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Physiologic Responses to High-Velocity, Low-Amplitude Toggle-Recoil Chiropractic Thrusts

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Abstract

Background

Spinal manipulation and chiropractic adjustments elicit consistent neuromuscular reflex responses in paraspinal musculature that are theorized to underpin their therapeutic mechanisms. The McTimoney Toggle-Torque-Recoil Technique (MTTR) is a distinctive high-velocity, low-amplitude chiropractic adjustment characterized by a rapid whole-hand toggle, simultaneous torque, and immediate recoil. No previous study had characterized the physiologic response to MTTR thrusts or examined how thrust biomechanical parameters relate to the neuromuscular outcome. This study aimed to quantify paraspinal surface electromyographic (EMG) responses during MTTR adjustments, characterize thrust force profiles, and evaluate the effect of inter-clinician differences in thrust delivery on physiologic outcomes.

Methods

Seventeen asymptomatic participants (10 female, 7 male; mean age 41.2 years) underwent MTTR adjustments in a repeated-measures design. Surface EMG electrodes were placed bilaterally over the erector spinae at the levels of L5 (E1 left, E2 right) and L1 (E3 left, E4 right). A dynamic piezoelectric load cell over the L3 spinous process captured thrust force-time profiles. Two experienced McTimoney-certified chiropractors each delivered six MTTR thrusts per subject. Thrust force parameters (peak force, preload force, time to peak, total duration) were extracted and electromechanical delay (EMD) calculated defined as time from thrust onset to peak EMG. EMG amplitude was quantified relative to pre-thrust baseline across successive 250 ms epochs and normalized to maximal trunk extension. Independent-samples t-tests compared all measures between clinicians.

Results

Both clinicians elicited consistent paraspinal neuromuscular reflex responses. For Clinician 1, first-epoch EMG responses were significantly elevated above baseline at all four electrode sites (range 142.8–519.9% of baseline; all $p \leq 0.048$). Clinician 2 produced similar qualitative responses, though individual electrode site responses did not reach significance. Clinician 1 applied significantly lower peak thrust force (20.9 N vs. 33.9 N), lower preload force (0.75 N vs. 5.47 N), shorter time to peak force (74.5 ms vs. 247.3 ms), and shorter total thrust duration (148.3 ms vs. 336.3 ms) than Clinician 2 (all $p \leq 0.0001$). These thrust kinematic differences were associated with significantly shorter EMG electromechanical delay for Clinician 1 across all electrodes combined (44.8 ms vs. 95.4 ms; $p < 0.0001$) and higher normalized thrust-epoch EMG amplitude across all electrodes combined (2.58× vs. 1.50× trunk extension; $p < 0.0001$). Pooled across both clinicians, thrust-evoked EMG significantly exceeded both pre-thrust baseline and maximal trunk extension reference at all electrode sites.

Conclusions

This is the first study characterizing both the neuromuscular reflex responses and thrust biomechanical parameters of MTTR chiropractic adjustments. Significant inter-clinician differences in thrust force delivery were associated with corresponding differences in EMG timing and amplitude, indicating that thrust kinematics are important determinants of neuromechanical outcome. These findings provide direct biomechanical evidence relevant to chiropractic education and training, suggesting that optimizing thrust speed, force application, and preload may enhance the neuromechanical efficacy of MTTR adjustments.

Background

Chiropractic adjustments and spinal manipulation encompass a range of high-velocity, low-amplitude (HVLA) thrust techniques and are among the most widely utilized interventions for musculoskeletal disorders of the spine [1, 2]. Despite growing evidence for clinical efficacy, particularly for acute and chronic low back pain, the underlying neurophysiologic mechanisms through which manipulative therapy exerts its therapeutic effects remain incompletely understood [3, 4].

A well-established line of research has focused on the neuromuscular responses that occur in the paraspinal musculature immediately following a manipulative thrust. Studies using surface electromyography (EMG) have consistently demonstrated that HVLA manipulations produce rapid, short-latency reflex activations in lumbar paraspinal muscles, with peak activity typically observed within 50–150 ms post-thrust [5–7]. These responses are believed to reflect afferent input from mechanoreceptors and proprioceptors in the facet joint capsules, ligaments, and muscle spindles, which are transiently loaded during the thrust [8, 9]. The clinical significance of this neuromuscular recruitment lies in its potential to normalize aberrant afferent signaling, modulate segmental motor tone, and contribute to the analgesic and functional outcomes associated with chiropractic care [10, 11].

The biomechanical parameters of a thrust including its speed, peak force, and preload have been shown to influence the neuromechanical response. Colloca et al. [12] demonstrated that spinal manipulation force magnitude and duration significantly affect vertebral movement and reflex responses, with faster, lower-amplitude thrusts producing shorter electromechanical delays and more distinct reflex bursts. This has practical implications for chiropractic education and training, where optimizing thrust delivery characteristics is a core learning objective.

The McTimoney Toggle-Torque-Recoil Technique (MTTR) is a specific chiropractic adjustment approach taught at the McTimoney College of Chiropractic (Abingdon, UK) and practiced by hundreds of McTimoney-trained chiropractors worldwide. The MTTR is characterized by a rapid, whole-hand contact over the target spinous or transverse process, with a simultaneous toggle (low-amplitude thrust), torque (rotational force), and immediate recoil of the clinician's hands following contact. This distinctive biomechanical profile and notably its rapid recoil phase differentiates MTTR from other HVLA methods, but raises important questions about the nature, magnitude, and kinematic determinants of the neuromuscular responses it elicits.

Despite the widespread clinical use of McTimoney techniques and a growing body of force characterization data [12], no published study had quantified the surface EMG response of lumbar paraspinal muscles during MTTR adjustments, nor examined how inter-clinician variation in thrust biomechanics influences neuromechanical outcomes. Understanding whether MTTR produces neuromuscular reflex responses of similar character to those observed with other chiropractic techniques, and identifying the thrust parameters that optimize these responses, would provide important mechanistic context and training guidance.

The purpose of this study was therefore to: (1) quantify the paraspinal surface EMG response during MTTR adjustments delivered by two experienced clinicians; (2) characterize the thrust force profiles of each clinician including peak force, preload force, time to peak, and total thrust duration; (3) examine the electromechanical delay (EMD) and normalized EMG amplitude as a function of thrust delivery; and (4) determine the extent to which inter-clinician differences in thrust biomechanics are associated with differences in neuromechanical outcomes.

Methods

Participants

Seventeen asymptomatic volunteers (10 female, 7 male; mean age 41.2 years, range 22–62 years) participated in this study. Participants were recruited from the general population and screened to exclude individuals with a history of spinal surgery, current spinal pain, neurologic deficits, osteoporosis, or any contraindications to chiropractic manipulation. All participants provided written informed consent prior to participation. The study was conducted in accordance with the Declaration of Helsinki and received ethical approval from the institutional review board committee of McTimoney College of Chiropractic in Abingdon, Oxfordshire, England.

Experimental Setup

Participants lay prone on a standard chiropractic adjusting table throughout the protocol. Following standard skin preparation (light abrasion and cleansing with isopropyl alcohol), pre-gelled, self-adhesive 1-cm silver/silver chloride bipolar surface EMG electrodes were attached bilaterally in pairs placed 2.5 cm apart. Electrode placement sites were: (1) over the erector spinae at

its aponeurotic origin overlying the multifidus muscle at the level of L5 (electrodes E1 [left] and E2 [right]); and (2) over the iliocostalis lumborum at the level of L1 (electrodes E3 [left] and E4 [right]). Electrode positions were carefully selected to permit delivery of MTTR thrusts to both spinous and transverse processes without contact with the electrode leads or adhesive patches (Fig. 1).

