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Research paper

Surface recording of the H-reflex from a relaxed flexor carpi ulnaris: Reliability and normative values for healthy young adults

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ABSTRACT

Objective: H-reflex recordings of the relaxed flexor carpi ulnaris (FCU) muscle are not frequently performed in clinical or laboratory settings. There are no normative values or reliability standards. This is most likely because of technical difficulties associated with this technique. This study performed surface recordings of the H-reflex of relaxed FCU muscles to establish the normative values and the reliability of these recordings. *Methods:* The maximum amplitude and latency of the FCU H-reflex were recorded bilaterally in 53 healthy young adults. Normative values and interclass correlation coefficients (ICCs) were calculated. *Results:* The amplitude of the relaxed FCU H-reflex were recorded in nearly all participants (96 %). The FCU H-reflex average maximum amplitude was 1.35 mV. The average latency was 18.8 ms. H-reflex amplitude and latency were not statistically different among gender or limb sides. Amplitude and latency were recoded reliably both within and between sessions with ICCs ranging from 0.96 to 0.99. *Conclusions:* Recordings of the relaxed FCU H-reflex were readily available and could be assessed reliably within and between sessions. *Significance:* This method might be used more frequently in clinical and laboratory settings to examine C7 and C8 spinal segments and upper limb muscle normal function or neuromuscular pathology.

1. Introduction

The Hoffmann reflex (also known as the H-reflex) can theoretically be recorded from any muscle in the human body (Miller et al., 1995). However, it is most frequently recorded in both clinical and laboratory settings from resting soleus muscles in the lower limbs or the flexor carpi radialis (FCR) muscles in the upper limbs.

FCR H-reflex recordings can be used to examine the activation and inhibition of C6 and C7 spinal segments. It is valid and reliable method under varied recording conditions (Jaberzadeh et al., 2004; Christie et al., 2005; Stowe et al., 2008; Alrowayeh, 2020). H-reflex recordings are not typically performed on other muscles in the upper limbs, most likely due to technical difficulties encountered, particularly when the muscle is relaxed (Sabbahi and Khalil, 1990).

H-reflex recordings from the flexor carpi ulnaris (FCU) can be used to examine C7 and C8 spinal segments in the upper limbs, because this muscle is most innervated by the lateral root of the ulnar nerve (Pyun et al., 2010). In a previous study, Bodofsky (1999) recorded the contraction-induced FCU H-reflexes to establish normative values. However, muscle weakness observed in some patients with neuromuscular disorders might limit their ability to perform muscle contraction. In these cases, it might be more appropriate to record FCU H-reflexes with the muscle in a relaxed state.

Recordings from a relaxed FCU might provide information regarding the integrity of the afferent-efferent pathways in both healthy participants as well as patients with neuromuscular pathology. Currently, there are no normative data for a relaxed FCU H-reflex recordings nor is there any information available on the reliability of this recordings. Therefore, the purpose of this study was to report the normative values of the relaxed FCU H-reflex recordings and examine the reliability of this test in young healthy adults. Results from this study might provide clinicians and researchers with (1) a reference standard that can be used to evaluate neuromuscular pathology in patients with C7 and C8 segment dysfunction; (2) a tool to examine the activation or inhibition of the FCU during normal function, after an injury, or in response to treatment interventions of the upper limbs; and (3) an assessment of the reliability of the FCU H-reflex recordings both within and between test trials.

