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## Effects of 5 Different Finger Rest Positions on Arm Muscle Activity During Scaling by Dental Hygiene Students

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**Purpose.** *This study was conducted to determine the effects of 5 different finger rest positions: opposite arch, standard intraoral, basic extraoral, cross arch, and finger on finger on the muscle activity of 4 forearm muscles (extensor carpi radialis longus, flexor carpi ulnaris, biceps brachii, and pronator teres) during a simulated periodontal scaling experience.*

**Methods.** *A convenience sample of 32 consenting senior dental hygiene students who met inclusion criteria participated. Using a 4 x 5 counter-balanced research design, each participant used a Gracey 11/12 curet to scale one cc of artificial calculus from first permanent molar typodont teeth (#3,14,19,30). Five different typodonts were set up for each participant with fulcrums randomly assigned for use on each typodont. While scaling, the participant's muscle activity was measured by surface electromyography. Two-way analysis of variance with repeated measures was used to determine if significant differences existed in the amount of muscle activity generated with each fulcrum.*

**Results.** *Results revealed no statistically significant interaction effect between area of the mouth scaled, muscle activity, and fulcrum used. Similar muscle activity was produced throughout the mouth regardless of the fulcrum used. The upper right quadrant produced the most muscle activity ( $p = 0.0101$ ) and the lower left quadrant produced the least ( $p < .0001$ ). When comparing the overall muscle activity generated with each fulcrum, only the cross arch fulcrum when compared to the opposite fulcrum produced statistically significant results ( $p = 0.0110$ ).*

**Conclusions.** *Based on the results, similar muscle activity is produced when using any of the 5 fulcrums in each quadrant of the mouth. Clinicians appear to experience minimal ergonomic advantage in terms of fulcrums used and area of the mouth scaled during a simulated scaling experience.*

**Keywords:** Dental hygiene, finger rest positions, musculoskeletal disorders, fulcrum

### Introduction

The well-documented, high incidence rate of musculoskeletal and cumulative trauma disorders (CTD) in dental hygienists attests to the musculoskeletal trauma experienced by dental hygienists.<sup>1-8</sup> Dental hygiene practice is physically demanding, requiring dental hygienists to use high prehension forces, perform highly repetitive hand and wrist motions, apply heavy pressure to fulcrum fingers, and hold their wrists in awkward positions for long periods of time. Researchers have been

challenged with determining causes and preventive strategies for CTD in dental practitioners since these disorders threaten productivity, career longevity, and health of the professionals affected. Risk factors associated with CTD in dental hygienists include repetitiveness of task, posture, and mechanical stresses. Many different strategies have been promulgated to decrease CTD risk in dental practitioners. Preventive strategies include the use of powered scaling devices, larger diameter instrument handles, improved work pacing, and the use of fulcrums during instrumentation.<sup>9-14</sup> However, minimal quantitative evidence is available to support these strategies.

In dental hygiene, a fulcrum is a finger rest used by a practitioner to stabilize the hand and reduce muscle stress while performing clinical procedures such as therapeutic scaling on a patient's dentition. Use of a fulcrum during instrumentation has been advocated since 1915.<sup>15</sup> However, minimal evidence exists concerning what instrument fulcrums pose the greatest protection against CTD. Moreover, dental hygienists are educated to use a variety of instrument fulcrums to provide therapy, stabilize the instrument and reduce muscle stress, yet there is limited research, based on sound ergonomic theory, to support the use of these fulcrums.

To date, only one study has been found that compared fulcrums and muscle activity during scaling. In the one identified study on fulcrums, Dong et al used 12 pre-dental students as participants to determine the effects of 3 different fulcrums on muscle activity and pinch force in a simulated periodontal scaling experience.<sup>9</sup> With surface electromyography (sEMG), hand muscle activity was measured in relation to 3 different fulcrums: extra oral, intraoral with one finger rest, or intraoral with 2 finger rests when scaling tooth number 13. Each participant was provided with typodont teeth coated with nail polish to simulate calculus. Participants had no previous scaling experience and were instructed in scaling techniques prior to the study. Participants scaled the typodont tooth using each of the fulcrums for up to 2 minutes. Results revealed that muscle activity reduced when oral fulcrums were used compared to no fulcrum. As a way to reduce CTD, the authors concluded that dental practitioners would benefit from using fulcrums.

