

Original Article

Relationships and Patterns of Variation in the Strength of Finger and Wrist Flexor Muscle Groups and the Identification of Simulated Paralysis

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Abstract

Objective: To investigate the relationship between muscle strength in various flexor muscle groups of the fingers and wrist and establishes a method for identifying simulated paralysis using the MicroFET2 muscle strength tester. **Methods:** Subjects were divided into three groups: a young cooperative group (n = 60), an elder cooperative group (n = 17), and a simulated paralysis group (n = 25). The peak force of wrist palmar flexion, thumb palmar abduction, and distal finger flexion was measured in different positions using the MicroFET2. **Results:** The highest muscle strength was observed in wrist joint dorsal extension at 30°, followed by the neutral position at 0°, and then palmar flexion at 30°. For thumb palmar abduction, strength was higher at 30° than at 60°. Regarding overall flexion strength, wrist palmar flexion was the strongest, followed by the thumb, then the index finger, middle finger, ring finger, and finally, the little finger. In contrast, the simulated paralysis group exhibited irregular muscle strength patterns, providing a basis for identifying simulated muscle weakness. **Conclusion:** The use of MicroFET2 for measuring finger and wrist flexor muscle strength reveals consistent patterns, aiding in the detection of simulated muscle weakness. These findings enhance the objectivity and accuracy of muscle strength testing in forensic clinical practice.

Keywords: Clinical Forensic Medicine, Finger Grip Strength, Quantitative Muscle Strength Testing, Simulated Identification, Wrist Flexor Strength

Introduction

In China, individuals injured in traffic accidents, work-related incidents, and other mishaps must undergo disability level assessments to qualify for compensation. The hands and wrists are the most commonly affected areas in cases

of simulated functional disorders¹. Muscle strength testing plays a crucial role in the forensic clinical assessment of disability levels. Variations in muscle strength test results directly influence disability evaluations, thereby affecting the compensation amount the injured party may receive.

Currently, muscle strength testing methods used in clinical diagnosis and forensic clinical assessments in China typically follow the Lovett manual muscle strength assessment method or the MRC muscle strength grading method¹. Due to its simplicity and the lack of complex auxiliary equipment, manual muscle testing (MMT) is widely used. However, this method provides only qualitative results, lacking precise quantitative data and being susceptible to examiner subjectivity². In recent years, both domestic and international research on the reliability of various quantitative muscle testing devices across different populations has increased³⁻⁵. Isometric muscle

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strength testing stabilizes muscle strength by maintaining a fixed finger angle without movement, offering advantages such as simplicity, non-invasiveness, high stability, high reliability, and easy standardization⁶. Grip and pinch strength measurements using a dynamometer are examples of isometric muscle strength testing methods⁷⁻⁸. However, these methods assess strength only when all five fingers exert force together in a fist or when the thumb and other four fingers pinch together. They cannot measure the strength of individual fingers moving in a specified direction, limiting their ability to assess individual muscles or muscle groups. Some researchers in China have begun studying digital muscle strength testing devices, demonstrating good test reliability⁶⁻⁷, though these devices have not yet been widely adopted. MicroFET2, produced by HOGGAN, is a digital quantitative muscle force tester that converts the force detected by its transducer pad into numerical values in pounds (lbs), Newtons (N), or kilograms-force (kgf). This instrument offers high sensitivity and accuracy⁹.

Based on the isometric muscle strength testing method, this study utilized the MicroFET2 muscle strength quantitative testing instrument to measure the strength of the flexor muscles in the fingers and wrist. This instrument provides accurate quantification of muscle strength. By assessing the strength of various muscle groups in the hand and wrist across different positions in healthy subjects, this study explores the relationships between different muscle groups and variations in strength within the same muscle group across different test positions. This approach contributes to the development of a system for identifying simulated paralysis, enhancing the objectivity of muscle strength assessments, and improving the accuracy of disability level and injury severity evaluations based on muscle strength.

Materials and Methods

Materials and Equipment

Portable Digital Dynamometer: Model MicroFET2, manufactured by HOGGAN (USA). The device includes three interchangeable transducer pads—flat plane, curved arc, and flat point—to accommodate different testing areas, such as the wrist joint or fingertip. The most suitable pad is selected for each measurement based on the test surface. The dynamometer offers three-unit options for measuring muscle strength: pounds (lbs), newtons (N), and kilograms-force (kgf), with a measurement range of 0 to 136 kgf (0 to 300 lbs, 0 to 1334 N) and an accuracy of one decimal place. In this study, kilograms-force (kgf) was used as the unit of measurement. After each test, the peak force and duration of sustained force are displayed on the instrument's screen. The device automatically resets to zero when the subject re-applies force, enabling repeated testing without manual resetting.

Finger Fixing Plate: A foldable steel plate wrapped in food-grade soft silicone, with a bending angle range of

-60° to 60°. Two straps securely stabilize the wrist and palm joints on the steel plate, ensuring proper fixation for the test positions used in this experiment (wrist joint dorsal extension at 30°, palmar flexion at 30°, and neutral position at 0°).

Wrist Support Brace: An unbendable aluminum plate wrapped in shock-absorbing padding, equipped with adjustable straps to accommodate different wrist sizes. The brace provides excellent stability and rigidity, meeting the fixation requirements for the test position (wrist joint at 0°) in this experiment.

Participants

This is a prospective observational study conducted to assess muscle strength and identify simulated paralysis using the MicroFET2 muscle strength tester. Participants were recruited from the Shanghai area through local advertisements and the Shanghai Key Laboratory of Forensic Medicine. Three groups were selected: a young healthy group, an elderly healthy group, and a simulated paralysis group.