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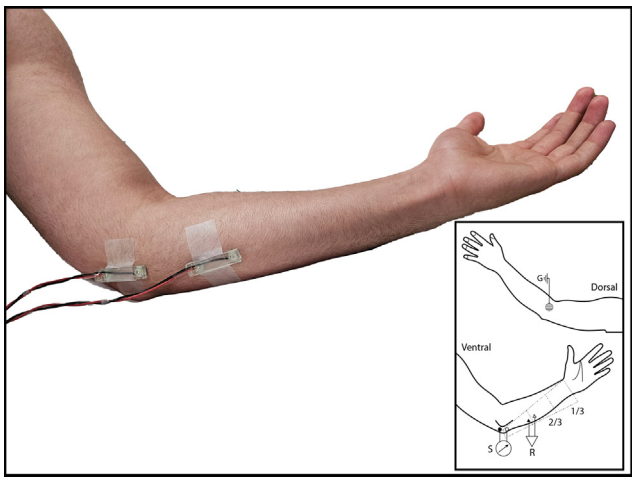

Fig. 1. Location of the stimulating and recording electrodes used to record the FCU H-reflex. S, stimulating; G, ground; R, recording.

2. Materials and methods

2.1. Participants

Fifty-three healthy young adults between 20 and 53 years of age were enrolled in this study. Inclusion criteria included no history or clinical signs suggesting musculoskeletal, metabolic, systemic, or neurologic disorders. Ten participants were randomly selected to participate in the reliability testing [Five female (age range = 23–47), Five male (age range = 25–49)], based on power analysis. All participants read and signed an informed consent form that was approved by the Institutional Ethical Review Board.

2.2. H-reflex stimulation and recording

The FCU H-reflex was stimulated and recorded using an electromyography unit (Cadwell Laboratories, Inc., Kennewick, WA, USA) set at a gain of 500–2000× and a filter bandpass of 3 Hz–10 kHz. The unit elicited the FCU H-reflex electrically by placing an Ag/AgCl surface-stimulating bar electrode with coupling gel just above the medial epicondyle of the humerus. It was over and in line with the ulnar nerve (Fig. 1). The active electrode was positioned proximal to the reference electrode to avoid generating an anodal block (Fisher, 1992). The stimulating electrode delivered percutaneous electrical stimuli of 1.0-millisecond square-wave pulses at a frequency of 1 pulse every 5 s. Four traces were recorded at each incremental electrical stimulus. Stimulus intensities were increased in steps of 0.1–0.5 mA until the maximum H-reflex amplitude was obtained. The traces of the maximum H-reflex amplitude were recorded with minimum M-response, and it was maintained by verifying that the amplitude of M-wave was identical. For the maximum M-wave, stimulus intensities were increased in steps of 0.5–1 mA. An Ag/AgCl surface recording bar electrode with coupling gel was placed over the belly of the FCU, at upper one-third the distance from elbow to wrist, with the reference placed distally over the FCU tendon to record the H-reflex amplitude and M-wave of the muscle (Fig. 1). One 2-cm (diameter) round metal ground electrode was placed on the dorsal aspect of the forearm (Fig. 1).

2.3. Experimental procedures

Participants medical history was collected to ensure absence of musculoskeletal, metabolic, systemic, or neurologic complaints. Then, the skin was prepared for stimulation and recording by abrasion with fine sandpaper followed by cleaning with alcohol. Electrodes with conductive gel were then applied to the participant's

Table 1
Participant characteristics.

Gender	Participants	Age			Arm length (cm)		H-reflex amplitude (μV)				H-reflex latency (ms)			
	No.	Mean	SD	Range	Mean	SD	Mean		SD		Mean		SD	
							R	L	R	L	R	L	R	L
Male	13	25	11	20–53	101	4	1368.76	1484.63	724.21	723.39	18.45	17.79	1.30	1.43
Female	38	21	3	20–47	90	4	1626.78	1561.12	939.63	1061.70	17.25	17.99	1.65	1.59

Centimeters, cm; microvolts, μV; milliseconds, ms.

Table 2
The means, standard deviations (SDs), standard errors of measurement (SEM), 95% confidence intervals (CI), and within-session ICCs (2,4) for the average FCU H-reflex amplitude and latency determined for both the right and left arms in Sessions 1 and 2 during Day 1.