Dong and colleagues used 4 extrinsic hand muscles, which were very close together and likely with sEMG, had cross-talk susceptibility confounding the results.<sup>9</sup> The 12 participants were evaluated in one quadrant of the mouth, on one tooth, and coupled with no scaling experience, limit generalization of the results. Clearly, more research is needed to clarify the role of fulcrums in the ergonomic practice of dental hygiene. To compensate for these limitations, this present study used 4 muscles, far enough apart, to reduce the probability of cross-talk. The comparative effects of 5 different finger rests on forearm muscle activity in 32 senior dental hygiene students who had scaling experience in all 4 quadrants of the mouth, were used to ensure valid and reliable research outcomes. Therefore, the purpose of this study was twofold: 1) to compare the effects of 5 different finger fulcrums-opposite arch (OA), standard intra-oral (IO), basic extra-oral (EO), cross arch (CA), and finger-on-finger (FF)-on the arm muscle activity of 4 muscles, (extensor carpi radialis longus, flexor carpi ulnaris, biceps brachii, and pronator teres) during a simulated periodontal scaling experience, and 2) to determine if there was an interaction effect between quadrants scaled, muscle activity, and fulcrums used. Kinesiological sEMG was used to determine change in muscle activity.

## **Methods and Materials**

Prior to study initiation, the protocol was reviewed and approved by the University Institutional Review Board for the Protection of Human Subjects. Participants comprised a convenience sample of 31 female and 1 male, first-semester, right-handed, senior dental hygiene students ranging in age from 22-44. Participants were recruited by distributing an invitational letter to second year dental hygiene students. To determine whether interested participants met the inclusion and exclusion criteria, a preliminary screening questionnaire was completed. Any past or present injury or disability of the working hand, wrist, forearm, or shoulder excluded participants from the study. Exclusion criteria controlled for past injury, which might skew the sEMG readings. Potential participants who qualified were invited to participate and given an informed consent form explaining the purpose of the study, procedures involved, and the risks and benefits. Those that qualified and agreed to participate signed a written informed consent form prior to the study's initiation. Random assignment of participants to the various trials controlled for sequence effects, selection bias, investigator bias, and any unanticipated participant-relevant variable.

Dental chair-mounted typodonts equipped with an artificial face were used to simulate a client's oral cavity during scaling. Teeth numbers 3, 14, 19, and 30 were coated with up to one cc of artificial calculus on the mesiobuccal surfaces. Artificial calculus (Columbia Dental, NY) was dispensed using a 6 cc syringe and placed from midbuccal to the mesiobuccal embrasure of the test teeth and covered to the height of the crown from the gingival margin. To standardize the calculus application process, a paint mask was placed over each molar before the artificial calculus was applied.

A pilot study was conducted with 2 participants to test and refine the methods. The pilot included placing the sEMG electrode sensors on the right forearm of each of the 2 pilot participants and collecting muscle activity data during dental hygiene instrumentation. Participants performed movements planned for in the study and an examiner measured muscle activity. The pilot study was conducted to determine set up time, accuracy of readings, characteristics of the software, and data recording.

## **Electromyography**

With 32 participants and 20 trials per participant, sEMG measured muscle activity on 4 superficial muscles independent of each other. As an electrodiagnostic test, sEMG is a valid and reliable measure of real-time muscle activity and has been used in multiple studies evaluating musculoskeletal disorders.<sup>9,14,16-19</sup> Physical therapy consultants verified the 4 muscles selected for testing. sEMG muscle cross-talk susceptibility was decreased by placement of each electrode sensor directly over the middle of each of the identified muscles. Each sensor was placed at least 2 cm apart from the other according to accepted protocol (Figure 1).<sup>20-22</sup> A sensor was placed on the biceps brachii muscle as the examiner palpated the middle of the anterior belly exposed with the forearm supinated. The orientation of the sensor was parallel to the muscle fibers. Once the sensor was placed and secured by tape, the participant made a fist, flexed the forearm at the elbow joint, and Maximum Voluntary Isometric Contraction (MVIC) was tested and recorded with the examiner applying forced resistance pulling on the forearm at the wrist with the participant resisting the pull.

