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Test-retest reliability of near-fibre jiggle in the ulnar intrinsic hand muscles

Philemon Tsang[a,*], Joy C. MacDermid[a,b,d], Michelle Eventov[a], Thomas A. Miller[c], Timothy J. Doherty[c,e], Douglas C. Ross[d], Christopher D. Doherty[d]

[a] Department of Health and Rehabilitation Sciences, Western University, London, Ontario, Canada
[b] Hand and Upper Limb Centre Clinical Research Lab, St. Joseph's Health Centre, Canada
[c] Department of Physical Medicine and Rehabilitation, Schulich School of Medicine and Dentistry, Western University, Canada
[d] Department of Surgery, Division of Plastic Surgery, Roth-McFarlane Hand & Upper Limb Centre, Schulich School of Medicine and Dentistry, Western University, Canada
[e] Lawson Health Research Institute, Canada

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ABSTRACT

Objective: Near-fibre (NF) jiggle is one method of measuring the shape variability of motor unit potentials (MUPs) from successive firings during voluntary contractions. MUP shape variability has been associated with neuromuscular stability and health. The purpose of this study was to analyze the test-retest reliability of NF jiggle in the ulnar nerve innervated intrinsic hand muscles of healthy subjects.
Methods: Twenty healthy adult were tested (Mean age = 23.2 ± 1.9; 8 females). Measurements of NF jiggle were assessed with a standard concentric needle during mild-moderate contractions from the first dorsal interosseous (FDI), the abductor digiti minimi (ADM), and the forth dorsal interosseous (4DI) muscles. Test-retest reliability were evaluated using intraclass-correlation coefficient (ICC).
Results: NF jiggle showed good test-retest reliability in the FDI, ADM and 4DI muscles with ICC values of 0.86, 0.85, and 0.87, respectively. The SEM for the FDI, ADM, and 4DI were 1.9%, 2.1%, and 2.5%. Finally, the MDC of the FDI, ADM and 4DI were 4.4%, 5.0%, and 7.1%.
Conclusion: To date, this is the first investigation to explore NF jiggle in the intrinsic hand muscles. NF Jiggle demonstrates good test-retest reliability coefficients and with low measurement error.

1. Introduction

Measurement of motor unit potentials (MUP) via quantitative electromyography is an objective and *in vivo* method of studying alpha motor neuron health and muscle innervation (Stålberg, 1966). The stability of neuromuscular transmission may be assessed through MUP shape variability from a single motor unit (MU). Stålberg and Sonoo (1994) had originally described motor unit shape variability, describing the terms jitter, impulse blocking and jiggle (Stålberg and Sonoo, 1994). In a recent investigation, jitter was described as the variation in the time interval between the firing of adjacent muscle fibres from the same motor unit (Zalewska and Hausmanowa-Petrusewicz, 2018). In severe cases of neuromuscular transmission disturbance, there may be loss of some action potentials believed to be due to impaired motor endplate transmission, known as impulse blocking. Finally, jiggle refers to the MUPs' shape variability across multiple discharges within a single motor unit. Collectively, jitter, impulse blocking of the single fibre action potentials are believed to contribute to jiggle (Stålberg and Sonoo, 1994). However, other technical factors like background activity, needle movement, and physical noise may also contribute to EMG jiggle (Daube and Rubin, 2009; Rodríguez et al., 2011).

Decomposition-based quantitative EMG (DQEMG) concurrently uses needle and surface electromyography to measure motor unit physiology, offering clinically relevant data. DQEMG has been used as an approach and technique to capture near fibre (NF) jiggle and jitter. Similar to jiggle as originally described, NF jiggle was developed to further investigate the integrity of neuromuscular transmission (Allen et al., 2015). NF MUP is generated by high-pass filtering the MUP template waveform and is therefore primarily composed of fibres that are close to the recording area of the needle (Boe et al., 2004). MU stability is believed to be inversely related to increases in NF jiggle and jitter (Stålberg et al., 1996).