Young Healthy and Co-operative Group: A total of 60 healthy subjects were selected as research participants, including 30 males (average age: 25.3 ± 3.00 years) and 30 females (average age: 25.4 ± 1.22 years). They underwent testing for peak force values in seven target muscle groups across different test positions under fully cooperative conditions.

Elderly Healthy and Co-operative Group: Seventeen healthy older adults aged 65 and above were selected as research participants, including 10 males (average age: 72.0 ± 6.08 years) and 7 females (average age: 72.7 ± 8.17 years). They underwent testing for peak force values in seven target muscle groups across different test positions under fully cooperative conditions.

Simulated Paralysis Group: Twenty-five healthy young subjects were selected as research participants, including 5 males (average age: 24.4 ± 2.41 years) and 20 females (average age: 25.2 ± 1.73 years). They underwent testing for peak force values in seven target muscle groups across different test positions while simulating muscle paralysis.

Inclusion Criteria

Participants met the following criteria:

1. No history of fractures, joint soft tissue injuries, or ligament injuries in the hands, wrists, arms, or elbows.
2. No symptoms affecting physical strength in the past seven days.
3. No participation in specific upper limb training (such as strength training).

Exclusion Criteria

1. History of fractures, joint soft tissue injuries, or ligament injuries in the hands, wrists, arms, or elbows.
2. Any symptoms affecting physical strength within the

past seven days.

3. Participation in specific upper limb training (e.g., strength training) within the past six months.
4. Presence of any conditions that could interfere with the accurate measurement of muscle strength.

All operators received professional training on the instrument's operation to ensure procedural proficiency and to provide guidance to participants during testing. This study was approved by the ethics committee of the Judicial Appraisal Institute, and all subjects provided written informed consent. Before formal testing, participants were informed about the purpose of the study, given a demonstration of the procedures, and provided with an explanation of relevant precautions.

Joint Positions for Testing

All subjects were tested using the following joint positions:

1. Flexion of the Index, Middle, Ring, and Little Fingers, and Active Wrist Flexion:

Subjects were seated with the elbow flexed at 90° and the forearm rotated 90° pronated. Fixed supports were used to stabilize the wrist at three positions: 30° of palmar flexion, neutral (0°), and 30° of dorsiflexion. The metacarpophalangeal (MCP) joints were extended at 0°, with the palm facing downward.

2. Thumb Flexion:

Subjects were seated with the elbow flexed at 90° and the forearm in a neutral position. A goniometer was used to measure and adjust the wrist at three positions: 30° of palmar flexion, neutral (0°), and 30° of dorsiflexion. The thumb was abducted to 60°, with the fingertip facing downward.

3. Thumb Abduction:

Subjects were seated with the elbow flexed at 90° and the forearm in a neutral position. The wrist was maintained in a neutral position, while a goniometer was used to measure and adjust the thumb at 30° and 60° of abduction, with the fingertip facing downward.

Testing Procedure

Young Healthy and Cooperative Group: A total of 60 subjects (30 males, 30 females) were tested under fully cooperative conditions. The peak force values of 7 target muscle groups were analyzed across different test positions. The data were analyzed using SPSS, and a bar chart was compiled to visualize changes in muscle strength across various test positions and the relationship between the strengths of different muscle groups.

Elderly Healthy and Cooperative Group (65 years and older): A total of 17 subjects (10 males, 7 females) were tested under fully cooperative conditions. The peak force values of 7 target muscle groups were analyzed across different test positions. The data were analyzed using SPSS, and a bar chart was compiled to visualize changes in muscle

strength across various test positions and the relationship between the strengths of different muscle groups.

Simulated Paralysis Group: A total of 25 subjects (5 males, 20 females) underwent testing under simulated muscle paralysis conditions. The peak force values of 7 target muscle groups were measured across different test positions. To simulate muscle paralysis, subjects completed each muscle group strength test with non-maximal effort contractions. A total of 25 sets of data were obtained, from which 5 sets were randomly selected to create a bar chart using SPSS. This process was repeated twice. The analysis aimed to evaluate changes in muscle strength across different test positions and the relationship between the strength of different muscle groups.

Operator Training and Testing Protocol: The operator was required to be proficient in the testing procedure and familiar with the operation methods. Prior to formal testing, subjects were given time to adapt to the test positions and practice the force generation technique. The transducer pad was switched according to the size of the area where force was applied, and subjects exerted force vertically against the transducer pad. The MicroFET2 device could be handheld or fixed on a horizontal table. When handheld, the operator needed to apply the same counterforce (resistance) to stabilize the instrument without displacement. After the operator's command, the subject began to exert force, with each exertion lasting approximately 5 seconds. Each data point was measured 3 times and averaged. To prevent muscle fatigue, a gap of at least 30 seconds was maintained between each exertion. After each trial, the operator read and recorded the peak force value displayed on the screen. Factors affecting muscle strength, such as hunger, fullness, and recent intense exercise, were considered.

For healthy and cooperative subjects, the operator provided verbal encouragement, and subjects were allowed to observe the changes in muscle strength values on the display screen. This dual visual and auditory stimulation encouraged the subjects to exert maximum strength in the muscle group being tested. In contrast, for the simulated paralysis group, subjects were not permitted to observe the changes in muscle strength values on the display screen to ensure that the muscle strength values remained arbitrary.