**Figure 1. Surface Electromyography sensors attached to muscles while scaling**



A sensor was placed on the pronator teres muscle as the examiner briefly palpated the proximal anterior forearm with the forearm partially flexed at the elbow joint and slightly pronated. The sensor was placed parallel to this muscle. Once the sensor was secured by tape, the MVIC was tested and recorded with the examiner applying forced resistance to the participant's clenched fist, resisting the twisting pressure from pronated to supinated position.

A third sensor was placed on the flexor carpi ulnaris muscle as the examiner palpated the muscle and the participant flexed the wrist and adducted the hand at the wrist with fingers extended. From the anterior view, the sensor was placed medially mid-way between the wrist and the elbow, parallel to the muscle and secured by tape. The MVIC was tested and recorded with the examiner applying forced resistance to the participant's ulnar deviation of the hand at the wrist joint.

A fourth sensor was placed on the extensor carpi radialis longus muscle as the examiner, with the forearm pronated, asked the participant to make a fist and squeeze. The muscle contraction could be palpated with the fist squeeze. The sensor was placed parallel to the muscle on the lateral side of the forearm midway between the wrist and elbow. Once the sensor was secured by tape, the MVIC was tested and recorded with the examiner applying forced resistance to the participant's fingers in a fist.

Data from the sEMG readings were collected during MVIC for each of the muscles by one physical therapy examiner. MVIC values were considered 100% activity for that muscle. The sEMG activity measured during scaling was expressed as a percentage of MVIC activity. This standard method has been reevaluated and found to be reliable for use with surface electrodes.<sup>19-21</sup> It also controls for any baseline activity/noise, because this noise would be present in both the MVIC readings and the scaling activity readings, and is thus cancelled.<sup>13,18-21</sup>

On each of the sEMG electrodes are 3 medical-grade stainless steel 12 mm disks. Electrode contact surfaces come in contact with the skin. There is a fixed distance of 22 mm between the centers of the active surfaces and the reference or ground electrode in the middle of the row of electrodes.

The electrodes are linked by coaxial cable to an amplifier that is connected to a personal computer with a DataQ data acquisition board. Lead wires from the electrodes allowed the participant to move and work. The computer program, produced by DataQ Instruments (Akron, Ohio), collected and analyzed the sEMG data. A sampling rate of 1000 samples per second per channel was used. The University Physical Therapy Motion Lab's sEMG system used in this study is a 10-channel, cabled, biological signal-acquisition system that records the electrical activity of superficial muscles using MA-110 surface electrodes with preamplifiers from Motions Lab Systems, Inc (Baton Rouge, La). Four channels were used since the study measured only 4 muscles, with one muscle per channel measured by sEMG.

## **Procedures**

To ensure standardization of the participants, a 20-minute fulcrum training and practice session was conducted by the principal investigator. The training occurred immediately before the experiment. To simplify the process, only supragingival scaling was used. To further ensure standardization, one physical therapy examiner conducted all of the sEMG recordings; a second physical therapy examiner timed the 20 second measurement period during each one minute of scaling.

Typodonts were prepared and set up by the principal investigator. Five different typodonts were set up for each participant with a different fulcrum: opposite arch, standard intra-oral, basic extra-oral, cross arch, and finger-on-finger (IO, EO, OA, CA, and FF), and were randomly assigned for use on each of the typodonts. To ensure blinding, the principal investigator was blind to the order of the fulcrums. The research assistant randomized the fulcrums, signaled to the physical therapy student the beginning and ending of scaling, and completed participant paperwork. Each participant was provided with a new Premier Gracey 11/12 curet (Plymouth, PA), personal protective equipment, and instructed to hand scale the mesiobuccal surfaces of the permanent first molars in each of the 4 quadrants (UR, UL, LL, and LR) for up to one minute using one of the assigned fulcrums per typodont. The process continued until all 5 fulcrums were used resulting in 4 readings per typodont. Testing took approximately one hour per participant. The one minute rest between quadrants allowed sufficient time for recovery from any muscle fatigue that might occur. Also projected was the counterbalanced design of fulcrum assignment would eliminate any systematic error that fatigue might cause. Considering the pace at which dental hygienists normally practice, the rest period was sufficient.