Changes in NF jiggle has been previously observed in several clinical populations. Increased NF jiggle has been previously observed within the lower extremity muscles in individuals with amyotrophic lateral sclerosis (ALS) (Campos et al., 2000), diabetic neuropathy (Allen et al., 2015), chronic inflammatory demyelinating polyneuropathy (CIDP) (Gilmore et al., 2017a), and older adults (Allen et al., 2015). Likewise,

* Corresponding author at: 1201 Western Rd, London, ON N6G 1H1, Canada.
E-mail address: ptsang8@uwo.ca (P. Tsang).

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increases in MUP jiggle has been observed in facial muscles of patients with myasthenia gravis (Benatar et al., 2006) and ALS (Stålberg and Sonoo, 1994). However, to date, there have been no investigations that have explored the test-retest reliability of NF jiggle measurements, specifically, within the intrinsic hand muscles. Measurement of reliability are critical for the usage of a measurement tool, particularly if this tool will be used for clinical assessments. The purpose of the present study was to investigate the reliability of NF jiggle in the ulnar nerve innervated intrinsic hand muscles.

2. Methods

2.1. Participants

Twenty healthy adults (Mean age = 23.2 ± 1.9; 8 females) volunteered to participate in the study. All subjects gave informed consent in accordance with University of Western Ontario's ethics review board (Reference: 2016-107863-2120).

2.2. Data acquisition

Measurements of DQEMG NF jiggle were made with a standard single-strand 25 mm disposable stainless-steel concentric needle (Model N53153; Teca Corp., Hawthorne, NY) with an inner tungsten core. The concentric needle was connected to a single wire lead. Needle electromyography (EMG) signals were acquired using a standard clinical EMG system Cadwell and Sierra Summit and bandpass filtered at 10 Hz to 10 kHz with a sampling rate of 48 kHz.

Participants were comfortably positioned with their arm supported during data acquisition. Participants were instructed to immobilize and maintain the other digits in a relaxed position. This allowed for resistance during voluntary contractions and minimized movement artifacts. The concentric needle (the needle has a stainless-steel cannula to increase the comfort of insertion) was inserted into the largest portion of the muscle belly of the muscles being examined (~10 mm in depth). Participants were asked to contract the muscle being examined to produce a mild to moderate intensity voluntary isometric contraction. Following each contraction, subjective feedback was provided by the researcher to the participant to reach a contraction intensity to approximately 40–60 pulses per second (pps). Subjects were initially asked to minimally contract the muscle isometrically and the needle position was adjusted until it minimized the rise time of the first few motor units. Rise time was evaluated subjectively through auditory and visual feedback as the Sierra system did not provide an objective measure of rise time. Once the needle was in a satisfactory and stable position, the contraction was sustained for ~30 s where MUPs from several MU were detected. Participants were coached to maintain the contraction at the same mild-moderate intensity throughout the 30 s through auditory feedback and verbal cueing from the investigator. Approximately four to six contractions were collected to acquire 20 or more MUP trains for each muscle. The needle position was adjusted between contractions to minimize the chances of sampling the same motor units. To obtain NF MUPs, we used a high-pass filter using a second ordered low-pass differentiator. The formula and methods for the filters have been reported elsewhere (Allen et al., 2015; McGill et al., 1985; Stashuk, 1999) (an example of MUPs before and after high pass filtering is shown in Fig. 2A and B). NF jiggle was obtained from the first dorsal interosseous (FDI), the abductor digiti minimi (ADM), and the forth dorsal interosseous (4DI) muscles. Calculations of NF jiggle were quantified with the consecutive amplitude difference (CAD) statistic previously described by Stålberg and Sonoo (1994), Stashuk (1999). However, this statistic was applied to NF MUPs rather than the original MUPs.

One of the authors (P.T.) collected and reviewed the MUP trains. For the retest portion of the study, the data collection was repeated on the same day. The same concentric needle was used for the retest portion but performed after a brief 15-minute break. Data analysis was only performed following both the test and retest portions. Data review was not performed with the author blinded.