				Amplitude (μV)				
				Mean	SD	SEM	ICC	95 % CI
Sides	Right	Day 1	1	2015.4	1023.0	323.5	0.99	0.92–0.99
		Sessions	2	2105.3	1084.8	343.0		
	Left	Day 1	1	2013.7	1013.9	320.6	0.99	0.97–0.99
		Sessions	2	2026.2	1033.9	326.9		
				Latency (ms)				
				Mean	SD	SEM	ICC	95 % CI
Sides	Right	Day 1	1	18.7	2.3	0.7	0.98	0.94–0.99
		Sessions	2	19.8	2.4	0.7		
	Left	Day 1	1	18.4	2.3	0.7	0.98	0.92–0.99
		Sessions	2	18.6	2.2	0.7		

Microvolts, μV; milliseconds, ms.

right and left arms at the appropriate locations and secured in place with adhesive tape throughout the recording.

After the placement of the electrode, the participant's FCU H-reflex recruitment curves (H-reflex changes with five incremental electrical stimuli) were recorded while seated with the forearm resting on a pillow in a prone position with the elbow slightly flexed. Participants were instructed to relax the forearm fully during the entire recording period while keeping the head in the neu-

Table 3
The means, standard deviations (SD), standard errors of measurement (SEM), 95% confidence intervals (CI), and between-session ICCs (2,1) for the average FCU H-reflex amplitude and latency evaluated on Days 1 and 2.

			Amplitude (μV)				
		Days	Mean	SD	SEM	ICC	95 % CI
Sides	Right	1	2015.4	1023.0	323.5	0.96	0.86–0.991
		2	1966.6	9.82.3	310.6		
	Left	1	2013.7	1013.9	320.6	0.96	0.88–0.99
		2	1972.1	976.4	308.7		
			Latency (ms)				
		Days	Mean	SD	SEM	ICC	95 % CI
Sides	Right	1	18.7	2.3	0.7	0.96	0.88–0.99
		2	19.8	2.3	0.7		
	Left	1	18.4	2.3	0.7	0.98	0.93–0.99
		2	18.6	2.2	0.6		

Microvolts, μV; milliseconds, ms.