A dynamic piezoelectric load cell (Kistler Instruments AG, Winterthur, Switzerland) was secured over the spinous process of L3 using medical-grade adhesive tape to capture the time-force profile of each MTTR thrust. All EMG and load cell signals were digitized using a Biopac MP150 16-bit data acquisition system (Biopac Systems Inc., Goleta, CA, USA) and processed using AcqKnowledge software (version 4.2) at a sampling rate of 2000 Hz.

Procedure and Intervention

To normalize the surface, linear-enveloped electromyographic (sEMG) data, active contraction of the trunk muscles was performed. After a brief familiarization session, participants performed three consecutive prone isometric trunk extensions, lifting their chest and shoulders off the table maximally for 3 seconds while sEMG data were collected over a 30-second time interval. A 5-second rest was given between exertions. No trunk force measurement devices or trunk confinement apparatus were employed.

Two licensed chiropractors (Clinician 1 and Clinician 2), each with more than ten years of post-graduation clinical experience and trained and certified in the McTimoney Method, administered the MTTR adjustments. Each clinician delivered six MTTR thrusts over the mounted load cell at the L3 spinous process (Fig. 2) to each participant in a randomized order, with a minimum 90-second rest period between thrusts to allow return to baseline EMG levels. Neuromuscular EMG reflex activity of the erector spinae muscles and thrust force were recorded simultaneously during each thrust. Clinicians were blinded to the EMG output during the trials. The MTTR was performed according to standard McTimoney teaching: a rapid whole-hand contact applied to the target vertebral segment with simultaneous toggle, torque, and immediate recoil targeting the L3 spinous process.

Data Processing and Analysis

Raw EMG signals were processed using a low-pass Butterworth filter (cutoff frequency 500 Hz), then full-wave rectified and integrated to yield the linear envelope. The onset of peak MTTR thrust force as detected by the load cell defined time zero for each trial. EMG amplitude was quantified in three successive 250-ms time intervals: (1) a pre-thrust baseline epoch (250 ms immediately preceding force onset); (2) a first post-thrust epoch (0–250 ms following force onset); and (3) a second post-thrust epoch (250–500 ms following force onset). For each interval, peak-to-peak EMG amplitude was calculated for each electrode site. Post-thrust EMG activity was expressed as a percentage of the corresponding pre-thrust baseline value. EMG data from trunk extension trials were similarly processed and peak-to-peak values used as a normalization reference (EMG reference ratio), expressed as the ratio of thrust-evoked to trunk-extension EMG amplitude.

The electromechanical delay (EMD) was defined as the interval from thrust force onset to peak EMG activation. Four force-time parameters were extracted from each thrust using the load cell signal: peak thrust force (N), preload (contact) force (N, measured in the 50 ms immediately preceding peak force), time from initial contact to peak force (ms), and total thrust contact duration (ms).

Mean values were calculated across the six trials for each participant at each electrode site. Descriptive statistics (mean and standard deviation) were computed for all variables. To enable an overall summary of EMG responses across the measurement array, mean values were also computed across all four electrode sites combined (E1–E4). One-sample t-tests assessed whether mean first-epoch EMG activity differed significantly from 100% of pre-thrust baseline or from unity (ratio = 1.0) for the trunk-extension-normalized measures. Independent-samples two-tailed t-tests compared all outcome measures between clinicians. Statistical significance was set at $\alpha = 0.05$. All analyses were performed using Microsoft Excel (Microsoft Corporation, Redmond, WA, USA).

Results

Thrust Force Profiles

Both clinicians successfully delivered MTTR thrusts over the mounted load cell throughout the study. The load cell data confirmed that each thrust had a characteristic rapid rise to peak force followed by an immediate recoil, consistent with the McTimoney Toggle-Torque-Recoil technique (Fig. 3). However, the two clinicians differed substantially and significantly in all four thrust force parameters (Tables 1 and 2). Clinician 1 applied a lower mean peak force (20.9 N, SD = 12.2) compared to Clinician 2 (33.9 N, SD = 18.8; $t = -4.14$, $p = 0.0001$). Clinician 1's preload force was markedly lower (0.75 N, SD = 0.58 vs. 5.47 N, SD = 5.77; $t = -5.82$, $p < 0.0001$), indicating a more decisive initial contact. Clinician 1 reached peak force substantially faster (74.5 ms, SD = 3.9 vs. 247.3 ms, SD = 249.3; $t = -4.95$, $p < 0.0001$) and had a shorter total thrust duration (148.3 ms, SD = 10.0 vs. 336.3 ms, SD = 252.7; $t = -5.31$, $p < 0.0001$). Notably, the remarkably low within-clinician variability for Clinician 1 on timing measures (SD = 3.9 ms for time to peak force) compared to Clinician 2 (SD = 249.3 ms) indicates a highly stereotyped, mechanically consistent thrust pattern for Clinician 1 and greater thrust-to-thrust variability for Clinician 2.

Neuromuscular Reflex Responses

Consistent paraspinal neuromuscular reflex responses were observed at all four electrode sites for both clinicians (Table 1). The general pattern comprised a marked increase in EMG amplitude during the first 250 ms post-thrust epoch followed by a partial return toward baseline in the second 250 ms epoch. For Clinician 1, first-epoch EMG responses were significantly elevated above pre-thrust baseline at all electrode sites: 385.9% (SD = 349.5%) at E1 (L5 left, $t = 2.88$, $p = 0.011$), 519.9% (SD = 317.1%) at E2 (L5 right, $t = 5.02$, $p < 0.001$), 142.8% (SD = 45.2%) at E3 (L1 left, $t = 3.67$, $p = 0.002$), and 203.3% (SD = 184.6%) at E4 (L1 right, $t = 2.14$, $p = 0.048$). Combining all four electrode sites, the mean first-epoch response for Clinician 1 was 313.2% (SD = 248.6%) of baseline. During the second 250 ms epoch, EMG levels remained moderately elevated (range 120.7–143.8% of baseline), indicating a gradual return toward pre-thrust levels.

For Clinician 2, mean first-epoch responses were 304.0% (SD = 411.2%) at E1, 169.4% (SD = 100.5%) at E2, 135.5% (SD = 43.2%) at E3, and 157.5% (SD = 70.3%) at E4 (overall mean across all electrodes: 191.6%, SD = 178.0%). Although individual electrode-site responses did not reach statistical significance for Clinician 2, post-thrust EMG activity was consistently elevated above pre-thrust baseline across all sites. The second-epoch values for Clinician 2 were notably higher than those for Clinician 1 (range 162.5–238.9% of baseline), suggesting a more prolonged or delayed response profile, consistent with the longer EMD observed for this clinician.

When data from both clinicians were pooled ($n = 34$ per electrode site), first-epoch EMG elevations at E1 (mean = 345.0%, SD = 378.1%; $t = 2.65$, $p = 0.012$) and E2 (mean = 344.6%, SD = 292.1%; $t = 3.26$, $p = 0.003$) reached significance, while E3 (mean = 139.2%, SD = 43.7%; $t = -0.23$, $p = 0.816$) and E4 (mean = 180.4%, SD = 139.5%; $t = 1.51$, $p = 0.14$) did not individually.

Electromechanical Delay

The EMD differed significantly between clinicians at three of four electrode sites (Table 3). For Clinician 1, mean EMD was 22.4 ms (SD = 21.4) at E1, 15.6 ms (SD = 18.6) at E2, 71.0 ms (SD = 104.9) at E3, and 70.2 ms (SD = 107.0) at E4. For Clinician 2, the corresponding values were 65.1 ms (SD = 125.4), 91.7 ms (SD = 95.4), 130.6 ms (SD = 168.8), and 94.3 ms (SD = 117.0). Pooled across all four electrodes, Clinician 1 had a substantially shorter overall mean EMD (44.8 ms, SD = 80.0) than Clinician 2 (95.4 ms, SD = 130.6; $t = -4.72$, $p < 0.0001$). All EMD values for both clinicians fall within the 0–200 ms window generally accepted as consistent with neuromuscular reflex responses. Only E4 (L1 right) did not show a significant between-clinician difference in EMD ($p = 0.280$).

