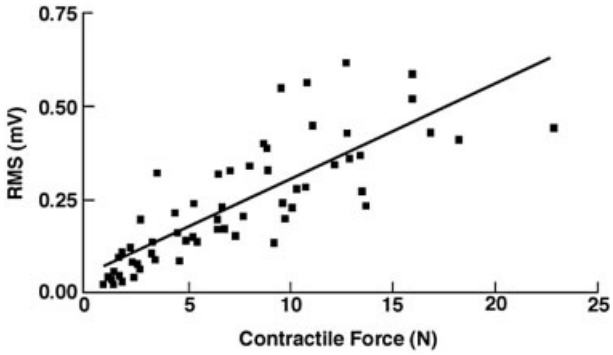

FIGURE 4. Relationship between contractile force (N) and the RMS of the surface-detected EMG signal.

factors that involve the progressively lower probability of detecting and classifying lower-amplitude needle-detected MUPs with increasing levels of force.

In our study, the DQEMG algorithms used an absolute amplitude criterion of 50 μV combined with a minimum slope criterion of 0.3 V/s to detect a concentric needle MUP. At low levels of force, lower-amplitude MUPs are often isolated as single units or combine with the MUPs of several other active MUs to comprise an interference pattern of low complexity, which is conducive to MUP detection and classification, even for lower-amplitude MUPs. However, as force increases, a greater number of MUs are active, including larger, higher-threshold MUs that create a more complex, fuller interference pattern. This increased MU activity results in increased numbers of MUP superpositions, producing a lower probability for detecting and classifying low-amplitude MUPs due to their increased probability of temporal overlap with larger-amplitude MUPs.

The size distributions of S-MUPs were similar to those of the needle-detected MUPs, exhibiting a loss of lower-amplitude S-MUPs with increasing force (Figs. 2, 3, and 5). This finding would be expected given the decreased probability of sampling low-amplitude needle-detected potentials at higher forces, as indicated above. However, due to the weak, albeit significant relationship between needle- and surface-detected MUP sizes, it is also possible that other factors contribute to the loss of smaller S-MUPs.

In order to extract S-MUPs, DQEMG uses the firing times of the needle-detected MUPs to serve as triggers for STA. Epochs of 100 ms of the surface EMG signal centered on the time of occurrence of the needle-detected MUPs are ensemble-averaged to extract the S-MUP corresponding to the needle-detected potential.[28] This averaging process is influenced by the RMS value of the surface-detected EMG signal. As the level of force increases for any given number of triggers, there is a decrease in the signal-to-noise ratio of the extracted S-MUP, which lessens the probability of including lower-amplitude S-MUPs with a given number of triggers over a 30-s contraction. Furthermore, relatively fewer MUPs are detected and classified at higher levels of force, likely because of increased numbers of MUP superimpositions, further decreasing the number of triggers available for STA. These findings decrease the probability that at higher levels of force, MUs with small S-MUPs will have a sufficient number of triggers to allow an S-MUP with adequate signal-to-noise ratio to be extracted.

The factors described above may be further accentuated by the motor control properties of the FDI. It has been previously established that the majority of MUs in intrinsic hand muscles are activated by 30% of MVC.[1,16] This early activation of a large number of MUs results in a more complex interference pattern that, coupled with increased MU firing rates during contractions at higher levels of force, contributes to the decreased probability of sampling lower-amplitude MUPs.

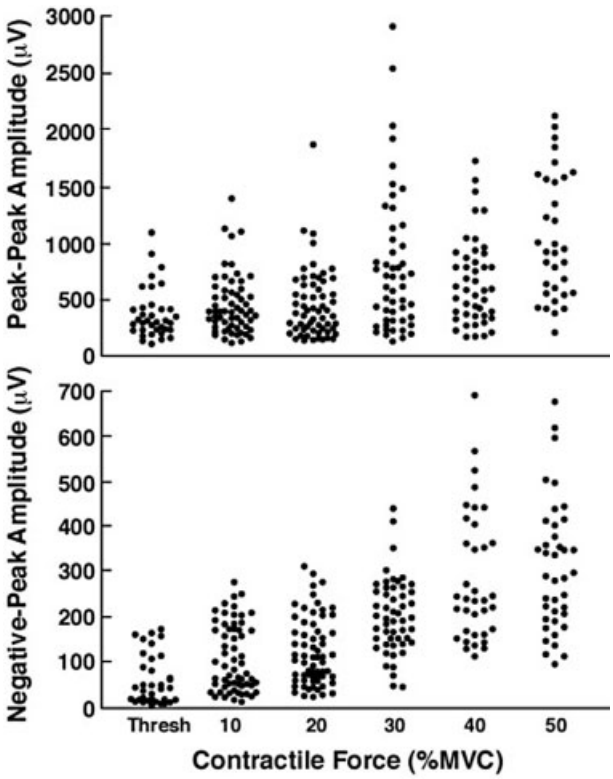

FIGURE 5. Needle- (upper graph) and surface-detected (lower graph) MUP amplitudes for two subjects at specific percentages of contractile force.

