

Technique or body proportions? Segment lengths, execution variants and muscle activation in the seated cable row

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Abstract

Purpose

Seated cable row technical cues rest on assumed, not demonstrated, effects on muscle activation, usually analyzed over the whole repetition only. We compared three variants (maintained scapular adduction, ADP; no scapular adduction, NAP; kyphotic thoracic position, KTP) over the whole repetition and in concentric and eccentric phases.

Methods

Thirty resistance-trained adults (15 men, 15 women; 24.5 ± 2.8 years) performed the variants in randomized order at six-repetition maximum with metronome-imposed tempo. Surface electromyography of biceps brachii, middle and lower trapezius, latissimus dorsi and posterior deltoid was normalized to maximal voluntary contraction (%MVC); segment lengths were measured to test anthropometric moderation.

Results

Variants redistributed activation across muscles (variant $\times$ muscle, $\eta p^2 = 0.219$), phase-dependently (variant $\times$ muscle $\times$ phase, $\eta p^2 = 0.102$). Latissimus dorsi activation did not differ concentrically ($p = 0.196$) but increased eccentrically from ADP (32.1%MVC) to NAP (35.6) to KTP (42.0; $p < 0.001$, $\eta p^2 = 0.285$); its eccentric share of total activity followed the same order ($\eta p^2 = 0.668$, largest effect). ADP increased middle trapezius and KTP reduced posterior deltoid activation in both phases. No anthropometric or sex-related effect survived multiple-comparison correction.

Conclusions

Technical variation acts mainly on the eccentric phase, which whole-repetition analyses understate.

1. Introduction

Resistance training prescription assumes that different exercises, as well as different ways of performing the same exercise, distribute mechanical demands differently across muscles. Because the training stimulus depends not only on the external load but also on how the exercise is performed (1), understanding which muscles are activated and to what extent is essential for informed exercise prescription.

Surface electromyography (sEMG) is widely used to characterize how exercise selection and execution technique influence muscle activation. Evidence is relatively extensive for exercises such as the deadlift

and its variants (2) and the bench press (3), whereas pulling exercises, particularly horizontal pulling movements, have been investigated less systematically. The seated cable row is widely used in training and rehabilitation to target the back and posterior shoulder girdle muscles; however, different execution techniques are commonly prescribed despite limited evidence regarding their neuromuscular consequences.

Two technical aspects are particularly relevant. The first concerns scapular movement: the scapulae may be actively retracted or kept relatively fixed while movement occurs primarily at the glenohumeral joint and elbow. Accordingly, the scapular muscles may contribute dynamically or act isometrically as stabilizers. This distinction is important because the relative activation of the scapular muscles guides the selection of rowing and retraction exercises (4) and because, compared with protraction, retraction increases the subacromial space and enhances supraspinatus force-generating capacity during humeral elevation (5). The second aspect concerns spinal position: the seated row is generally performed with an upright trunk and neutral spine, but it is also frequently executed while maintaining thoracic and lumbar flexion, resulting in a kyphotic posture. Although scapular movement has recently received experimental attention, the effects of spinal posture remain poorly investigated.

The seated-row literature has examined these factors only partially. Saeterbakken et al. (6) compared different exercise variants while focusing on the core musculature, without describing scapular technique or spinal position. Subsequent studies primarily examined grip position and shoulder abduction angle (7), reporting greater latissimus dorsi activation with a narrow grip and greater activation of the three portions of the trapezius and the lateral deltoid with a wide grip (8). Park and Kim (9) compared different trunk inclinations, but examined only trapezius activation and did not alter the sagittal curvature of the spine. Finally, Padovan et al. (10) showed that restricting scapular movement redistributes activation between the concentric and eccentric phases; however, both conditions were performed with the spine in a neutral position.

The kyphotic execution remains unexplored (11), despite a plausible biomechanical rationale. Thoracic flexion alters scapular kinematics, reduces range of motion and isometric force by approximately 16% (12), and increases activation of the upper and lower trapezius and serratus anterior (13). During the seated row, these changes may therefore influence both the magnitude and distribution of muscle activation. Furthermore, because repeated spinal flexion under compressive loading has been associated in vitro with intervertebral disc damage (14), this execution technique is relevant from both practical and biomechanical perspectives.

Anthropometry represents another understudied factor. During the seated row, body-segment dimensions influence joint positions and, consequently, muscle moment arms (15) and the contribution of individual muscles to joint compression and shear forces (16). Thus, the same movement may impose different mechanical demands and elicit different levels of muscle activation across individuals. However, no study has examined whether anthropometric proportions moderate the electromyographic response to technical variations of the seated row or similar horizontal pulling exercises.