EMG Amplitude Normalized to Trunk Extension

When expressed as a percentage of pre-thrust baseline (Fig. 4), the first 250 ms post-thrust epoch was significantly elevated above pre-thrust levels at every electrode site and in the pooled all-electrode mean (E1: 385.9%, SD = 349.5, $p = 0.004$; E2: 519.9%, SD = 317.1, $p < 0.001$; E3: 142.8%, SD = 45.2, $p = 0.001$; E4: 203.3%, SD = 184.6, $p = 0.035$; All E1-E4: 313.0%, SD = 290.5, $p < 0.001$), confirming a consistent short-latency neuromuscular reflex response across the lumbar paraspinal musculature. The second 250 ms epoch remained significantly elevated above baseline at all sites (range 120.7-143.8%; All E1-E4: 130.8%, SD = 43.8, $p < 0.001$), indicating sustained but attenuating activation that did not return to pre-thrust levels within the 500 ms observation window.

When normalized to maximal trunk extension (Fig. 5), E1 and E2 first-epoch responses equaled or exceeded 100% of the extension reference (E1: 100.4%, SD = 134.9; E2: 100.1%, SD = 76.3), while L1-level responses were significantly below that reference (E3: 28.8%, $p < 0.001$; E4: 41.7%, $p < 0.001$), reflecting the spatial gradient of reflex recruitment from the L3 application site. During the second 250 ms epoch, all sites fell significantly below the extension reference (range 23.7–38.2%; All E1-E4: 28.6%, SD = 31.3, $p < 0.001$), consistent with phasic burst dissipation. Figure 6 presents the second-epoch post-thrust activation alongside the pre-thrust resting baseline, both as a percentage of maximal extension, and demonstrates that neither residual post-thrust activation nor pre-thrust resting tone approached volitional capacity at any electrode site (all $p < 0.001$), with All E1-E4 post-event mean of 28.6% (SD = 31.3) and baseline mean of 22.4% (SD = 23.6). Across all three normalization frameworks, the L5 electrode sites consistently showed larger absolute responses than the L1 sites, reflecting anatomical proximity to the L3 thrust application site.

When EMG amplitude during the thrust epoch was expressed as a ratio relative to maximal trunk extension (Tables 1 and 4), both clinicians exceeded the trunk-extension reference at all electrode sites (all one-sample t-tests vs. ratio of 1.0, $p \leq 0.001$). For Clinician 1, mean normalized thrust-epoch ratios were 2.95 at E1, 4.21 at E2, 1.25 at E3, and 1.89 at E4 (all-electrode mean: 2.58, SD = 3.10). For Clinician 2, the values were 2.20, 1.31, 1.20, and 1.30, respectively (all-electrode mean: 1.50, SD = 1.47). Clinician 1 produced significantly higher all-electrode normalized thrust-epoch amplitude than Clinician 2 ($t = 4.46$, $p < 0.0001$), driven primarily by a large difference at E2 L5 right (4.21 vs. 1.31; $t = 4.97$, $p < 0.0001$).

Post-thrust normalized EMG (second 250 ms epoch) remained substantially elevated above trunk-extension levels for both clinicians at all electrode sites (all one-sample t-tests vs. 1.0, $p < 0.0001$). Clinician 1's all-electrode mean post-thrust ratio was 25.7 (SD = 25.0) versus 16.7 (SD = 13.3) for Clinician 2 ($t = 4.52$, $p < 0.0001$), again with E2 L5 right showing the greatest absolute difference (46.2 vs. 20.0; $t = 4.83$, $p < 0.0001$).

Between-Clinician Comparisons

Statistically significant between-clinician differences were found for all four thrust force parameters (all $p \leq 0.0001$), three of four individual EMD sites (E1, E2, E3; $p \leq 0.035$), the all-electrode pooled EMD ($p < 0.0001$), and the all-electrode pooled thrust-epoch and post-thrust normalized EMG amplitudes (both $p < 0.0001$; Tables 2–4). The pattern of results consistently indicated that Clinician 1's faster, lower-force thrust with minimal preload was associated with shorter neuromuscular reflex latencies and higher normalized EMG amplitude, particularly at the L5 electrode sites.

Table 1

Summary of EMG responses across electrode sites for both clinicians (n = 17 each). First and second 250 ms epoch responses are expressed as percentage of pre-thrust baseline; one-sample t-tests assess departure from 100% baseline. Thrust EMG / trunk extension and Post-thrust EMG / trunk extension are ratios relative to maximal isometric trunk extension EMG; one-sample t-tests assess departure from 1.0. For EMG Electromechanical Delay rows, between-clinician t-statistics are shown. All-electrode columns (shaded green) represent pooled means across E1-E4. *p < 0.05. E1 = L5 left; E2 = L5 right; E3 = L1 left; E4 = L1 right.

Measure	**Clinician 1 (n = 17)**					**Clinician 2 (n = 17)**				
	E1 (L5L)	**E2 (L5R)**	**E3 (L1L)**	**E4 (L1R)**	**All E1-E4**	**E1 (L5L)**	**E2 (L5R)**	**E3 (L1L)**	**E4 (L1R)**	**All E1-E4**
First 250 ms/baseline % - Mean (SD)	385.9 (349.5)	519.9 (317.1)	142.8 (45.2)	203.3 (184.6)	313.0 (290.5)	304.0 (411.2)	169.4 (100.5)	135.5 (43.2)	157.5 (70.3)	191.6 (221.0)
t-statistic	*2.88*	*5.02*	*3.67*	*2.14*	*6.05**	*0.85*	*-1.31*	*-1.44*	*-1.03*	*3.42**
p-value	*0.011**	*< 0.001**	*0.002**	*0.048**	*< 0.001**	*0.41*	*0.21*	*0.17*	*0.32*	*0.001**
Second 250 ms/baseline % - Mean (SD)	138.0 (51.0)	143.8 (57.9)	120.7 (25.0)	120.8 (31.6)	130.8 (43.8)	238.9 (142.9)	202.0 (158.5)	162.5 (76.5)	173.0 (73.6)	194.1 (120.2)
t-statistic	*3.08*	*3.12*	*3.42*	*2.71*	*5.81**	*4.01*	*2.65*	*3.37*	*4.09*	*6.45**
p-value	*0.007**	*0.007**	*0.004**	*0.016**	*< 0.001**	*0.001**	*0.017**	*0.004**	*0.001**	*< 0.001**
EMG Electromechanical Delay (ms) - Mean (SD)	22.4 (21.4)	15.6 (18.6)	71.0 (104.9)	70.2 (107.0)	44.8 (80.0)	65.1 (125.4)	91.7 (95.4)	130.6 (168.8)	94.3 (117.0)	95.4 (130.6)
t-statistic (between clinicians)	*-2.40*	*-5.59*	*-2.14*	*-1.09*	*-4.72**	*-2.40*	*-5.59*	*-2.14*	*-1.09*	*-4.72**
p-value (between clinicians)	*0.018**	*< 0.001**	*0.035**	*0.280*	*< 0.001**	*0.018**	*< 0.001**	*0.035**	*0.280*	*< 0.001**
Thrust EMG / trunk extension reference - Mean (SD)	2.95 (3.42)	4.21 (4.15)	1.25 (0.29)	1.89 (2.21)	2.58 (3.10)	2.20 (2.72)	1.31 (0.45)	1.20 (0.33)	1.30 (0.61)	1.50 (1.47)
t-statistic (vs. 1.0)	*4.06*	*5.53*	*6.16*	*2.88*	*7.25**	*3.14*	*4.88*	*4.32*	*3.55*	*4.89**
p-value (vs. 1.0)	*0.001**	*< 0.001**	*< 0.001**	*0.006**	*< 0.001**	*0.003**	*< 0.001**	*< 0.001**	*0.001**	*< 0.001**
Post-thrust EMG / trunk extension reference - Mean (SD)	23.2 (17.2)	46.2 (34.2)	13.2 (10.3)	20.2 (18.6)	25.7 (25.0)	18.2 (10.0)	20.0 (18.2)	12.5 (9.2)	16.4 (13.0)	16.7 (13.3)
t-statistic (vs. 1.0)	*9.21*	*9.44*	*8.50*	*7.37*	*14.11**	*12.29*	*7.42*	*8.89*	*8.46*	*16.92**
p-value (vs. 1.0)	*< 0.001**	*< 0.001**	*< 0.001**	*< 0.001**	*< 0.001**	*< 0.001**	*< 0.001**	*< 0.001**	*< 0.001**	*< 0.001**