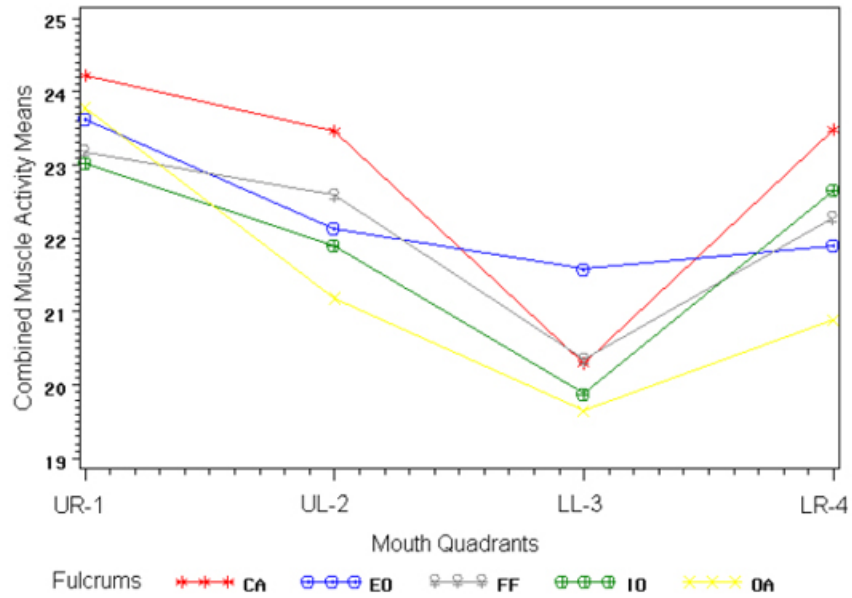
## **Statistical Treatment**

The University Physical Therapy Motion Lab's sEMG system utilizes a Windows-based operating system for collecting MVIC for each of the muscles. Measurements were averaged using root mean squares (RMS); sEMG activity was expressed as a percentage of MVIC activity. Two-way ANOVA with repeated measures was used to analyze the data collected. If significant interaction occurred between quadrants and fulcrums, the Tukey post hoc test was run to locate significant differences.

## Results

The overall muscle activity means and standard deviations for the 5 fulcrums in each of the 4 quadrants is found in Table 1. The combined muscle activity means versus the 4 quadrants for the 5 fulcrums is graphically presented in Figure 2. Data reveal the opposite arch fulcrum generated the least amount of muscle activity; however, no statistically significant interaction among quadrants, muscle activity, and type of fulcrums ( $p=0.4727$ ) was found (Table 2).

**Figure 2. Combined Muscle Activity Means vs. Quadrants for the Five Fulcrums.**



**Table 1. Muscle Activity Means and Standard Deviations Using Four Quadrants and Five Fulcrums per Quadrant.**

Analysis Variable : Combined Muscle Activity Quadrants vs. Fulcrums							
Quadrants	Fulcrums	N Obs	N	Mean Muscle Activity	Std Dev	Minimum	Maximum
UR - 1	CA	32	32	24.22	7.99	13.14	46.00
	EO	32	32	23.62	10.66	11.44	59.96
	FF	32	32	23.18	7.71	11.36	36.66
	IO	32	32	23.02	8.74	12.30	52.43
	OA	32	32	23.77	10.53	12.42	51.14
UL - 2	CA	32	32	23.47	9.16	11.70	53.07
	EO	32	32	22.14	9.73	11.62	53.67
	FF	32	32	22.59	9.41	12.05	53.06
	IO	32	32	21.91	9.65	10.18	53.64
	OA	32	32	21.18	8.74	10.06	41.60
LL - 3	CA	32	32	20.29	8.65	11.02	47.34
	EO	32	32	21.59	10.64	8.68	66.76
	FF	32	32	20.36	8.72	8.89	48.93
	IO	32	32	19.88	7.83	8.88	45.21
	OA	32	32	19.65	7.50	10.04	39.39
LR - 4	CA	32	31	23.49	9.43	11.73	54.69
	EO	32	32	21.90	9.32	10.56	46.61
	FF	32	32	22.28	8.69	9.82	47.16
	IO	32	32	22.66	9.15	10.40	45.75
	OA	32	32	20.89	7.98	9.89	44.96

**Table 2. Repeated Measures Two-Way ANOVA Test Results**

Test Effect	df	F value	p value
Quadrants	3	20.88	<.0001*
Fulcrums	4	2.95	0.0226*
Quadrants paired with fulcrums	12	0.97	0.4727

\*Significance

Participants' overall muscle activity mean scores correlated with each fulcrum are found in Table 3. When comparing overall muscle activity for each fulcrum, results revealed statistically significant differences (F=2.95, df=4, p=0.0226). However, out of 20 repeated ANOVA measures, Tukey's test revealed only one pairing resulted in significant results (Table 4). The cross arch fulcrum produced statistically significant more muscle activity only when compared to the opposite arch fulcrum (p=0.0110). The cross arch fulcrum produced the most muscle activity regardless of area scaled.