Finally, muscle activation may differ between the concentric and eccentric phases, which involve different muscle lengths and neural strategies (17). Whole-repetition analysis may therefore obscure phase-specific effects, as previously observed when scapular movement was restricted during the seated row (10). Whether spinal position also produces phase-specific responses remains unclear.

Accordingly, the present study compared activation of the back muscles and biceps brachii across three standardized seated-row variants performed by resistance-trained men and women, considering both the whole repetition and the concentric and eccentric phases separately. A secondary aim was to determine whether segmental anthropometric measurements of the arm, forearm, and trunk moderated muscle activation across the three variants or predicted which execution elicited the greatest response in a given muscle. Because men and women systematically differ in these dimensions, sex was included as an analytical factor rather than treated solely as a nuisance variable.

2. Materials and Methods

2.1. Study Design

This cross-sectional observational study was designed to assess the electromyographic activation of the main dorsal muscle groups during the execution of the seated cable row, in order to determine whether a biomechanical mechanism exists that can induce greater activation of the latissimus dorsi. Three execution variants of the same exercise were compared: the seated cable row performed in a kyphotic thoracic position, the seated cable row performed with maintained scapular adduction, and the seated cable row performed without scapular adduction.

2.1.1. Participants

For the present study, 30 physically active participants of both sexes were recruited (age: 24.50 ± 2.83 years; males: 24.60 ± 3.48 ; females: 24.40 ± 2.10). All participants had been engaged in resistance training for at least two years, with a minimum training frequency of three sessions per week. The anthropometric characteristics of the participants are reported in Table 1.

Table 1

Descriptive characteristics of the study participants, reported for the total sample and stratified by sex. Values are mean $\pm$ standard deviation. Humerus length was not measured directly: it was obtained by subtraction, as the difference between total upper-limb length and forearm-plus-hand length (Section 2.1.2), so that total upper-limb length equals the sum of the other two segment lengths in every participant. Constant-hydration fat mass and fat-free mass are the two compartments estimated by the bioelectrical impedance device under a constant-hydration model; they are referred to different reference masses and are therefore not complementary fractions of body mass, so that the two percentages do not sum to 100%.

Variable	Total (n = 30)	Males (n = 15)	Females (n = 15)
Participants (n)	30	15	15
Age (years)	24.50 $\pm$ 2.83	24.60 $\pm$ 3.48	24.40 $\pm$ 2.10
Training experience (years)	4.48 $\pm$ 2.42	4.87 $\pm$ 3.16	4.10 $\pm$ 1.34
Body mass (kg)	68.83 $\pm$ 11.23	78.77 $\pm$ 4.80	58.89 $\pm$ 5.15
Height (cm)	170.10 $\pm$ 8.47	176.93 $\pm$ 3.90	163.27 $\pm$ 5.76
Body mass index (kg/m ²)	23.65 $\pm$ 2.35	25.19 $\pm$ 1.80	22.11 $\pm$ 1.76
Humerus length (cm)	26.93 $\pm$ 2.94	28.91 $\pm$ 2.70	24.95 $\pm$ 1.50
Forearm-plus-hand length (cm)	27.47 $\pm$ 2.91	28.42 $\pm$ 3.51	26.51 $\pm$ 1.79
Total upper-limb length (cm)	54.40 $\pm$ 3.94	57.33 $\pm$ 3.17	51.47 $\pm$ 1.92
Trunk length (cm)	54.90 $\pm$ 4.30	57.27 $\pm$ 2.27	52.53 $\pm$ 4.60
Constant-hydration fat mass (%)	19.96 $\pm$ 4.04	19.17 $\pm$ 3.68	20.76 $\pm$ 4.35
Fat-free mass (%)	54.41 $\pm$ 1.61	54.88 $\pm$ 1.38	53.94 $\pm$ 1.73

The inclusion criteria were: (a) age between 18 and 30 years; (b) a minimum of two years of experience in resistance training; (c) specific familiarity with the seated cable row; and (d) the absence of upper-limb musculoskeletal injuries during the six months prior to the study.

Before the beginning of the experimental procedures, all participants were thoroughly informed about the aims and procedures of the study and provided written informed consent. The research protocol was approved by the Local Bioethics Committee of the University of Molise (protocol no. 6306/2025) and was conducted in accordance with the principles of the Declaration of Helsinki for research involving human participants.

2.1.2. Experimental procedure

Participants were instructed to avoid intense physical activity, particularly exercises involving the back and upper-limb musculature, during the three days preceding the experimental sessions.