Table 2
Between-clinician comparisons (independent-samples t-tests) for thrust force parameters derived from the piezoelectric load cell. Values are mean (SD). Combined column presents pooled mean across both clinicians. *p < 0.05.

Measure	Clinician 1 Mean (SD)	Clinician 2 Mean (SD)	Combined Mean (SD)	t	p	Sig.
Peak thrust force (N)	20.9 (12.2)	33.9 (18.8)	27.4 (17.1)	-4.14	0.0001	*
Preload / contact force (N)	0.75 (0.58)	5.47 (5.77)	3.11 (4.72)	-5.82	< 0.0001	*
Time to peak force (ms)	74.5 (3.9)	247.3 (249.3)	160.9 (195.7)	-4.95	< 0.0001	*
Total thrust duration (ms)	148.3 (10.0)	336.3 (252.7)	242.3 (201.4)	-5.31	< 0.0001	*

Table 3
Between-clinician comparisons (independent-samples t-tests) for EMG electromechanical delay (EMD) at each electrode site and pooled across all electrodes (shaded). Values are mean (SD) in milliseconds. *p < 0.05.

Measure	Clinician 1 Mean (SD)	Clinician 2 Mean (SD)	Combined Mean (SD)	t	p	Sig.
E1 - L5 Left (ms)	22.4 (21.4)	65.1 (125.4)	43.7 (92.1)	-2.40	0.018	*
E2 - L5 Right (ms)	15.6 (18.6)	91.7 (95.4)	53.7 (78.3)	-5.59	< 0.0001	*
E3 - L1 Left (ms)	71.0 (104.9)	130.6 (168.8)	100.8 (143.0)	-2.14	0.035	*
E4 - L1 Right (ms)	70.2 (107.0)	94.3 (117.0)	82.3 (112.2)	-1.09	0.280	ns
All electrodes E1-E4 (ms)	44.8 (80.0)	95.4 (130.6)	70.1 (111.1)	-4.72	< 0.0001	*

Table 4
Between-clinician comparisons (independent-samples t-tests) for EMG amplitude normalized to maximal trunk extension reference, for both the thrust epoch (first 250 ms) and post-thrust epoch (250–500 ms). Values are mean (SD) ratio multiples of trunk extension EMG. All-electrode rows (shaded) represent pooled means across E1-E4. *p < 0.05.

Measure	Clinician 1 Mean (SD)	Clinician 2 Mean (SD)	Combined Mean (SD)	t	p	Sig.
Thrust epoch EMG / trunk extension reference (ratio)						
E1 - L5 Left	2.95 (3.42)	2.20 (2.72)	2.57 (3.10)	1.23	0.223	ns
E2 - L5 Right	4.21 (4.15)	1.31 (0.45)	2.76 (3.28)	4.97	< 0.0001	*
E3 - L1 Left	1.25 (0.29)	1.20 (0.33)	1.22 (0.31)	0.74	0.461	ns
E4 - L1 Right	1.89 (2.21)	1.30 (0.61)	1.60 (1.64)	1.83	0.071	ns
All electrodes E1-E4	2.58 (3.10)	1.50 (1.47)	2.04 (2.48)	4.46	< 0.0001	*
Post-thrust epoch EMG / trunk extension reference (ratio)						
E1 - L5 Left	23.2 (17.2)	18.2 (10.0)	20.7 (14.2)	1.81	0.074	ns
E2 - L5 Right	46.2 (34.2)	20.0 (18.2)	33.1 (30.3)	4.83	< 0.0001	*
E3 - L1 Left	13.2 (10.3)	12.5 (9.2)	12.8 (9.7)	0.39	0.697	ns
E4 - L1 Right	20.2 (18.6)	16.4 (13.0)	18.3 (16.1)	1.21	0.228	ns
All electrodes E1-E4	25.7 (25.0)	16.7 (13.3)	21.2 (20.5)	4.52	< 0.0001	*

Discussion

This study provides the first comprehensive characterization of both neuromuscular reflex responses and thrust biomechanical parameters associated with McTimoney Toggle-Torque-Recoil chiropractic adjustments. The key findings have identified: (1) MTTR thrusts from both clinicians consistently elicited short-latency paraspinal EMG responses with amplitudes well exceeding pre-thrust baseline and maximal trunk extension reference values; (2) the two clinicians differed significantly and substantially in all thrust force parameters including peak force, preload, time to peak, and total duration of their thrusts; (3) these thrust kinematic differences were directly associated with significant between-clinician differences in EMG electromechanical delay and normalized amplitude across most electrode sites; and (4) Clinician 1's faster, lower-force thrust with minimal preload consistently produced shorter reflex latencies and higher normalized EMG amplitude, particularly at the L5 electrode sites. Together these findings have important implications for understanding the neuromechanical mechanisms of MTTR and for chiropractic education and clinical training.

Neuromuscular Reflex Responses Consistent with HVLA Manipulation

The EMG activation patterns observed in this study are quantitatively comparable to those documented for other HVLA chiropractic techniques. Colloca and Keller [5] reported mean paraspinal EMG reflex latencies of approximately 50–110 ms and peak amplitudes of 200–400% of baseline following mechanically-assisted manipulation. Symons et al. [6] found consistent reflex responses of 150–300% of baseline following instrument-assisted thrusts, and Herzog et al. [7] documented responses of 100–700% of baseline following manual lumbar HVLA, with high inter-individual variability. The present study's first-epoch peak amplitudes ranging from 135% to 520% of baseline across electrode sites and clinicians, with all-electrode combined means of 313% (Clinician 1) and 192% (Clinician 2) fall squarely within this established range, confirming that MTTR produces neuromuscular reflex responses comparable in character and magnitude to other clinically employed spinal manipulation techniques.

Furthermore, when EMG responses were normalized to maximal trunk extension in the current study, both clinicians' thrusts evoked EMG amplitude that exceeded maximal voluntary contraction reference values (all-electrode means: 2.58× for Clinician 1 and 1.50× for Clinician 2 during the thrust epoch; 25.7× and 16.7× in the post-thrust epoch). This indicates that MTTR thrusts activate paraspinal musculature to a degree that substantially exceeds volitional capacity, consistent with mechanoreceptor-mediated reflex recruitment pathways rather than voluntary motor activation [8, 9].