2.3. Data analysis

EMG data was then inspected and analyzed following the sessions. In order to ensure that there was a consistent MU firing pattern represented, visual checks were made for each MUP train. Also, the inter-discharge-interval (IDI) histogram was inspected to confirm the that the distribution was Gaussian in nature and with a coefficient of variation < 0.3. MUP trains were required to have > 50 detected potentials. Any MUP trains that did not meet the inclusion criteria stated were not included further in the analysis. NF MUP parameters include NF count, NF jiggle, NF jitter, NF dispersion and maximum NF interval. However, for the purpose of this investigation, NF jiggle will be the focus. NF jiggle is a statistical measurement used to represent the shape variability of the MUPs produced by a single MU. Analysis of shape variability requires that the MUPs be representative of a single MU. The investigator viewed raster plots of the NF MUPs of each MUP train analyzed and excluded contaminated NF MUPs.

2.4. Statistical analyses

Mean values of jiggle and standard deviations of jiggle are represented on Table 2. Relative test-retest reliability was calculated using the intraclass correlation coefficient (ICC) (Shrout and Fleiss, 1979). Further, standard error of measurement (SEM) was calculated using the following formula $SD_{pooled} \times \sqrt{1} - ICC$ (Harvill, 1991). SEM is an indication of the expected measurement error in a single individual's score using the same metric of jiggle. Minimal detectable change (MDC) was calculated at the 90% level, which is appropriate for assessing change in clinical practice. For the rater to be 90% confident that true change occurred, a threshold value of jiggle was calculated using the formula $MDC_{90} = SEM \times \sqrt{2} \times 1.65$ (Leslie G. Portney, 2009).

The Bland-Altman technique was used to determine the distribution of differences between the test and retest scores for NF jiggle. As per Bland and Altman, the differences between test and retest NF jiggle scores were plotted against the mean of their scores (Martin Bland and Altman, 1986). Limits of agreement (LOA) were placed at ± 1.96 standard deviations (SD) around the mean difference, which was also indicated by a line. A patterned relationship between the score differences with the means would indicate a systematic bias. This was done through visual inspection of the plot, but also through the use of a linear regression model. Similarly, the plot allows for a visual inspection of the LOAs, where a narrower range would suggest better agreement between the two measures.

3. Results

All twenty healthy adults successfully completed the study (Mean age = 23.2 ± 1.9; 8 females) (See Table 1 for demographics).

The mean value of NF Jiggle values for the FDI, ADM, and 4DI were 32.5%, 32.4%, and 34%, respectively (Table 2). The mean value of Traditional Jiggle values for the FDI, ADM and 4DI were 59.5%, 55.1%, and 57.4%, respectively (Table 2).

Table 1
Study demographics.

Demographics (n = 20)	
Age	23.2 (± 1.9)[a] years
Men	12 (60%)
Women	8 (40%)
Right hand dominant	18 (90%)

[a] Standard Deviation.

Table 2
Descriptive statistics for Near-fiber (NF) jiggle and traditional jiggle.

	NF jiggle (%)			Traditional jiggle (%)		
Muscles	*FDI*[a]	*ADM*[b]	*4DI*[c]	*FDI*[a]	*ADM*[b]	*4DI*[c]
Mean	32.5	32.4	34	59.4	55.1	57.4
Standard Deviation	5.1	5.6	7.1	30.1	25.6	25.7

[a] First Dorsal Interosseous (FDI).
[b] Abductor Digiti Minimi (ADM).
[c] Fourth Dorsal Interosseous (4DI).