The study comprised two visits. In a familiarization session held one week before the experimental session, participants were instructed in the three execution variants and determined their six-repetition maximum (6RM) for each. All experimental measurements were obtained in a single subsequent session, in the following fixed order: surface electrode placement, anthropometric assessment, maximal voluntary contraction (MVC) tests and, after a standardized warm-up, the three seated cable row variants in randomized order. Electrodes were positioned before any measurement and were never removed or repositioned, so that MVC trials and all experimental conditions were recorded from identical sites.

During familiarization, the load was adjusted individually for each variant so that the participant could complete exactly six repetitions to failure. The criterion was thus identical across participants and variants, whereas the absolute load was participant-specific and could differ between variants. This load was then used in the corresponding experimental condition.

To minimize variability due to fluid shifts, participants refrained from eating and drinking for at least 4 h before testing.

After electrode placement, participants underwent a standardized anthropometric assessment. Standing height and body mass were determined with a calibrated column scale fitted with a telescopic stadiometer (seca 700; seca GmbH & Co. KG, Hamburg, Germany). Fat mass and fat-free mass were assessed by multifrequency bioelectrical impedance analysis (BIA) (Biody Xpert II™; eBIODY SAS, La Ciotat, France).

All linear measurements were taken on the right side, with the participant standing relaxed and upright, using a flexible tailor's tape, according to the standards of the International Society for the Advancement of Kinanthropometry (ISAK) (18). Four landmarks were palpated and marked: the acromial (most superior and lateral point on the superior border of the acromion process), the radiale (most proximal and lateral point on the head of the radius), the dactylion (tip of the third digit) and the trochanterion (most superior point of the greater trochanter of the femur).

Four measurements were taken directly: standing height; total upper-limb length (acromial–dactylion distance); forearm-plus-hand length (radiale–dactylion distance); and trunk length (acromial–trochanterion distance). Humerus length (acromial–radiale distance) was derived by subtracting forearm-plus-hand length from total upper-limb length, so that total upper-limb length is, by construction, the exact sum of the two segments. Trunk length was defined for the present study as a practical index of the trunk segment relevant to the seated pulling posture and does not correspond to a standard ISAK measurement. Each direct measurement was taken three times in succession and the mean was used in the analyses. All measurements were performed by the same operator to minimize inter-rater variability.

Anthropometric characteristics, including the segment lengths reported in Table 1, were assessed because limb length may affect biomechanical leverage and joint moment arms, and thus the mechanical demands placed on the musculature. They were used to evaluate whether differences in

muscle activation across conditions depended solely on the exercise condition or were also partly associated with individual anthropometric characteristics.

After the anthropometric assessment, participants performed MVCs for each analyzed muscle. Each MVC was a 5-s isometric contraction. Five trials were performed per muscle with 30 s of recovery between trials, and the MVC value was defined as the peak EMG activation recorded across these trials. The MVC order was randomized to minimize potential fatigue effects (19, 20, 21).

MVCs were performed for the biceps brachii (BB), posterior deltoid (PD), middle trapezius (MT), lower trapezius (LT) and latissimus dorsi (LD), each against a fixed resistance in a muscle-specific position. For the LD, participants sat at a lat pull-down machine and pulled isometrically against the immobilized bar, with 90° angles between trunk and humerus and between humerus and forearm. For the PD, participants lay prone on a flat bench and performed an isometric posterior fly with the arm hanging perpendicular to the floor. For the BB, participants stood upright and performed an isometric curl with a 90° elbow angle and the humerus aligned with the trunk. For the MT and LT, participants performed an isometric horizontal row with a 90° elbow angle and the humeri abducted so that both elbows and shoulders lay on a single horizontal line. The maximum EMG value obtained in these trials was used to normalize the EMG signal.

Finally, after a standardized warm-up, participants performed three seated cable row variants with a triangle handle, in randomized order: (a) pull with scapular adduction maintained throughout the movement (ADP); (b) pull without maintaining scapular adduction (NAP); and (c) pull with a kyphotic thoracic spine position (KTP).

For each condition, participants performed five consecutive repetitions with their variant-specific 6RM load. Before each variant, a qualified instructor provided technical instructions and supervised all repetitions to ensure adherence to the protocol. Particular attention was given to the standardized tempo: 2-s concentric and 2-s eccentric phases, with an isometric pause of approximately 0.5 s. Cadence was imposed by an electronic metronome with auditory and visual signals (Franz Mfg. Co. Inc., East Haven, CT, USA). Execution speed was monitored in real time using the time indicators of the EMG acquisition software. The same cadence defined the time windows used to segment the EMG signal (Section 2.2). A 5-min recovery interval was provided between conditions to prevent fatigue. The order of the variants was randomized for each participant to minimize order and fatigue effects, which are known to influence acute responses to resistance exercise (22). The three variants are shown in Fig. 1.