Thrust Biomechanics as a Determinant of Neuromechanical Response

A central and novel finding of this study is the demonstration that inter-clinician differences in thrust delivery parameters are significantly associated with differences in the neuromechanical outcome. Clinician 1 applied a faster thrust with lower peak force, negligible preload, a stereotyped time-to-peak of 74.5 ms (SD = 3.9 ms), and a total duration of 148.3 ms (SD = 10.0 ms) characteristics that correspond closely to the mechanically efficient, low-amplitude, rapid thrust described as the MTTR ideal. Clinician 2's thrusts were slower (time to peak 247.3 ms, SD = 249.3 ms) with substantially higher preload (5.47 N), higher peak force (33.9 N), and longer duration (336.3 ms) are suggestive of a less decisive MTTR technique application with greater precontact loading.

These differences in thrust kinematics were directly reflected in the neuromechanical response. Clinician 1's shorter, faster thrust produced a markedly shorter all-electrode mean EMD (44.8 ms vs. 95.4 ms; $p < 0.0001$), consistent with a more discrete, temporally focused afferent volley to the spinal cord. This finding aligns with the work of Colloca et al. [12], who demonstrated that faster HVLA thrusts produce shorter EMDs and more distinct reflex bursts, presumably because a more rapid force rate of change more effectively activates mechanoreceptors particularly Ia afferents from muscle spindles and Ruffini endings in the facet joint capsule that are sensitive to rate of deformation rather than absolute force magnitude [8].

The higher preload force applied by Clinician 2 is also mechanistically relevant. Preload represents the force applied during initial contact before the peak thrust, and higher preload may partially pre-tension mechanoreceptors, altering their sensitivity at the moment of the thrust impulse [9]. This could contribute to the less distinct, more prolonged EMG response profile observed for Clinician 2 characterized by higher second-epoch values and longer EMDs compared to the sharper, shorter-latency responses of Clinician 1. The greater within-session variability in Clinician 2's timing measures (SD = 249.3 ms vs. SD = 3.9 ms for time to

peak) also suggests less consistent technique execution, which may contribute to variability in neuromechanical outcomes across trials.

Implications for Chiropractic Education and Training

The finding that significant differences in thrust biomechanics between two experienced, certified McTimoney chiropractors were associated with measurable differences in neuromechanical outcomes has direct relevance for chiropractic education and training. Although both clinicians successfully elicited paraspinal neuromuscular reflex responses, the pattern of results suggests that specific thrust characteristics including speed, preload minimization, and temporal consistency may be important determinants of the quality and character of the physiologic response.

The importance of thrust speed and rate of force application in spinal manipulation has been recognized in the broader literature in a number of studies by Pickar and colleagues and others [8]. Triano [14] emphasized that the biomechanical parameters of HVLA thrusts are teachable and modifiable, and that practitioner-specific variation in force delivery is a significant source of variability in clinical and experimental outcomes. More recently, studies using instrumented mannequins and patient simulators have demonstrated that novice practitioners apply slower, more variable thrusts than experienced clinicians, and that structured feedback training can improve thrust consistency [14]. The present findings support extending this framework specifically to the MTTR, suggesting that training programs should emphasize minimizing preload, maximizing thrust speed, and achieving a consistent time-to-peak force as measurable biomechanical competency targets.

The highly stereotyped thrust kinematics of Clinician 1 (SD = 3.9 ms for time to peak force vs. SD = 249.3 ms for Clinician 2) represent an exemplar of the technical consistency that underpins reliable neuromechanical outcomes. Incorporating objective force measurement feedback into MTTR training as has been proposed for other manual therapy techniques [14] could provide students and practitioners with actionable metrics to refine their technique and improve neuromechanical reproducibility.

Mechanistic Interpretation

The normalized EMG data presented in Figs. 5–7 provide additional mechanistic context for the reflex responses observed. The finding that L5 electrode responses during the first 250 ms epoch equaled or exceeded 100% of maximal trunk extension capacity is particularly striking, indicating that the mechanoreceptor-driven reflex volley is capable of recruiting paraspinal musculature to a degree that matches or surpasses maximal voluntary effort. This supramaximal activation pattern is consistent with direct alpha motor neuron recruitment via high-threshold, rapidly adapting mechanoreceptors in the facet joint capsule and paraspinal ligaments [8, 9], and suggests that the MTTR generates a mechanically sufficient stimulus to saturate the available motor neuron pool at segments adjacent to the thrust site. The more modest, but still significant, L1-level responses (28–42% of extension reference) reflect the decrement in segmental reflex recruitment with increasing distance from the stimulus, consistent with the dermatome-segmental organization of spinal reflex pathways. The rapid decay of this activation to the 23–38% range in the second 250 ms epoch, combined with baseline resting tone of approximately 19–29% of extension capacity, indicates that the neuromuscular effect of an MTTR thrust is temporally discrete: a brief, high-amplitude reflex burst followed by return toward pre-thrust resting levels within half a second. This temporal profile supports the proposed neurophysiologic basis of MTTR as an intervention that transiently resets paraspinal afferent activity rather than producing sustained motor facilitation.

The mechanistic basis for the observed short-latency paraspinal EMG responses involves afferent input from mechanoreceptors in the facet joint capsule, paraspinal ligaments, and muscle spindles, which are transiently deformed during the thrust [8]. The sudden high-rate loading of the vertebral segment is thought to produce a volley of afferent signals that reflexively activate alpha motor neurons via spinal interneuronal pathways, producing the short-latency EMG burst [9]. The MTTR's distinctive recoil phase may generate a secondary mechanical input distinct from the initial thrust, potentially contributing to the prolonged second-epoch elevations observed. Whether the recoil represents a clinically meaningful second afferent input or merely a passive structural response merits investigation with high-speed kinematic measurement technologies.

Clinician 2’s proportionally higher second-epoch values relative to first is consistent with a slower rise and return of afferent input associated with a longer-duration thrust. This contrasts with Clinician 1's pattern of a sharp first-epoch peak followed by rapid return toward baseline, consistent with a brief, high-rate mechanical input. These patterns parallel the distinction between

phasic and tonic reflex responses in neurophysiology, where high-rate stimuli preferentially activate phasic reflexes while slower-rate stimuli may more equally engage tonic mechanisms [8].

Limitations

Several limitations should be considered in the current work. First, the sample comprised asymptomatic individuals; neuromuscular responses in patients with chronic low back pain may differ due to altered baseline motor control and reflex excitability [15]. Second, all thrusts were delivered to L3 to standardize load cell placement; responses at other spinal levels or on transverse process contacts remain uncharacterized. Third, the within-session repeated-measures design with a 90-second inter-trial rest period does not preclude habituation effects, though use of trial-mean values mitigates this. Additionally, the study included only two clinicians, limiting generalizability across the broader spectrum of McTimoney practitioner variability. Future studies with larger samples of practitioners are needed to confirm the relationship between thrust kinematics and neuromechanical outcomes. Finally, the high variability in several measures such as first-epoch EMG for Clinician 2 at E1 (SD = 411.2%) warrants cautious interpretation at individual electrode sites.

Future Directions

Future research should examine MTTR-evoked responses in symptomatic patients; characterize responses at multiple spinal levels and contact sites; investigate the relationship between thrust kinematics and clinical outcomes; and explore whether biofeedback-guided MTTR training improves thrust consistency and neuromechanical reproducibility. Longitudinal studies examining whether repeated MTTR adjustments alter resting paraspinal muscle tone or reflex sensitivity and the clinical associations of these findings would also the advance clinical utility of McTimoney chiropractic care.