Statistical Analysis

Data were analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics, including means and standard deviations (SD), were calculated for each muscle group under different test positions. For inferential statistics, independent t-tests were used to compare differences between genders and between hands. One-way ANOVA was conducted to compare peak force values among the young healthy group, elderly healthy group, and simulated paralysis group. Bonferroni correction was applied for multiple comparisons when ANOVA results indicated statistical significance. The significance level was

Table 1. Maximum Mean Muscle Strength Values for Finger Flexion and Wrist Joint Palmar Flexion at Different Test Positions in Young Healthy Subjects.

Flexor muscle groups	Test position		Male (n=30)		Female (n=30)		P1 value	P2 value
	Forearm rotation angle	Wrist joint position	Left	Right	Left	Right		
Thumb flexion	Neutral position	Dorsal extension 30°	5.16±1.69	5.35±1.86	2.44±0.96	2.51±1.05	<0.001	<0.001
		Neutral position 0°	4.79±1.60	4.82±1.63	2.28±0.81	2.33±0.79	<0.001	<0.001
		Palmar flexion 30°	3.52±1.10	3.57±1.28	1.98±0.70	1.89±0.67	<0.001	<0.001
		Dorsal extension 30°	3.72±0.94	3.88±1.08	2.13±0.58	2.15±0.53	<0.001	<0.001
Index finger flexion	Forearm supinated 90°	Neutral position 0°	3.11±0.67	3.19±0.83	1.76±0.50	1.96±0.57	<0.001	<0.001
		Palmar flexion 30°	2.48±0.70	2.50±0.74	1.48±0.37	1.68±0.49	<0.001	<0.001
Middle finger flexion		Dorsal extension 30°	3.53±1.11	3.60±1.06	2.00±0.60	2.04±0.62	<0.001	<0.001
		Neutral position 0°	2.87±0.69	3.04±0.82	1.64±0.46	1.83±0.52	<0.001	<0.001
		Palmar flexion 30°	2.51±0.78	2.44±0.70	1.43±0.37	1.58±0.43	<0.001	<0.001
Ring finger flexion		Dorsal extension 30°	2.89±1.00	2.89±1.03	1.44±0.47	1.53±0.40	<0.001	<0.001
		Neutral position 0°	2.30±0.60	2.27±0.69	1.21±0.33	1.31±0.37	<0.001	<0.001
		Palmar flexion 30°	1.96±0.64	1.95±0.69	1.11±0.32	1.12±0.32	<0.001	<0.001
Little finger flexion		Dorsal extension 30°	2.35±0.69	2.33±0.69	1.28±0.31	1.36±0.30	<0.001	<0.001
		Neutral position 0°	1.85±0.57	1.84±0.57	1.05±0.27	1.15±0.33	<0.001	<0.001
		Palmar flexion 30°	1.54±0.56	1.60±0.56	0.88±0.23	0.95±0.24	<0.001	<0.001
Wrist joint palmar flexion		Dorsal extension 30°	7.92±1.81	8.05±1.91	4.82±1.19	4.80±1.61	<0.001	<0.001
	Neutral position 0°	7.87±2.26	8.05±2.29	4.46±1.23	4.46±1.47	<0.001	<0.001	
	Palmar flexion 30°	5.78±1.87	6.22±1.93	3.64±1.11	3.78±1.33	<0.001	<0.001	

P1, male left vs. female left; P2, male right vs. female right.

set at $p < 0.05$. The normality of the data was assessed using the Shapiro–Wilk test, and homogeneity of variances was evaluated using Levene’s test.

Results

Muscle Strength Measurement in Young Healthy and Co-operative Subjects

The maximum muscle strength values of 60 young healthy subjects were measured in different test positions for 7 target muscle groups, as shown in Tables 1 and 2. Figure

1 illustrates the relationship between the mean muscle strength of the different muscle groups in the left and right hands of males and females. The muscle strength values for finger flexion and wrist joint palmar flexion in different test positions followed this order: wrist joint dorsiflexion position > wrist joint neutral position > wrist joint palmar flexion position. For thumb abduction, the relationship in different test positions was as follows: thumb abduction at 30° > thumb abduction at 60°.

Independent-sample t-tests were conducted on the muscle strength data in Tables 1 and 2. The results showed

Table 2. Maximum mean muscle strength values for thumb abduction at different test positions in young healthy subjects.

Forearm rotation angle	Test position		Male (n=30)		Female (n=30)		P1 value	P2 value
	Wrist joint position	Thumb palmar abduction angle	Left	Right	Left	Right		
Neutral position	Neutral position	30°	2.21±0.77	2.37±0.81	1.28±0.46	1.29±0.48	<0.001	<0.001
		60°	1.57±0.51	1.71±0.64	1.00±0.30	1.04±0.30	<0.001	<0.001

P1, male left vs. female left; P2, male right vs. female right.



Figure 1. Mean muscle strength of finger flexion in the left and right hands of males and females.

that the muscle strength values in males were significantly greater than those in females for the same side, muscle, and position ($P < 0.01$). As shown in Tables 1, 2, and Figure 1, a comparison of muscle strength values between males and females revealed that the maximum strength for finger flexion and wrist joint palmar flexion occurred at wrist joint dorsiflexion at 30°, while for thumb abduction, it occurred

at thumb abduction at 30°.