**Table 3. Muscle Activity Means and Standard Deviations Using Five Fulcrums.**

Analysis Variable : Combined Muscle Activity for Each Fulcrum						
Fulcrum	N Obs	N	Mean Muscle Activity	Std Dev	Minimum	Maximum
CA	128	127	22.87	8.85	11.02	54.69
EO	128	128	22.31	10.01	8.68	66.76
FF	128	128	22.10	8.62	8.89	53.06
IO	128	128	21.87	8.85	8.88	53.64
OA	128	128	21.37	8.79	9.89	51.14

**Table 4. Tukey's Significance Testing Comparing Muscle Activity Between Fulcrums ("+" if  $p > 0.05$ , "-" if  $p < 0.05$ ).**

CA Mean 22.87 N 32 SD 8.85	EO Sig 0.7233 +	FF Sig 0.4367 +	IO Sig 0.1802 +	OA Sig <b>0.0110*</b> -
EO Mean 22.31 N 32 SD 10.01	FF Sig 0.9911 +	IO Sig 0.8676 +	OA Sig 0.2478 +	
FF Mean 22.10 N 32 SD 8.62	IO Sig 0.9856 +	OA Sig 0.5021 +		
IO Mean 21.87 N 32 SD 8.85	OA Sig 0.8162 +			
OA Mean 21.37 N 32 SD 8.79				

\*Significance

Muscle activity means and standard deviations were calculated for each of the 4 quadrants (UR, UL, LL, and LR) (Table 5). Two-way ANOVA with 20 repeated measures comparing muscle activity generated in each of the 4 quadrants revealed statistically significant differences ( $F=20.88$ ,  $df=3$ ,  $p<.0001$ ). Tukey's test revealed that when hand scaling, regardless of fulcrum used, the maxillary right quadrant generated significantly more muscle activity when compared to the other 3 quadrants ( $p=0.0101$ ) (Table 6). Further, the mandibular left quadrant consistently produced the least muscle activity when paired with the other 3 quadrants ( $p<.0001$ ). Data suggest moderate to high muscle activity in all quadrants, ranging from 19.65% MVIC to 24.22% MVIC.<sup>23</sup> Hand scaling in the UL or UR quadrants regardless of fulcrum used exhibited the same amount of muscle activity.

**Table 5. Muscle Activity Means and Standard Deviations Using Four Quadrants of the Mouth.**

Analysis Variable : Combined Muscle Activity for Each Quadrant						
Quadrant	N Obs	N	Mean Muscle Activity	Std Dev	Minimum	Maximum
UR - 1	160	160	23.56	9.10	11.36	59.96
UL - 2	160	160	22.26	9.26	10.06	53.67
LL - 3	160	160	20.35	8.65	8.68	66.76
LR - 4	160	159	22.24	8.86	9.82	54.69

**Table 6. Tukey's Significance Testing Comparing Muscle Activity Between Quadrants**

Quadrant	Quadrant	Adjusted p value
UR - 1	UL - 2	<b>0.0101*</b>
UR - 1	LL - 3	<b>&lt;.0001*</b>
UR - 1	LR - 4	<b>0.0100*</b>
UL - 2	LL - 3	<b>&lt;.0001*</b>
UL - 2	LR - 4	1.0000
LL - 3	LR - 4	<b>&lt;.0001*</b>

\*Significance

## Discussion

No significant interaction was found among quadrants, muscle activity, and type of fulcrums used when hand scaling in a simulated environment. Results suggest the amount of muscle activity generated when scaling, regardless of quadrant scaled, is not affected by the use of different fulcrums. Use of a different finger fulcrum does not reduce the amount of muscle activity experienced by participants during calculus removal.