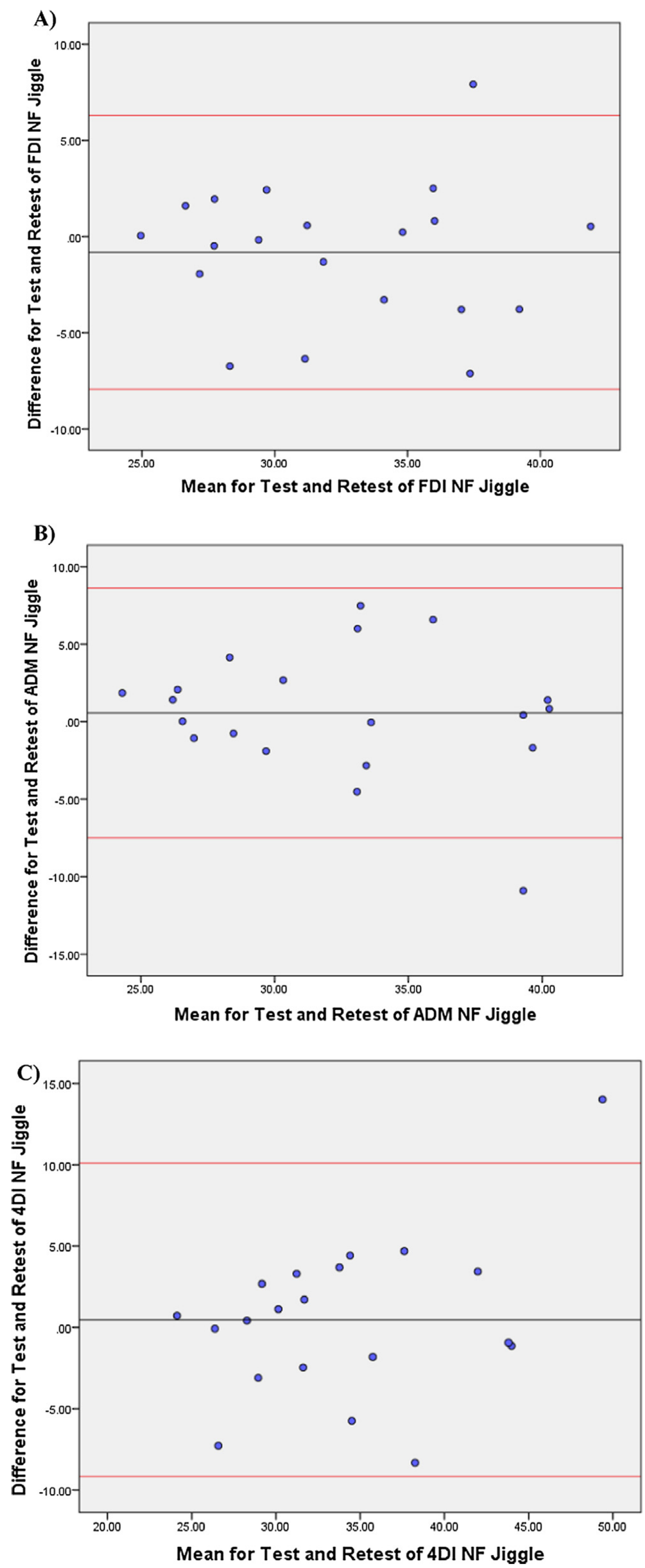

Fig. 1. Bland-Altman analysis comparing the test and retest session of NF jiggle (A) first dorsal interosseous (FDI) muscle (B) abductor digiti minimi muscle (ADM) (C) fourth dorsal interosseous muscle (4DI).

Fig. 1 represents the Bland-Altman plot for the FDI, ADM and 4DI muscles. Upon visual inspection of the scatterplot for the FDI and 4DI, the points indicate no observable systematic bias due to the relative even distribution. In contrast, the ADM scatterplot shows small increases in the mean difference range as the mean scores increase. This suggests a small systematic bias between the NF jiggle test and retest measurements (see Fig. 2C and D for an example of MUPs in the test and retest sessions). The mean differences for the FDI, ADM and 4DI muscles were −0.82%, 0.56%, and 0.47%, respectively. The limits of agreement (LOA) for the test and retest measurements were defined as 2 standard deviations (of the score differences) away from the mean difference. The LOA for the FDI, ADM and 4DI were −7.9% to 6.3% (range of 14.2%), −7.5% to 8.6% (range of 16.1%) and −9.2 to 10.1% (range of 19.3%), respectively. The ranges for the LOA suggest that there are greater score differences in the test and retest scores for 4DI NF jiggle in comparison to the other two muscles. However, the small asymmetry to the upper and lower limits for all three plots suggests minimal bias between the test and retest session in the FDI, ADM and 4DI. The linear regression models for the test and retest scores of all 3 hand muscles (FDI, ADM, and 4DI) indicated that NF jiggle averages were not a significant predictor of NF jiggle differences. Collectively, the low mean difference scores, the LOA and the regression model suggest a small amount of bias between the test and retest scores of NF jiggle in all 3 hand muscles.