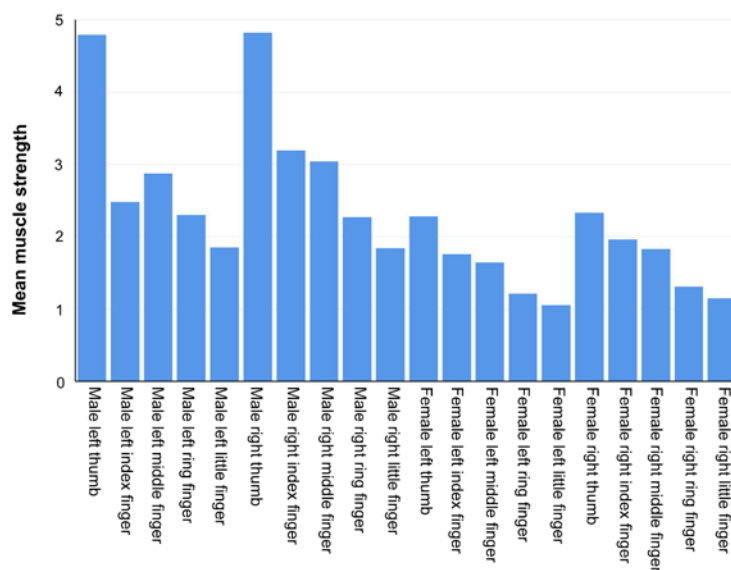
The mean muscle strength at the maximum muscle strength test position (i.e., wrist joint dorsiflexion at 30°) was used to compare muscle strength between females and males. The average muscle strength in females was approximately 47% to 61% of that in males, as shown in Table 3.

Table 3. Ratio of maximum mean muscle strength values between males and females for the same muscle and side.

Female: male	Thumb flexion	Index finger flexion	Middle finger flexion	Ring finger flexion	Little finger flexion	Wrist joint palmar flexion	Thumb abduction
Left	47%	57%	57%	50%	54%	61%	58%
Right	47%	55%	57%	53%	58%	60%	54%

Table 4. Ratio of maximum mean muscle strength values for different muscle groups on the same side and sex.

	Wrist joint palmar flexion	Thumb flexion	Index finger flexion	Middle finger flexion	Ring finger flexion	Little finger flexion
Male left	100%	65%	47%	45%	36%	30%
Male right	100%	66%	48%	45%	36%	29%
Female left	100%	51%	44%	41%	30%	27%
Female right	100%	52%	45%	43%	32%	28%

**Figure 2.** Relationship between mean muscle strength of finger flexion in the left and right hands of males and females.

The wrist joint palmar flexion strength and the flexion strengths of the thumb, index, middle, ring, and little fingers were compared. The mean muscle strength at the maximum muscle strength test position (i.e., wrist joint dorsiflexion at 30°) was used for comparison, with the maximum muscle strength of wrist joint palmar flexion set as 100%. The relationship between wrist joint palmar flexion strength and the flexion strength of the thumb, index, middle, ring, and little fingers is shown in Table 4.

Independent-sample t-tests were also used to analyze the muscle strength data in Tables 1 and 2. The results showed that there was no significant difference in the muscle strength values between the left and right hands in terms of sex, muscle, and position ($P > 0.05$). The flexion strengths of the thumb, index, middle, ring, and little fingers in both hands of males and females showed a clear decreasing trend, with the order: thumb > index finger > middle finger > ring finger > little finger. Furthermore, the

Table 5. Maximum mean muscle strength values for finger flexion and wrist joint palmar flexion at different test positions in 17 elderly healthy participants (kgf).

Flexor muscle groups	Test position		Male (n=10)		Female (n=7)	
	Forearm rotation angle	Wrist joint position	Left	Right	Left	Right
Thumb flexion	Neutral position	Dorsal extension 30°	3.72±1.45	4.00±1.67	3.35±0.62	3.26±0.70
		Neutral position 0°	3.42±1.42	3.48±1.47	2.94±0.57	2.99±0.90
		Palmar flexion 30°	2.82±1.19	2.92±1.47	2.45±0.88	2.46±0.84
		Dorsal extension 30°	3.91±0.86	4.16±1.15	2.95±0.77	3.15±0.73
Index finger flexion		Neutral position 0°	3.43±1.07	3.42±1.32	2.33±0.63	2.44±0.57
		Palmar flexion 30°	2.78±0.85	3.01±0.91	1.98±0.48	2.07±0.76
Middle finger flexion		Dorsal extension 30°	3.07±0.57	3.67±0.83	2.85±0.72	3.19±0.89
		Neutral position 0°	2.75±0.49	3.09±1.00	2.26±0.60	2.40±0.58
		Palmar flexion 30°	2.51±0.61	2.68±0.81	1.85±0.40	1.96±0.62
Ring finger flexion	Forearm supinated 90°	Dorsal extension 30°	2.45±0.48	2.87±0.87	2.46±0.67	2.59±0.68
		Neutral position 0°	2.11±0.45	2.38±0.80	1.95±0.52	2.14±0.59
		Palmar flexion 30°	1.79±0.51	2.19±0.71	1.63±0.35	1.73±0.52
Little finger flexion		Dorsal extension 30°	2.16±0.44	2.57±0.49	1.97±0.56	2.07±0.92
		Neutral position 0°	1.88±0.52	2.15±0.62	1.61±0.42	1.66±0.67
		Palmar flexion 30°	1.44±0.61	1.85±0.50	1.41±0.42	1.37±0.48
Wrist joint palmar flexion		Dorsal extension 30°	6.37±2.16	6.24±1.71	5.14±1.28	5.09±0.98
		Neutral position 0°	5.77±2.02	5.85±1.94	4.82±1.24	4.77±0.91
		Palmar flexion 30°	3.90±1.34	4.15±1.35	3.04±0.82	3.45±0.77

flexion strength of the index and middle fingers was most similar among the five fingers, as shown in Figure 2.