Dong et al reported that intraoral finger rests reduced muscle activity when scaling compared to no finger rests.<sup>9</sup> The extraoral fulcrum used in this present study can be compared to the no finger rest described by Dong et al. Their study had participants scale in only the maxillary left quadrant, the different results obtained from this study with the extraoral fulcrum may be expected since all quadrants of the mouth were studied. Extraoral fulcrum as reported by Dong et al produced more muscle activity in the maxillary left quadrant than standard intraoral fulcrums. Differences in sample size, characteristics of participants, number of fulcrums, muscles investigated, and quadrants tested may explain the conflicting outcomes between the 2 studies. In addition, this present study looked at the pronator teres and biceps brachii muscles, which were not evaluated by the Dong study.

Although statistically significant differences were found in muscle activity when comparing the 5 fulcrums to each other ( $p=0.0226$ ), only the cross arch fulcrum exhibited significantly higher mean muscle activity scores when compared to the opposite arch. These results might be attributed to difficulty keeping a neutral wrist position when using the cross arch fulcrum, especially in the upper right quadrant. Likewise the stretch of the hand across arches and the position of the wrist as it deviated from neutral might have contributed to the increased muscle activity when compared to the opposite arch. Advanced fulcrumming techniques are used selectively when another fulcrum is not effective or it is not possible to preserve fundamental scaling techniques. Cross arch fulcrums make it difficult to preserve a neutral wrist position while also achieving lower shank parallelism, access to deep pockets, appropriate muscle coordination, and calculus removal. Given the findings, selecting a fulcrum should be based on its benefits and disadvantages with a particular area of the mouth over the amount of muscle activity generated.

In general, results suggest that each of the 5 types of fulcrums produce similar amounts of muscle activity regardless of area scaled. Dental hygienists should continue to use alternative fulcrums to improve ergonomic instrumentation based



on individual needs and preferences. Patient characteristics and clinical needs should drive the selection process. Larger studies are needed, however, to determine the relationship between fulcrums and muscle activity while hand scaling.

The standard intraoral fulcrum was not significantly different in muscle activity when compared to the others. Since the opposite arch fulcrum had the least muscle activity, it might be an excellent alternative for the standard intraoral fulcrum when deep pockets with heavy calculus require variation in the technique.

Regardless of where calculus removal was started, more muscle activity was generated in the upper right quadrant. Results may be attributed to the angle of the wrist and forearm in the upper right being manipulated in a way that required more muscle movement and more force and effort to remove the deposits. These findings support Nield-Gehrig's belief that maxillary molar teeth are especially difficult to treat with the standard intraoral fulcrum and often require advanced fulcrums.<sup>12</sup>

Results suggest that dental hygienists may wish to start scaling in the upper right quadrant since scaling in that area, regardless of the fulcrum used, produced more muscle activity. By starting in the upper right instead of scaling this area last, fatigue may be less of an issue. Also, since the study revealed that scaling in the lower left quadrant produces the least amount of muscle activity, perhaps that quadrant could be scaled when most fatigued. As fatigue becomes an issue, clinician scaling may be less effective. Lastly, variable muscle activity might reflect improper wrist-forearm movement, incorrect finger placement, or artificial calculus being burnished during scaling.

Several limitations are worth noting when interpreting the results of this study. Because the study was conducted in a simulated environment with student dental hygienists, results can only be generalized to this population. Future research using patients with calculus and experienced dental hygienists in a real world environment is recommended. Human error could have influenced the results recorded on the University Physical Therapy Motion Lab's sEMG system computer; however, using the same 2 experienced physical therapy students minimized this risk. Also affecting muscle readings, may have been the rest some participants received when the typodonts dislodged from the manikin heads requiring a pause to reattach the devices for appropriate performance.

## **Conclusions**

Based on the result of this study, fulcrums have uniform impact on muscle activity during hand scaling in first semester, right-handed, senior-year dental hygiene students in a simulated clinical setting. Clinicians therefore appear to experience minimal ergonomic advantages in terms of muscle activity, fulcrums used, and area of the mouth scaled. Since performing a comprehensive service to the client includes examination and treatment of the entire dentition, more research should be conducted to determine how forearm muscles are affected by varying fulcrums while scaling, using different scaling instruments, or whether differing fulcrums affect grip and pinch force. Findings in this study do not support changes in clinical instrumentation protocols at this time, but do emphasize the need for more research in order to better understand fulcrums and arm muscle activity related to musculoskeletal disorders.

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