Table 3 presents the ICC, SEM and MDC values for all 3 hand muscles' NF Jiggle. Test-retest reliability was good in all three muscles' NF Jiggle (FDI, ADM and 4DI) with ICCs of 0.86, 0.85, and 0.87, respectively. The SEM and MDC were slightly smaller for the FDI and ADM muscles in comparison to the 4DI. Table 4 presents the ICC values for Traditional Jiggle of all 3 hand muscles. Test-retest reliability was moderate in the FDI (0.59) and 4DI muscle (0.55), the ADM muscle (0.79) demonstrated good reliability.

4. Discussion

This study has demonstrated that the physiological measurement of NF jiggle, a quantitative electromyography measurement of motor unit shape variability, can be reliably obtained using DQEMG in the ulnar innervated intrinsic hand muscles FDI, ADM and 4DI. In contrast to traditional jiggle, NF Jiggle for FDI, ADM and 4DI demonstrated good reliability through the ICC values. SEM and MDC90 values were determined based on the ICC values. Capturing the reliability of NF jiggle allows future clinicians and investigators to follow the natural history of diseases and the response to treatments of disorders. Collectively, these measurements may provide useful insight regarding where pathological changes may have occurred.

Reliability is affected by the overall consistency of the NF jiggle technique but is also context specific to the tested muscles and population. Different clinical populations may have different inherent levels of variability, both error variability and participant variability. When examining ICC calculations, higher participant variability increases the denominator of the ICC, which may enhance absolute reliability. In contrast, SEM and mean error are not ratio-based, so represent absolute size of measurement error. Overall, our data is specific to the reliability of jiggle in the hand muscles, in a relatively young and healthy population. Under these circumstances, all three hand muscles demonstrated good reliability. Further, the Bland-Altman plots demonstrated reasonable agreement between the test and retest trials of NF jiggle in all three hand muscles. When compared to traditional jiggle, NF jiggle