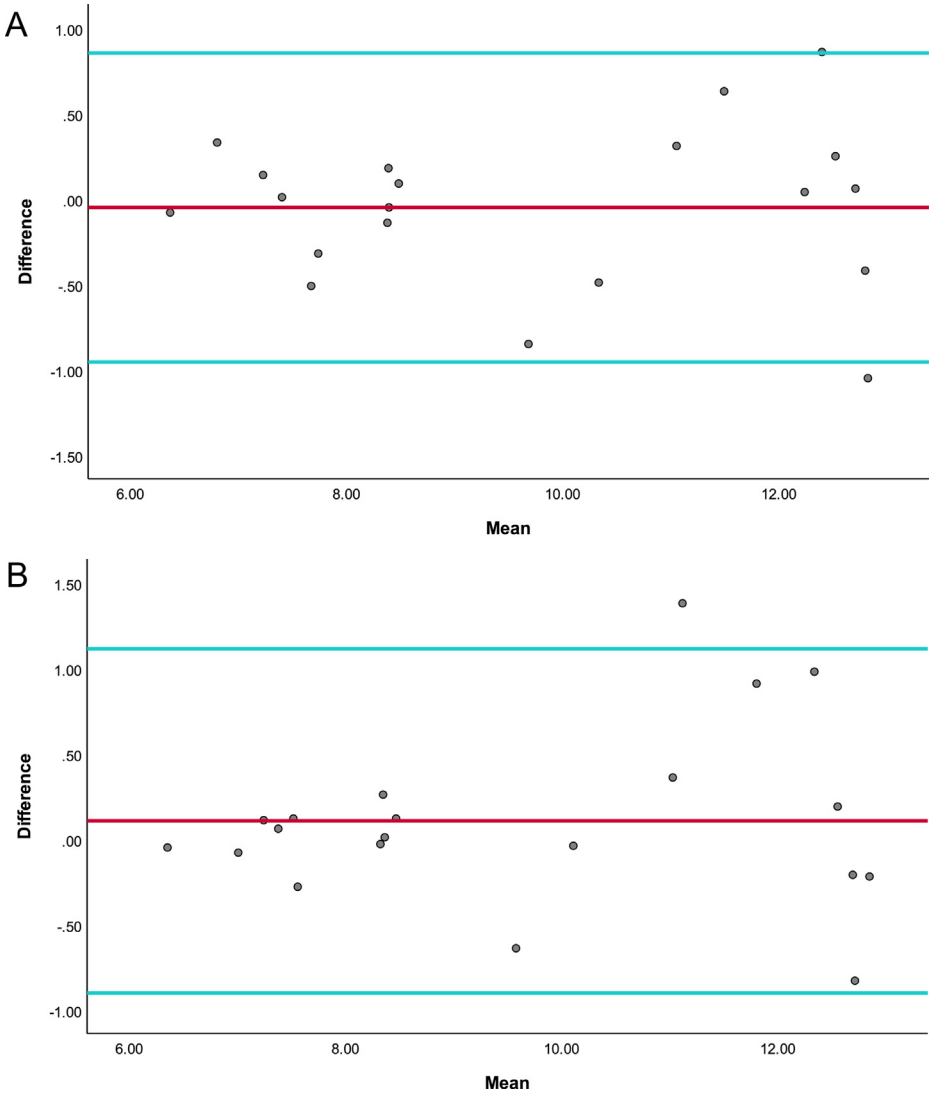

Fig. 2. Bland-Altman plot for the within (A; Day 1, between session one and two) and between (B; Day one and two, Session one) sessions reliability of the FCU H-reflex amplitude recordings.

tral position and eyes looking straight ahead. Electrical stimulation was applied to map the recruitment curve. Four traces were recorded at each incremental electrical stimulus, one trace every 5 s. In instances that the amplitude of the reflex was small, the gain of EMG machine was increased. If the H-reflex could not be elicited or if it was too small to be detected, the participant was excluded. However, this was never the case. After the completion of the procedure, electrodes were removed, and the skin was cleaned. For the reliability study, participants were asked to return the next day to repeat the identical procedure to establish the between-session reliability. To establish the within-session reliability, recordings were repeated during the same session.

2.4. Signal and data analyses

The maximum amplitude and latency of the four traces of the FCU H-reflex were measured. The maximum amplitude of the H-wave was measured from peak-to-peak of the H-wave. The latency was measured from the initial deflection of the electrical stimulation pulse to the initial deflection of the action potential of the H-reflex. The measured amplitude and latency were averaged to establish normative values, including the mean, standard deviation, and range of responses. T-tests were used to examine the differences between the male and female demographics data as well between limb sides.

A Pearson correlation test was used to assess the correlation between the arm length and H-reflex latency. Intraclass correlation coefficients were used to examine the within (ICC [2,4]; Shrout and Fleiss, 1979) and between (ICC [2,1]; Shrout and Fleiss, 1979) sessions reliability. An ICC value above 0.75 was consider high (Portney and Watkins, 2000). Bland-Altman plots were used to assess the variability of the H-reflex amplitude recordings. Statistical significance was evaluated at alpha = .05.

3. Results

Participant demographic data are shown in Table 1. In this study, the FCU H-reflex was detected bilaterally in nearly all participants (n = 51; 96 %). Two participants were excluded from further study because their FCU H-reflexes could not be detected bilaterally. More females (n = 38, 75 %) than males (n = 13; 25 %) participated in this study. Statistical analyses revealed no significant differences between the male and female demographic data or H-reflex amplitude and latency.

The range of the peak-to-peak amplitude of the maximum FCU H-reflex was 0.11–3.6 mV on the right side and 0.15–5.3 mV on the left side, with an average of 1.56 mV and 1.54 mV for the right and left sides, respectively. Statistical analysis revealed no significant differences between the right and left H-reflex amplitudes (t [50] = 0.185, p = 0.85). The FCU H-reflex average maximum amplitude for the combined right and left sides was 1.3 mV.