The MUNEs were also significantly affected by increasing force due to the factors described above. Physiologically, the DE-STA technique provides the ability to extract the S-MUPs of higher-threshold MUs, with the result that larger-amplitude S-MUPs, in keeping with the size principle, become included in the sample of S-MUPs used to determine the mean S-MUP size. Additionally, the decreased probability of sampling lower-amplitude S-MUPs at higher-force levels contributed to a larger mean S-MUP size. The resulting increase in mean S-MUP size leads to corresponding reductions in the MUNE.

Previously established MUNE techniques including multiple-point stimulation and the statistical method circumvent these factors by obtaining their sample of S-MUPs via electrical stimulation of the motor nerve as opposed to the voluntary muscle activation utilized in standard STA and DE-STA.[10,17] Therefore, with stimulation techniques, an unbiased sample is obtained because the population of axons stimulated has greater dependence on the relative position of a given axon than stimulus intensity.[10,11] Adding decomposition analysis to standard STA has decreased the physiological bias as much as possible with a voluntarily activated technique by allowing the inclusion of higher-threshold, larger S-MUPs. Our results, however, do show potential technical limitations with forces exceeding 30% of MVC in intrinsic hand muscles.

The decreased numbers of lower-amplitude needle-detected MUPs, in all likelihood, also had an impact on the mean MU firing rates observed in our study. In an intrinsic hand muscle such as the FDI, it would be expected that earlier recruited MUs represented by lower-amplitude needle-detected MUPs would display progressively higher firing frequencies as the level of force increased, resulting in a higher mean MU firing rate.[16,19] However, due to the decreased numbers of lower-amplitude MUPs detected at higher force, the mean MU firing rates reported in this study for higher forces may underrepresent the actual mean MU firing rate previously observed in intrinsic hand muscles.[1,23]

In order for DQEMG to maintain its efficiency and clinical usefulness, methods of controlling for the level of force must be equally efficient and applicable to the clinical setting. Dynamometers as well as devices used to isolate the action of a muscle or muscle group are often custom-made and vary from center to center, increasing the variability of the results and reducing the ability to compare findings obtained from different laboratories. In order to reduce this variability, a consistent measure is required during signal acquisition to provide an indication of the absolute or relative level of force or muscle activation.

The findings of this study, which are similar to previous studies examining intrinsic hand muscles, support the use of the RMS value of the surface-detected EMG signal as an indicator of the level of force or muscle activation.[2,22,30] Although it is not the intent of our study to suggest that RMS is a replacement for the measure of absolute force, our results support RMS as a valid, practical means of gauging the range of forces sampled or muscle activation in the FDI and other intrinsic hand muscles.

Our results demonstrate that the level of force can have a significant impact on the size of the MUPs sampled with DQEMG. Thus, similar to the conclusions of previous studies,[8,9,13,18] our results suggest the need to consider the level of force when evaluating results of DQEMG. This consideration is particularly important when a sample of S-MUPs is used to obtain a MUNE using DE-STA.

It has been concluded that physiological, electrophysiological, and technical factors contribute to the increase in the size of needle and surface-detected MUPs sampled with DQEMG and in turn the magnitude of the MUNEs obtained during higher force contractions. Despite this finding, DQEMG has improved upon previous QEMG techniques by increasing the efficiency with which a sample of MUPs is collected and in its ability to extract estimates of needle- and surface-detected MUPs of higher threshold MUs. In order to manage this contractile level effect for QEMG in general and MUNE specifically, there is a need to implement a standard protocol that will provide the most representative sample of MUPs possible. This sample will cover the greatest portion of the full physiological range of MUs and electrophysiological range of MUPs possible.

Currently, our research is directed at further examining this contractile level effect in order to determine the most appropriate protocol for obtaining this sample of needle- and surface-detected MUPs. The utilization of a protocol in which the levels of muscle activation are specifically defined will decrease the variability in MUP and MUNE analysis performed with DQEMG, thus increasing its clinical utility.

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