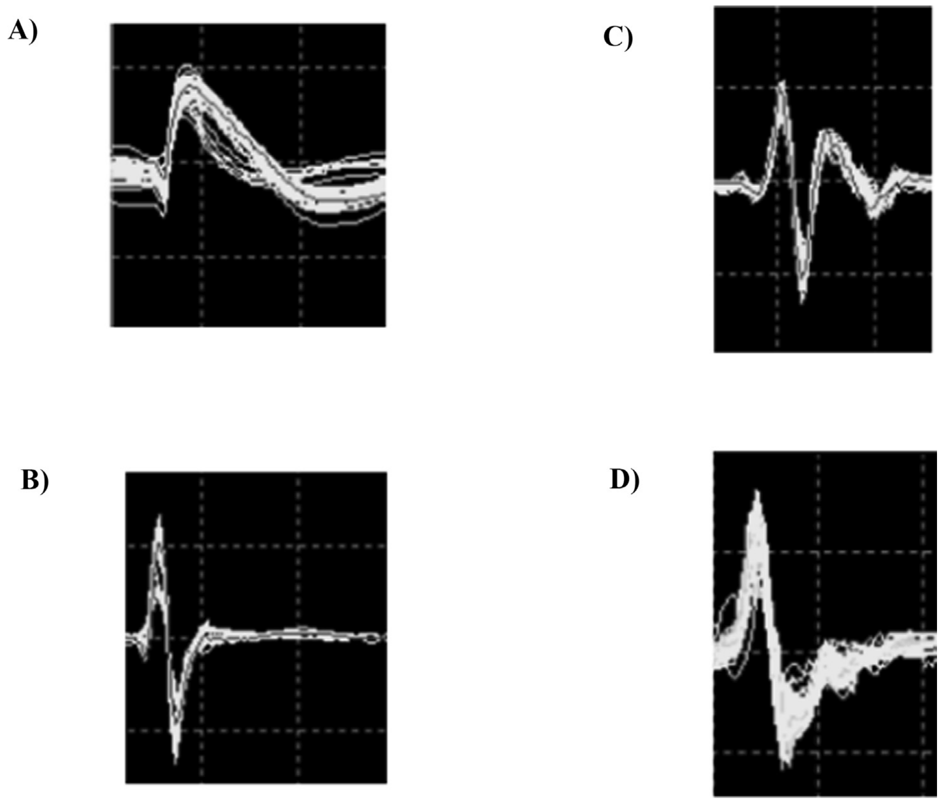

Fig. 2. Examples of MUP shimmer plots from the FDI muscle of one participant (A) MUP shimmer plot (before high pass filter) (B) NF MUP shimmer plot (after high pass filter) (C) NF MUP shimmer plot from test session (NF jiggle = 30.7%) (D) NF MUP shimmer plot from re-test session (NF jiggle = 47.4%).

Table 3
Intraclass Correlation Coefficient (ICC), Standard Error of Measurement (SEM) AND Minimal Detectable Change (MDC) for near-fiber jiggle of the hand muscles.

	FDI[a]	*ADM*[b]	*4DI*[c]
Intraclass Correlation Coefficient (ICC)	0.86	0.85	0.87
Standard Error of Measurement (SEM)	1.9	2.1	2.5
Minimal Detectable Change (MDC)	4.4	5.0	7.1

[a] First Dorsal Interosseous (FDI).
[b] Abductor Digiti Minimi (ADM).
[c] Fourth Dorsal Interosseous (4DI).

Table 4
Intraclass Correlation Coefficient (ICC) for traditional jiggle of the hand muscles.

	FDI[a]	*ADM*[b]	*4DI*[c]
Intraclass Correlation Coefficient (ICC)	0.59	0.79	0.55

[a] First Dorsal Interosseous (FDI).
[b] Abductor Digiti Minimi (ADM).
[c] Fourth Dorsal Interosseous (4DI).

demonstrated greater reliability (higher ICCs) in all 3 hand muscles. NF MUPs are obtained by high pass filtering MUP templates and therefore are comprised of fiber contribution that are closer to the needle detection surface (Allen et al., 2015; Stashuk, 1999). Measuring MUP configurations in more detail from the subset of motor units closer to the needle detection surface, the NF may provide more detailed information regarding neuromuscular transmission in contrast to traditional MUP measurements. Previous investigation of NF jiggle vs. traditional jiggle in healthy participants have shown lower values of jiggle in the NF measurements in contrast to traditional jiggle (Allen et al., 2015; Stashuk, 1999). Considering the differences between these two approaches of measuring motor unit stability, the overall statistic of NF jiggle appears to be more reliable and consistent when it was measured in the hand muscles of healthy participants.