2.2. EMG measurement and analysis

Electromyographic activity was recorded with a wireless sEMG system (Wave Plus Wireless EMG; Cometa srl, Bareggio, Milan, Italy) at a sampling frequency of 2000 Hz.

Electrodes were placed over the following muscle groups: BB, PD, MT, LT and LD. Electrode placement was performed according to the recommendations of the Surface ElectroMyoGraphy for the Non-

Invasive Assessment of Muscles (SENIAM) project (23).

Before electrode placement, the skin at each recording site was gently abraded and cleaned with an alcohol wipe to reduce skin impedance and improve signal quality. Self-adhesive surface electrodes (1 cm detection diameter) were then positioned longitudinally, in line with the orientation of the muscle fibres of the analyzed muscles, with an inter-electrode distance of 20 mm as recommended by SENIAM (23).

Raw signals were filtered with a fourth-order Butterworth high-pass filter (cut-off 10 Hz) and a fourth-order Butterworth low-pass filter (cut-off 450 Hz), full-wave rectified, and smoothed with a symmetrical moving root-mean-square window extending 100 ms on either side of each sample (200 ms in total, corresponding to 401 samples at the 2000 Hz sampling rate). Consistent with previous studies (19, 24), the root mean square (RMS) value of the signal was computed to express the mean level of muscle activation. Each repetition was segmented into its concentric and its eccentric portion using the 2-2-0,5 s cadence imposed by the metronome, and RMS values were computed separately over the concentric window, over the eccentric window and over the whole repetition. For each participant, muscle and experimental condition, the mean of the first three of the five repetitions performed was retained; this value was then normalized to the RMS recorded during the corresponding MVC test and is expressed throughout as a percentage of the maximal voluntary contraction (%MVC). All statistical analyses were performed on these %MVC values.

2.3. Statistical Analysis

All analyses were performed on normalized sEMG amplitude (nRMS), expressed as a percentage of maximal voluntary contraction (%MVC) and computed over three-time windows: the concentric phase, the eccentric phase and the whole repetition. Data distribution was assessed for normality using the D'Agostino–Pearson K^2 test and homogeneity of variance between sexes using the Brown–Forsythe test; descriptive data are presented as mean (SD). Anthropometric characteristics were compared between sexes using independent-samples t-tests (Table 1).

Differences in nRMS were examined using a mixed-design analysis of variance (ANOVA) with Variant (three levels), Muscle (five levels) and Phase (concentric, eccentric) as within-subject factors and Sex as a between-subject factor; the same model without Phase was refitted separately to each of the three windows. Sphericity was assessed with Mauchly's test and the Greenhouse–Geisser correction was applied throughout. Post hoc pairwise comparisons were conducted using paired t-tests with the Holm–Bonferroni correction and, because normality was not satisfied in every cell, repeated with Friedman (Kendall's W) and Wilcoxon signed-rank tests. The same models were applied to a latissimus dorsi selectivity index, defined for each participant and condition as latissimus dorsi activation expressed as a percentage of the summed activation of the five recorded muscles. Because each muscle is normalized to its own maximum, and because the whole-repetition window contains the other two, comparisons between muscles and comparisons involving the whole repetition are reported as descriptive.

Anthropometric variables (four segment lengths and four dimensionless ratios) were converted to z-scores within each sex and correlated both with activation and with the within-participant difference in activation between variants, with the Benjamini–Hochberg false discovery rate procedure applied within each family.

Effect size estimates were reported using partial eta-squared (η^2) for ANOVA models, Cohen's d_z with the 95% confidence interval of the mean difference for within-subject comparisons, and Cohen's d for between-sex comparisons, interpreted according to conventional benchmarks (25). At 80% power the design was sensitive to within-subject effects of $d_z \geq 0.53$ and to correlations of $|r| \geq 0.49$, whereas between-sex comparisons (15 vs. 15) were sensitive only to $d \geq 1.06$ and are reported as exploratory. All statistical analyses were performed in Python (version 3.10; NumPy 2.2, pandas 2.3), the factorial mixed-design ANOVAs being computed with a purpose-written routine validated against SciPy 1.15, statsmodels 0.15 and pingouin 0.6. The correction procedure applied within each family of comparisons (Holm-Bonferroni for pairwise contrasts, Benjamini-Hochberg false discovery rate for the anthropometric correlations) is reported alongside the corresponding results below. Statistical significance was set at $\alpha = 0.05$ and all tests were two-tailed.