Muscle Strength Measurements in Elderly Healthy and Co-operative Subjects

The maximum mean muscle strength values of 7 target muscle groups in different test positions for the 17 elderly participants are shown in Tables 5 and 6. Figure 3 illustrates that the relationship between muscle strength values for finger flexion and wrist joint palmar flexion in

both hands followed the ranking: wrist joint dorsiflexion at 30° > wrist joint neutral position at 0° > wrist joint palmar flexion at 30°. The relationship between muscle strength values for thumb abduction in different test positions was as follows: thumb abduction at 30° > thumb abduction at 60°. Furthermore, the thumb, index, middle, ring, and little finger flexion strengths of the 17 participants showed a clear decreasing trend, with the order: thumb > index finger > middle finger > ring finger > little finger, as shown in Figure 4.

Table 6. Maximum mean muscle strength values for thumb abduction at different test positions in 17 elderly participants.

Test position			Male (n=10)		Female (n=7)	
Forearm rotation angle	Wrist Joint position	Thumb palmar abduction angle	Left	Right	Left	Right
Neutral position	Neutral position	30°	2.76±1.05	2.48±0.90	2.31±0.85	2.34±0.81
		60°	1.72±0.76	1.74±0.69	1.66±0.69	1.74±0.72

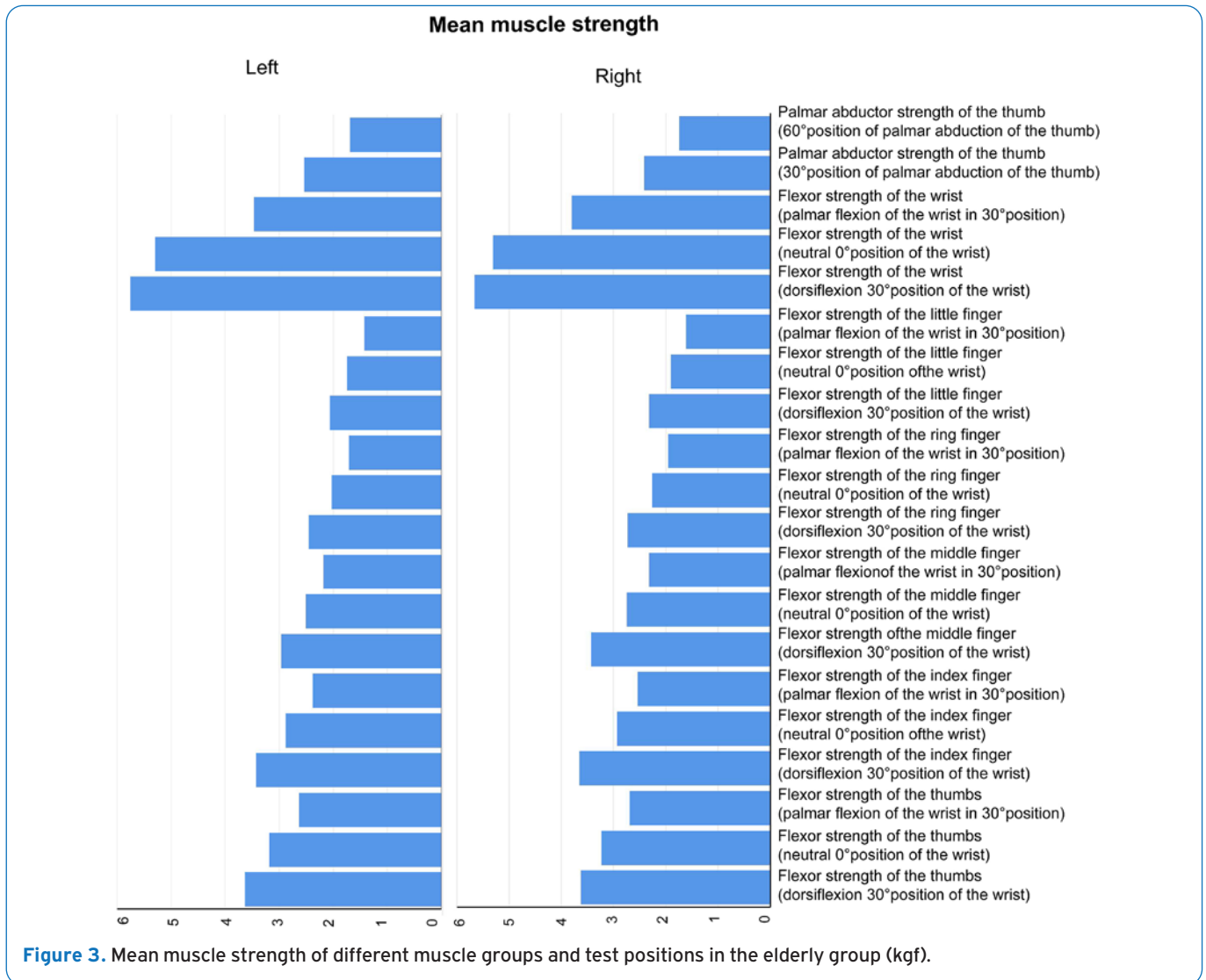


Figure 3. Mean muscle strength of different muscle groups and test positions in the elderly group (kgf).

Muscle Strength Measurement in the Simulated Paralysis Group

Muscle strength tests were conducted on 25 participants under simulated paralysis conditions. The muscle strength values in different test positions for 7 target muscle groups

were measured. Participants were required to simulate muscle paralysis by completing muscle strength tests with any non-maximum effort contraction force (Figures 5 and 6). A total of 25 datasets were obtained. Five datasets were randomly selected to construct Bar Graph 3, and another five were randomly selected to create Figure 4.