The H-reflex latency was not significantly different in a comparison between the right and left sides (t [50] = 0.495, p = 0.62). Pearson correlation revealed a small but statistically significant positive correlation between arm length and H-reflex latency (r [101] = 0.27, p = 0.005).

The ICC coefficients for the average amplitude and latency of the FCU H-reflex were high (range 0.96–0.99), indicating strong within and between-session reliability (Tables 2 and 3). Bland-Altman plots showed that the variability of differences between recordings was roughly constant across the within and between sessions (Fig. 2).

4. Discussion

The results of this study include two main findings: (1) the recordings of the FCU H-reflex amplitude were highly reliable both within and between sessions, and (2) the relaxed FCU H-reflex amplitudes could be recorded in almost all participants without the need for reinforcement.

The reliability coefficients determined in this study indicated that relaxed FCU H-reflex recordings in healthy young adults can be measured reliably both within and between sessions. However, no studies that addressed this specific point were available for comparison. The reliability of FCU H-reflex recordings was possibly due to: (1) correct placement of the stimulation and recording electrodes; (2) control of the stimulation intensity to avoid painful and unpleasant sensation; (3) stability of the arousal state of the participants. The availability of the FCU H-reflex amplitude in 96 % of the study participants without the need for reinforcement was possibly due to the young age of the participants (20–53 years of age), since H-reflex might be compromised in older participants. These findings contradict previous study's' findings (Jušic et al., 1995). Jušic et al. (1995) reported that relaxed FCU H-reflexes could be recorded from no more than 47 % of their study participants. Thus, the findings should encourage clinicians and researchers to record the relaxed FCU H-reflex more frequently, particularly in patients with neuromuscular disorders in which muscle weakness might limit their ability to perform muscle contraction.

Despite gender imbalance reported in this study, statistical analyses revealed no significant differences between the male and female FCU H-reflex amplitude. This contradicts previous studies that reported gender differences in H-reflex parameters (Hoffman et al., 2018; Mendonca et al., 2020). Thus, one might argue that the gender imbalance does not provide normal values for patients likely to have C7/C8 pathology. Since females tend to have more neck complaints than males (Kazeminasab et al., 2022), the data reported are still relevant.

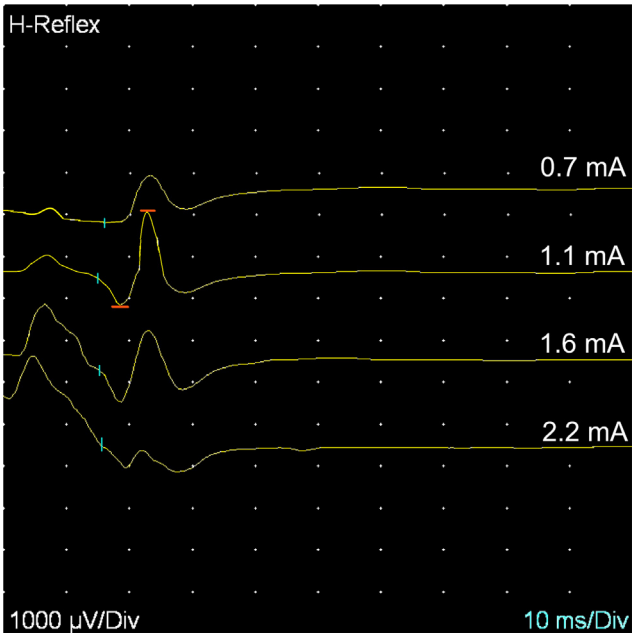

Fig. 3. Recruitment behavior of the FCU H-reflex with increasing stimulus intensities.