Conclusions

This study demonstrates for the first time that McTimoney Toggle-Torque-Recoil chiropractic adjustments produce consistent, short-latency paraspinal neuromuscular reflex responses with amplitudes substantially exceeding both pre-thrust baseline and maximal voluntary trunk extension. Critically, significant differences in thrust biomechanical parameters between two experienced McTimoney chiropractors were associated with directly corresponding differences in neuromechanical outcome including shorter EMD and higher normalized EMG amplitude for the clinician delivering faster, lower-preload, more consistent thrusts. These findings provide the first biomechanical evidence linking MTTR thrust delivery characteristics to the quality of the neuromechanical response, with direct implications for chiropractic education and training. Objective thrust performance targets including speed, preload minimization, and temporal consistency represent measurable competency criteria that could be incorporated into training programs to optimize the neuromechanical efficacy of chiropractic adjustments and investigations into the biomechanical efficacy in chiropractic technique performance.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Ethical approval was obtained from the institutional review board committee of McTimoney College of Chiropractic, Abingdon, Oxfordshire, England. All participants provided written informed consent prior to participation.

Consent for publication

Not applicable. This manuscript does not contain any individual person's data in any form that would require specific consent for publication.

Availability of data and materials

The datasets supporting the conclusions of this article are available from the corresponding author on reasonable request.

Competing interests

CCu is the Principal of McTimoney College of Chiropractic

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Authors' contributions

CC conceived the study, oversaw data collection, conducted statistical analysis, and drafted the manuscript. CCu contributed to study design and participant recruitment at the McTimoney College of Chiropractic and critically revised the manuscript. MP participated in data collection as one of the treating clinicians and critically revised the manuscript. MA contributed to biomechanical data processing and statistical analysis. RH contributed to experimental design, supervised data collection at the Biomechanics Laboratory, and critically revised the manuscript. All authors read and approved the final manuscript.

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Figures

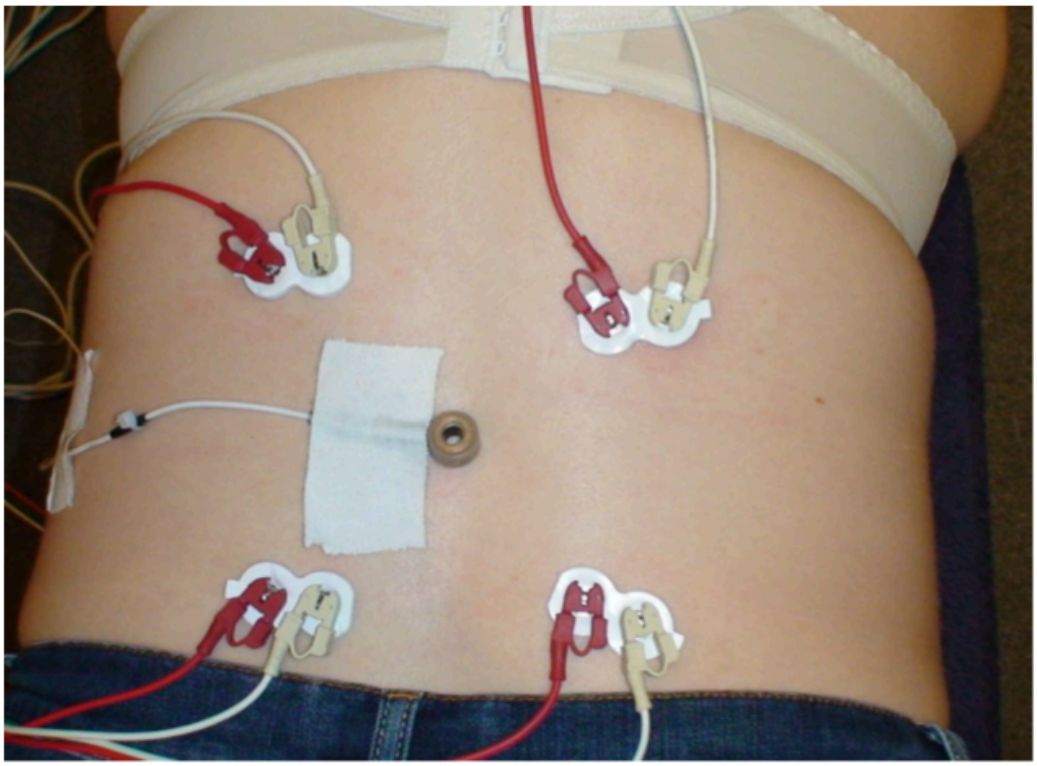


Figure 1

Electrode placement and experimental setup. Surface EMG electrodes were placed bilaterally at L5 (E1 left, E2 right) overlying the multifidus and at L1 (E3 left, E4 right) overlying the iliocostalis lumborum. The piezoelectric load cell was secured over the L3 spinous process.

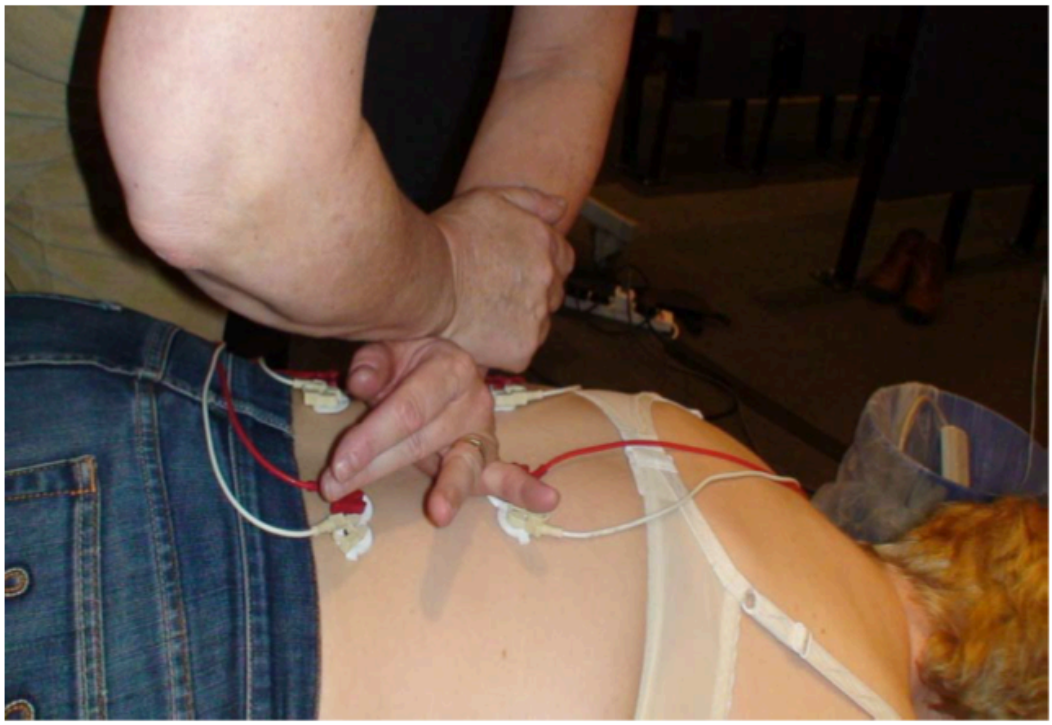


Figure 2

Clinician delivering a McTimoney Toggle-Torque-Recoil thrust over the mounted load cell with the subject in the prone position.