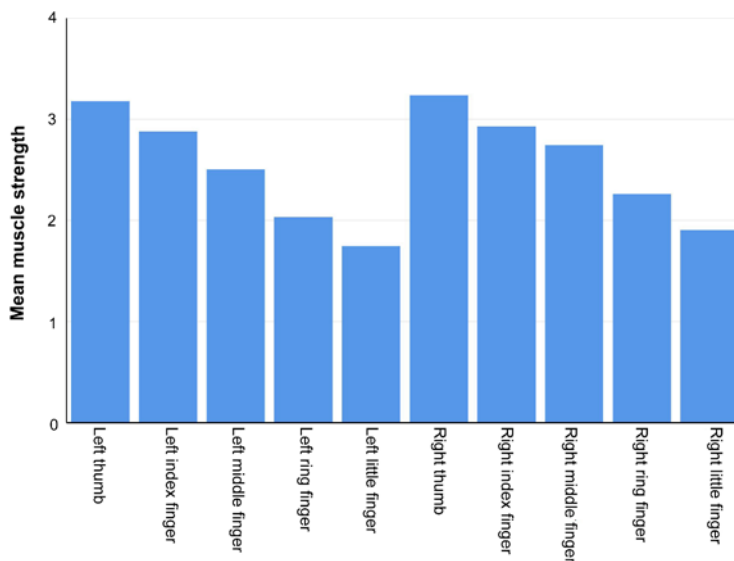


Figure 4. Mean muscle strength of finger flexion in both hands of the elderly group (kgf).

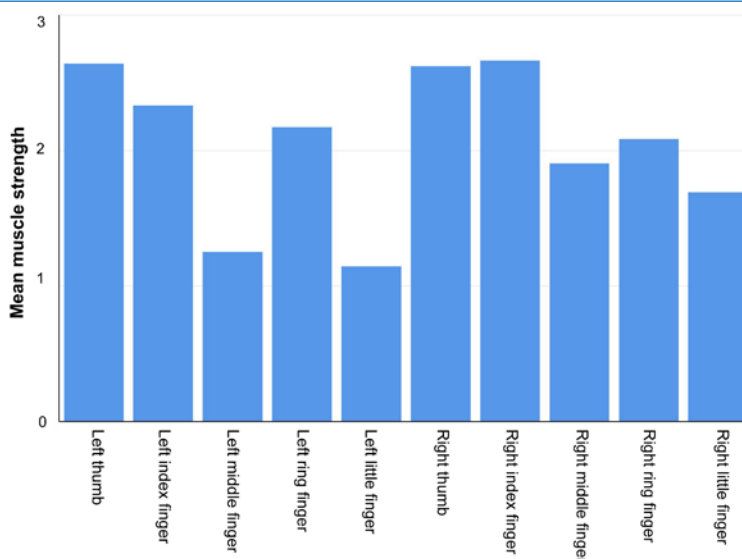


Figure 5. Mean muscle strength of finger flexion in the left and right hands of the simulated paralysis group.

It was observed that the relationship between finger strength was chaotic and irregular, not following the general pattern of “thumb > index finger > middle finger > ring finger > little finger.”

Five sets of data on the mean muscle strength values for different muscle groups and test positions were randomly selected from the simulated paralysis group to construct Bar Graph (Figure 7), and another five sets were similarly

selected to create Bar Graph (Figure 8). It was found that the relationship between thumb, index, middle, ring, and little finger flexion strengths, as well as wrist joint palmar flexion strength, was chaotic and irregular, not following the typical pattern of “wrist joint dorsiflexion at 30° > wrist joint neutral position at 0° > wrist joint palmar flexion at 30°.” Additionally, the relationship between different thumb abduction strengths was also chaotic and irregular, not

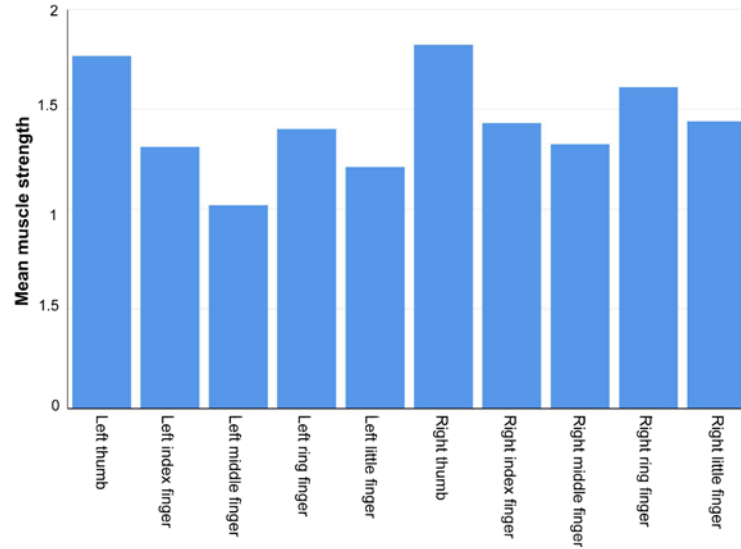


Figure 6. Mean muscle strength of finger flexion in the left and right hands of the simulated paralysis group.