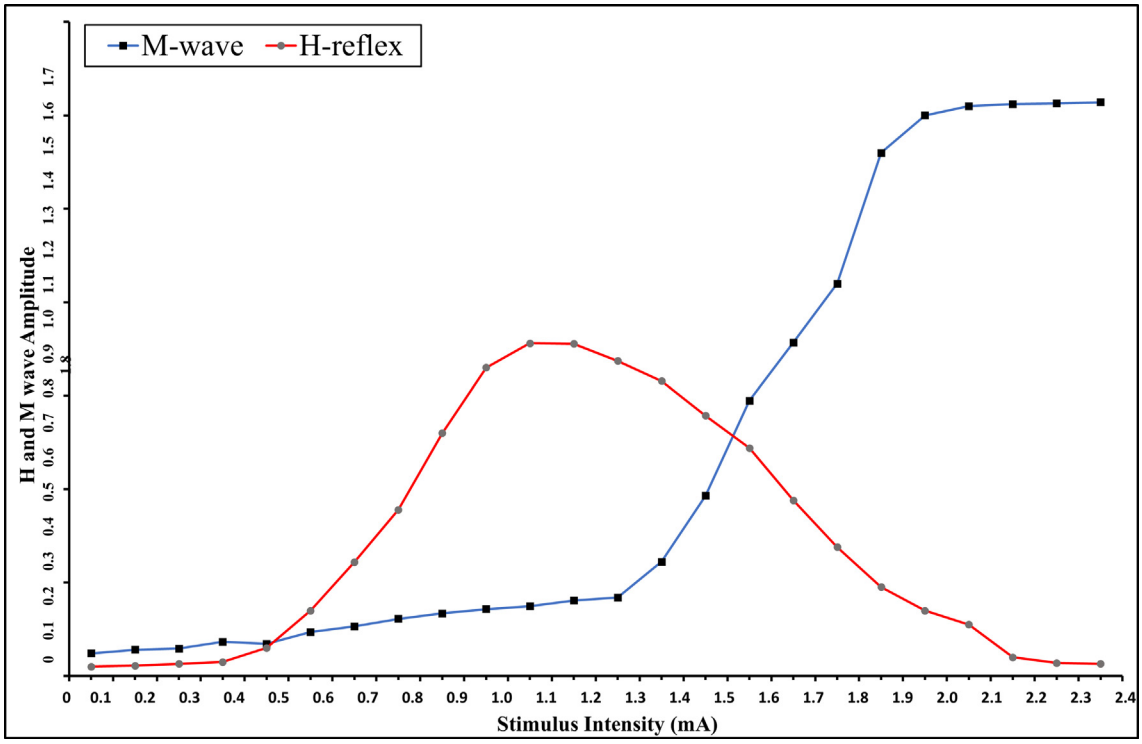

Fig. 4. The FCU H-reflex recruitment curve for a participant.

In this study, the H-reflexes recorded from relaxed FCU muscles were identical to those commonly recorded from other muscles in the upper and lower limbs. The H-reflex amplitudes were recorded below the threshold for obtaining M-waves. As the stimulation strength increased, the amplitude increased until it was blocked, and the M-wave appeared (Figs. 3 and 4).

The latency of the FCU H-reflex was stable during the recordings. This is expected, as one would not expect to detect latency changes in healthy participants. Our results revealed that the H-reflex latency was positively correlated with the arm length. However, the correlation was low while statistically significant, most likely because the entire arm was measured, not just the distance from the stimulation site.

5. Limitation

The results of this study may have some limitations. The participants in this study were mostly young and healthy. Thus, validation in disease and older participants where relaxed FCU H-reflexes may not be obtainable is needed. Future studies, thus, might record the FCU H-reflex in patients with documented C7 and C8 pathology to establish validity as well as diagnostic criteria. Furthermore, since previous studies have demonstrated that the reliability of the soleus H-reflex decreases with aging (Mynark, 2005), the study findings cannot be generalized beyond the ages of 20 and 53 years used in this study. Finally, the study did not compare between relaxed and contraction induced FCU H-reflexes. However, this was not the purpose of this study, and it should be the focus of future research.

6. Conclusion

Relaxed FCU H-reflexes were readily recorded from healthy young adults and can be measured reliably both within and between sessions. Therefore, this technique should be used more frequently to assess cervical pathology and motor control of the upper limbs.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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