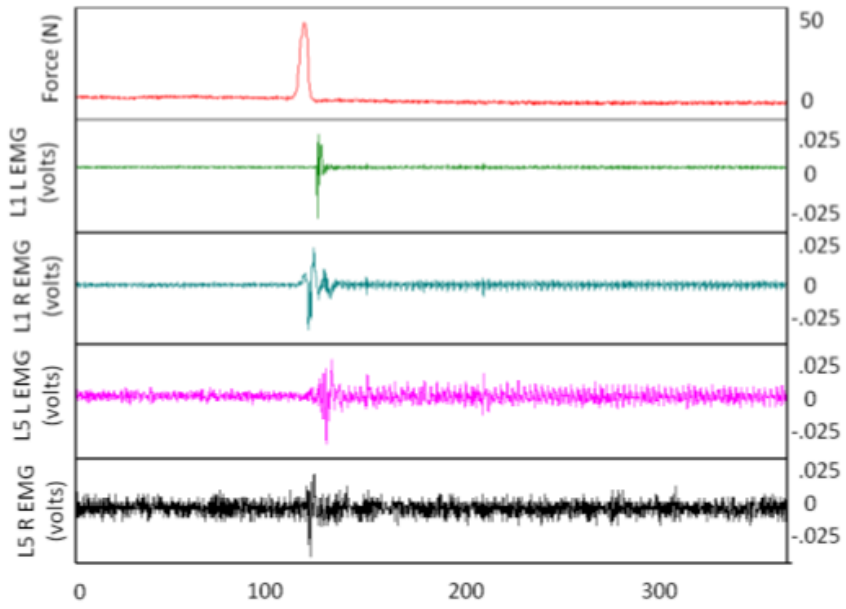


Figure 3

Representative load cell force-time profile of an MTTR thrust, illustrating the rapid rise to peak force and immediate recoil characteristic of the McTimoney technique. Time-to-peak and total thrust duration are indicated.

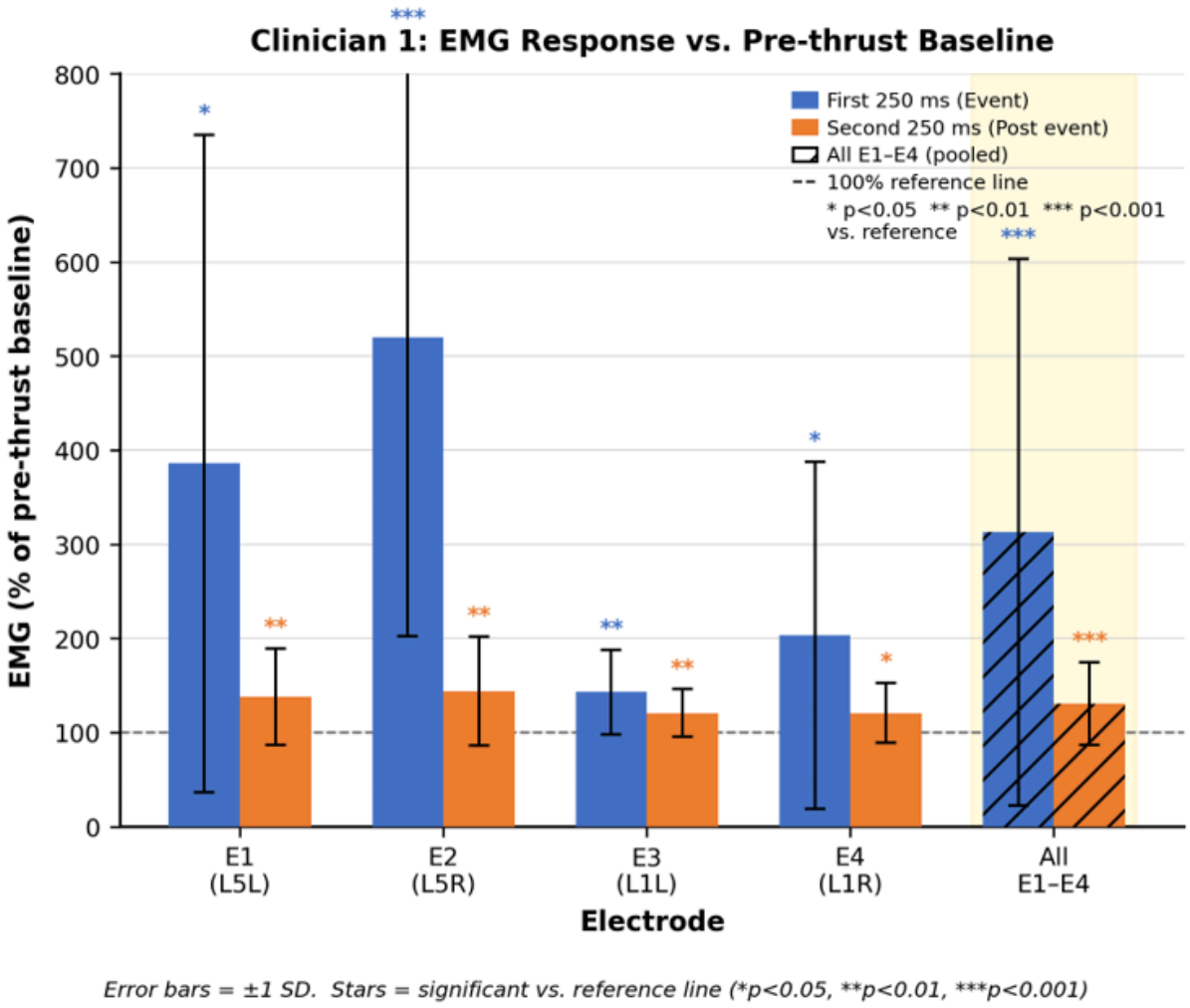


Figure 4

Mean paraspinal EMG amplitude during the first 250 ms post-thrust epoch (First 250 ms; blue bars) and second 250 ms post-thrust epoch (Second 250 ms; orange bars), expressed as a percentage of the pre-thrust baseline (100% reference, dashed line), for Clinician 1 (n=17). Results are shown for each individual electrode site (E1-E4) and the pooled mean across all four electrodes (All E1-E4, hatched bars). Error bars represent +/-1 standard deviation. Asterisks denote significant departure from pre-thrust baseline by one-sample t-test: *p<0.05, **p<0.01, ***p<0.001. E1=L5 left erector spinae; E2=L5 right erector spinae; E3=L1 left iliocostalis lumborum; E4=L1 right iliocostalis lumborum.