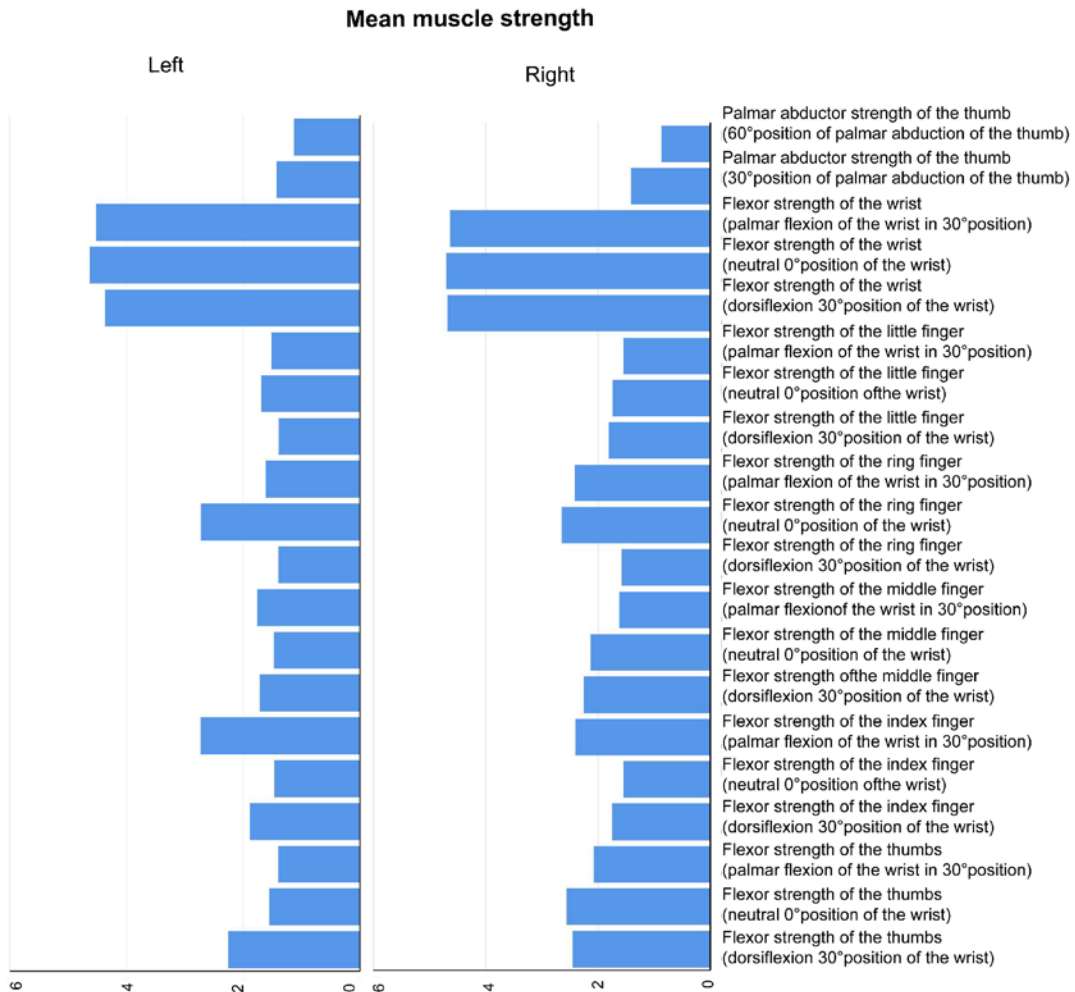


Figure 7. Mean muscle strength of different muscle groups and test positions in the simulated paralysis group.