Previous investigations have explored the test-retest and intra-rater reliability of DQEMG, particularly for the measurement of MUNE (Boe et al., 2006, 2004; Ives and Doherty, 2012; Piasecki et al., 2018). Likewise, other studies have reported DQEMG's reliability for needle MUP parameters such as amplitude, area, and duration (Boe et al., 2010; Calder et al., 2008; Ives and Doherty, 2012; Piasecki et al., 2018). The reliability coefficients in the previous investigations ranged from 0.53 (MUP area intra-rater reliability) (Ives and Doherty, 2012) to 0.99 (MUP amplitude intra-rater reliability) (Calder et al., 2008). Moderate levels of reliability have been observed in MUP parameters like duration and area (Boe et al., 2010; Ives and Doherty, 2012). Conceptually, these parameters should influence MUP configuration and create fluctuations in NF jiggle (shape variability) (Daube and Rubin, 2009). However, by specifically evaluating reliability of NF jiggle in the context of the intrinsic hand muscles, the measurement demonstrates good test-retest reliability for all the muscles observed. The current study's reliability coefficients of NF jiggle were similar to a previous investigation by Allen et al. (2015) where the tibialis anterior (TA) muscle's NF jiggle inter-rater reliability was reported to be 0.81 (Allen et al., 2015). The present study's SEM of 1.9 (FDI), 2.1 (ADM), and 2.5 (4DI) indicates the amount of variation that might be expected on repeated testing. Similarly, the MDC90 values of 4.4 (FDI), 5.0 (ADM), and 7.1 (4DI) indicates that if there was a change greater than these reported values, the user can be 90% confident that a change has occurred. These numbers provide a quantitative indicator of how much variation might be due to measurement error. Understanding how much error or random variation occurs in the normal population is the important prerequisite to understanding when variability is abnormal.

Previous studies have investigated DQEMG NF jiggle in healthy younger and older adults' lower extremity muscles (i.e. TA muscle). These studies have reported NF jiggle values of 34.3% (Gilmore et al., 2017a) and 33.8% (Allen et al., 2015), in the TA muscle. The current investigation is the first to provide data on hand muscles, and it is noteworthy that the estimates are similar to the lower extremity. Whether this range of values can be expected in all muscles will only become apparent as data on a larger pool of muscles is published. DQEMG has been previously used to investigate motor unit number estimation and other motor unit properties in the FDI muscle (Allen et al., 2015; Boe et al., 2010, 2006), although NF jiggle was not reported. Jiggle adds important information about neuromuscular transmission stability. Unstable MUPs are shown by the change in the characteristics of the MUPs including prolonged durations, low amplitude and polyphasic shape (Krarup et al., 2016). This is believed to be associated with influential factors such as damaged motor axons or unstable conduction along immature terminal fibers during remodeling (Krarup et al., 2016; Stålberg et al., 1996). These pathophysiological characteristics and increases in NF jiggle have been observed in age-related muscular changes (i.e. sarcopenia) (Gilmore et al., 2017b; Hourigan et al., 2015) and other neuromuscular pathologies such as diabetic neuropathy (Allen et al., 2015), myasthenia gravis (Benatar et al., 2006), ALS (Stålberg and Sonoo, 1994), and CIDP (Gilmore et al., 2017a).

While this study provides preliminary positive results that support the use of NF Jiggle to assess motor unit stability in the hand, limitations must be considered when interpreting our results. First, our sample cannot be considered a normative population since we sampled a relatively younger age group and had insufficient numbers to identify reliability across the age span. Changes in motor unit stability have been previously reported in an aging population (Gilmore et al., 2017b; Hourigan et al., 2015). Second, test-retest reliability was determined by one rater, using an intra-rater reliability approach. Considering that various neuromuscular conditions are treated from multiple centers and clinicians, it would be important for future investigations to measure the inter-rater reliability of the technique as it is applied.

5. Conclusions

The results of this study demonstrate that NF jiggle produces highly reliable results in healthy participants' intrinsic hand muscles, both in terms of detecting group differences (relative reliability), and absolute reliability (small SEM and MDC). NF jiggle may be a potentially useful measurement for measuring changes in motor unit stability for future investigations such as age-related changes in hand muscles and investigations of nerve injuries.

Declaration of Competing Interest

There are no conflicts of interest that the authors wish to declare.

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Philemon Tsang is a Physical Therapy graduate from Western University. He is currently completing his PhD in Health and Rehabilitation Sciences at Western University. Philemon is presently investigating muscle and nerve physiology in healthy individuals and patients with nerve injuries through the use of novel electromyography techniques. As a clinician-scientist, his goal is to advance physical therapy and neuroscience through research and clinical practice.