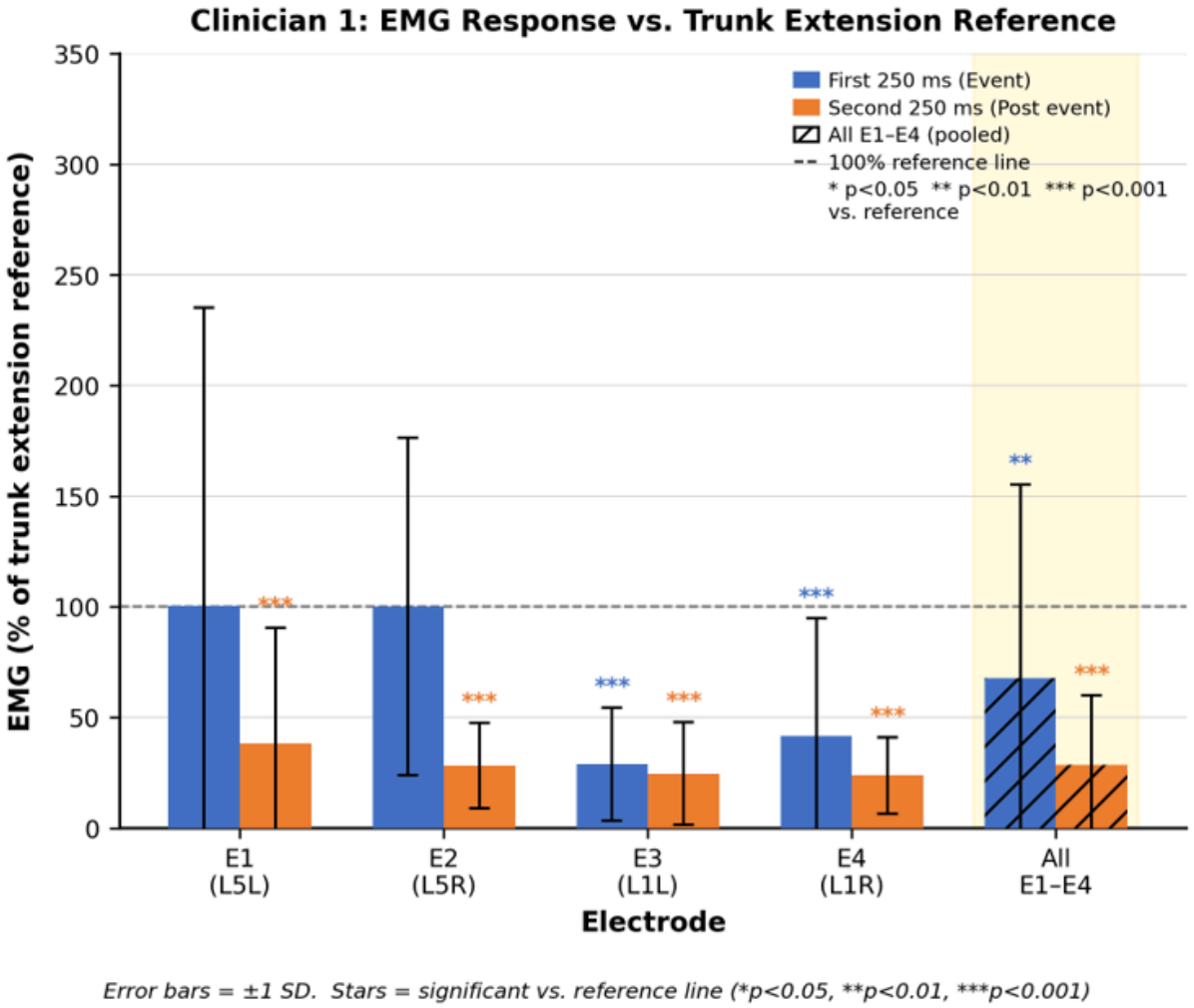


Figure 5

Mean paraspinal EMG amplitude during the first 250 ms post-thrust epoch (First 250 ms; blue bars) and second 250 ms post-thrust epoch (Second 250 ms; orange bars), expressed as a percentage of each participant's maximal isometric prone trunk extension EMG (100% reference, dashed line), for Clinician 1 (n=17). This normalization provides an effort-independent index of reflex magnitude relative to maximal voluntary muscle activation capacity. Results are shown for each individual electrode site (E1-E4) and the pooled mean across all four electrodes (All E1-E4, hatched bars). Error bars represent +/-1 standard deviation. Asterisks denote significant departure from the extension reference by one-sample t-test: *p<0.05, **p<0.01, ***p<0.001. E1=L5 left erector spinae; E2=L5 right erector spinae; E3=L1 left iliocostalis lumborum; E4=L1 right iliocostalis lumborum.

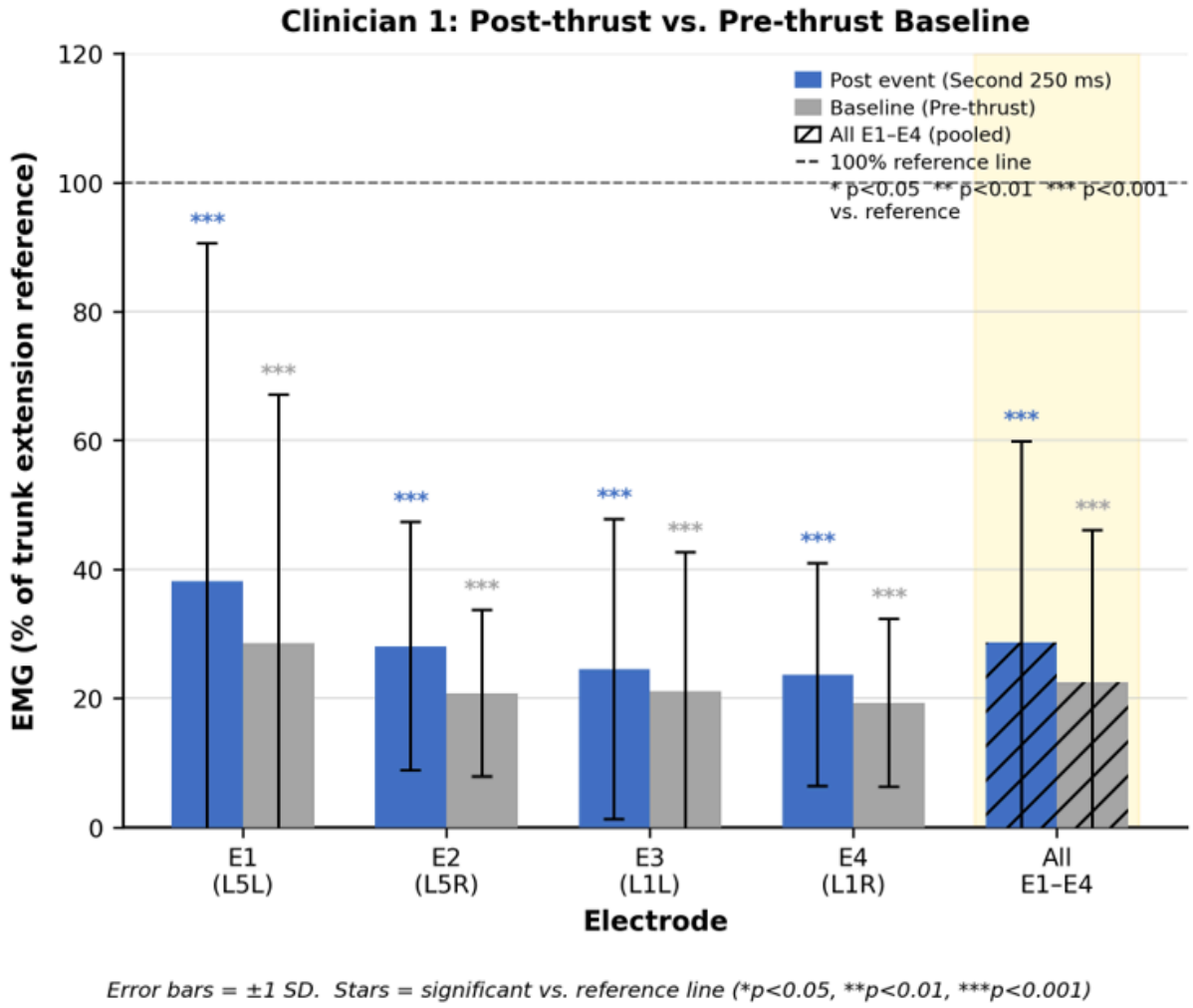


Figure 6

Mean paraspinal EMG amplitude during the second 250 ms post-thrust epoch (Post event; blue bars) and the pre-thrust resting baseline epoch (Baseline; gray bars), both expressed as a percentage of each participant's maximal isometric prone trunk extension EMG (100% reference, dashed line), for Clinician 1 (n=17). This panel directly compares residual post-thrust activation with pre-thrust resting tone relative to maximal voluntary capacity, illustrating that neither epoch approaches volitional levels. Results are shown for each individual electrode site (E1-E4) and the pooled mean across all four electrodes (All E1-E4, hatched bars). Error bars represent +/-1 standard deviation. Asterisks denote significant departure from the extension reference by one-sample t-test: *p<0.05, **p<0.01, ***p<0.001. E1=L5 left erector spinae; E2=L5 right erector spinae; E3=L1 left iliocostalis lumborum; E4=L1 right iliocostalis lumborum.

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