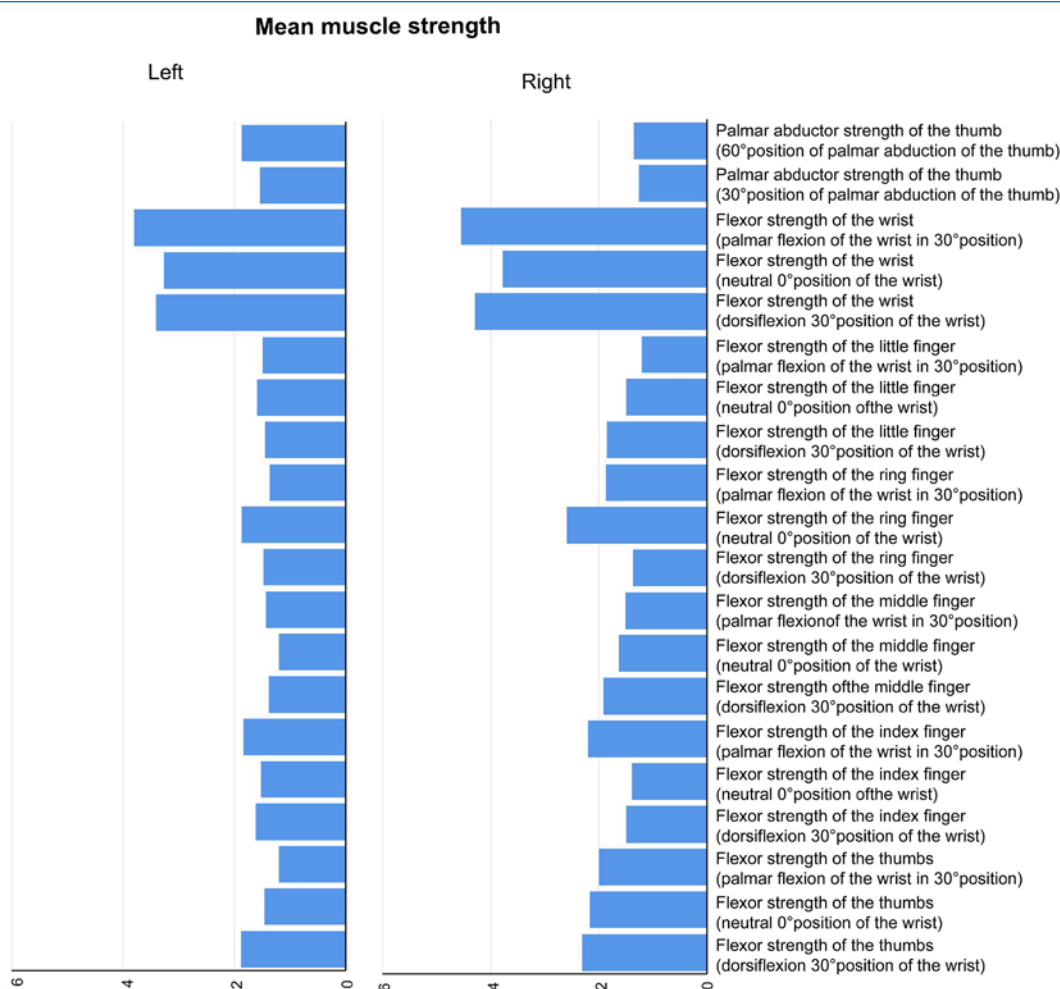


Figure 8. Mean muscle strength of different muscle groups and test positions in the simulated paralysis group.

conforming to the expected pattern of “thumb abduction at 30° > thumb abduction at 60°.

Discussion

This study assessed the muscle strength of flexor muscle groups in the fingers and wrist using the MicroFET2 muscle strength tester. The results consistently demonstrated that both healthy young and elderly subjects exhibited stable and predictable patterns of muscle strength across different positions. In contrast, subjects simulating paralysis showed irregular muscle strength patterns, highlighting the efficacy of the MicroFET2 in detecting simulated muscle weakness. These findings underscore the clinical significance of using quantitative muscle strength measurements in forensic assessments. Accurate muscle strength testing is essential for evaluating injury severity, determining disability levels,

and ensuring fair compensation in cases of occupational and traffic accidents. The consistency and reliability of the MicroFET2 measurements enhance the objectivity and accuracy of these assessments.

The results of this study align with recent research emphasizing the importance of objective and quantitative muscle strength assessments in forensic and clinical practice. Traditional manual muscle testing (MMT), while widely used, lacks the precision and objectivity offered by quantitative methods such as the MicroFET2. MMT evaluates muscle strength based on a subjective scale, which can be influenced by the examiner’s perception and the patient’s level of cooperation, limiting its reliability in forensic contexts where accuracy is critical⁸. In contrast, quantitative muscle strength testing devices, like the MicroFET2, offer a more reliable alternative by measuring muscle strength in objective units (e.g., kilograms-force), yielding consistent and reproducible results. Recent

studies have demonstrated the high reliability and validity of the MicroFET2 in various clinical and research settings. For instance, Xu et al. found that handheld dynamometry, including devices like the MicroFET2, produced reliable results when measuring muscle strength across different patient populations⁸. Similarly, studies by Chen et al. confirmed the reproducibility of muscle strength measurements using quantitative devices⁶.

The muscle strength patterns observed in healthy individuals in this study are consistent with established norms in the literature. Previous research has documented specific patterns of muscle strength across different age groups and sexes, reinforcing the findings of this study. For example, Jaric¹⁰ and Ploeg et al.¹¹ noted that muscle strength decreases with age but follows consistent patterns, which are crucial for identifying deviations due to injury or malingering. Additionally, studies by Li et al. and Benfica et al. have provided normative data for muscle strength in healthy populations, further validating our results^{12,13}.

The consistency and reliability of the MicroFET2 measurements enhance the objectivity and accuracy of muscle strength assessments, making it a valuable tool in forensic and clinical practice. Quantitative methods are particularly useful for detecting simulated muscle weakness, a common issue in forensic assessments⁶. Research by Zhuo et al.¹⁴ has highlighted the effectiveness of quantitative devices in identifying inconsistencies in muscle strength that may indicate malingering. Furthermore, studies have demonstrated the application of these devices in forensic cases, where accurate muscle strength assessment is crucial for determining compensation and legal outcomes^{15,16}.

The study has several limitations. The relatively small sample size, particularly in the elderly and simulated paralysis groups, may limit the generalizability of the results. Additionally, the study included only healthy young and elderly subjects, which may not fully represent the broader population with various health conditions. Future research should address these limitations by including larger, more diverse populations and exploring longitudinal changes in muscle strength patterns.

Conclusion

In conclusion, this study highlights the utility of the MicroFET2 muscle strength tester in providing reliable and consistent measurements of finger and wrist flexor muscle strength. These findings are essential for improving the objectivity and accuracy of muscle strength assessments in both forensic and clinical practice. The MicroFET2's capability to detect simulated muscle weakness is particularly valuable for ensuring fair compensation for injured individuals. Future research should focus on validating these findings across larger and more diverse populations, as well as exploring the long-term stability of muscle strength patterns over time.

Ethics approval

This study was approved by the Ethics Committee of the Shanghai Forensic Identification Science Research Institute, Key Laboratory of Forensic Science, Ministry of Justice (Ethics Approval No. 2022-3-11-01). All procedures involving human participants were conducted in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Consent to participate

Written informed consent was obtained from all participants prior to their participation in the study.

Authors' contributions

Dong GAO: Writing—original draft, Software, Methodology. Ze-ren YANG: Writing—original draft preparation, Software, Investigation. Dong TIAN: Resources. Qing XIA: Formal analysis. Xin-yao LI: Investigation, Data curation. Wen-tao XIA: Writing—review & editing, Project administration, Funding acquisition, Supervision, Conceptualization. All authors read and approved the final version of the manuscript

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