3. Results

3.1. Participant characteristics

Thirty resistance-trained participants (15 men, 15 women) completed the protocol, and no data were missing. Descriptive and anthropometric characteristics are reported in Table 1. Men and women differed on every segment length examined (humerus length and total upper-limb length, both $p < 0.001$; trunk length, $p = 0.008$); all anthropometric variables were therefore standardized within sex before entering the subsequent analyses.

3.2. Overall model

Mean activation for each combination of muscle and variant is shown in Fig. 2, separately for the whole repetition (Fig. 2A), the concentric phase (Fig. 2B) and the eccentric phase (Fig. 2C). The mixed-model analysis of variance with variant, muscle and phase as within-subject factors and sex as a between-subject factor is reported in full in Table 2. Variant, muscle and phase were significant, as were the variant by muscle, muscle by phase and variant by muscle by phase interactions; the variant by phase interaction and all effects involving sex were not.

The variant by muscle interaction ($F(4.70, 131.67) = 7.83, p < 0.001, \eta^2 = 0.219$) indicates that the three executions did not raise or lower activation uniformly but redistributed it among the muscles. Activation was higher during the concentric than during the eccentric portion when averaged over muscles and variants (28.6 ± 7.1 versus $25.9 \pm 6.7\%$ MVC; $F(1, 28) = 35.87, p < 0.001, \eta^2 = 0.562$), and the variant by muscle by phase interaction ($F(4.62, 129.31) = 3.19, p = 0.011, \eta^2 = 0.102$) shows that this redistribution

was itself phase-dependent. The effect of variant is accordingly reported separately in each phase below.

Table 2

Mixed-model analysis of variance with variant, muscle and phase (concentric, eccentric) as within-subject factors and sex as a between-subject factor. Degrees of freedom and p-values are Greenhouse-Geisser corrected. The between-subject effect of sex is not subject to the sphericity assumption and is reported with its uncorrected degrees of freedom (1, 28).

Effect	F	df1 (GG)	df2 (GG)	ϵ	p (GG)	ηp^2
Sex	1.86	1.00	28.00	n.a.	0.184	0.062
Variant	8.32	1.43	40.18	0.717	0.003	0.229
Muscle	15.43	3.33	93.17	0.832	< 0.001	0.355
Phase	35.87	1.00	28.00	1.000	< 0.001	0.562
Variant x Muscle	7.83	4.70	131.67	0.588	< 0.001	0.219
Variant x Phase	2.73	1.86	52.00	0.929	0.078	0.089
Muscle x Phase	4.05	3.36	94.18	0.841	0.007	0.126
Variant x Muscle x Phase	3.19	4.62	129.31	0.577	0.011	0.102
Variant x Sex	1.50	1.43	40.18	0.717	0.234	0.051
Muscle x Sex	0.46	3.33	93.17	0.832	0.732	0.016
Phase x Sex	2.82	1.00	28.00	1.000	0.104	0.092
Variant x Muscle x Sex	1.12	4.70	131.67	0.588	0.354	0.038
Variant x Phase x Sex	0.00	1.86	52.00	0.929	0.997	0.000
Muscle x Phase x Sex	0.55	3.36	94.18	0.841	0.671	0.019
Variant x Muscle x Phase x Sex	1.04	4.62	129.31	0.577	0.396	0.036

Normality and the homogeneity of variance between sexes were examined, with the D'Agostino-Pearson and Brown-Forsythe tests described in Section 2.3, for every condition of the design and for every set of within-participant differences submitted to a pairwise test. Because normality was rejected for part of the paired differences between variants, the comparison of variants was repeated with non-parametric procedures (Section 3.4). Refitting the whole-repetition model on log-transformed values left the variant by muscle interaction intact and slightly stronger ($F(4.67, 130.63) = 11.29, p < 0.001, \eta p^2 = 0.287$), so the redistribution is not an artefact of the additive scale.

3.3. Effect of variant on each muscle over the whole repetition

Over the whole repetition the model returned a main effect of variant ($F(1.78, 49.93) = 7.99, p = 0.001, \eta^2 = 0.222$), a main effect of muscle ($F(3.37, 94.42) = 14.37, p < 0.001, \eta^2 = 0.339$) and a variant by muscle interaction ($F(4.94, 138.36) = 8.40, p < 0.001, \eta^2 = 0.231$); sex had no effect ($F(1, 28) = 1.56, p = 0.222, \eta^2 = 0.053$) and entered none of the interactions (Supplementary Table S1). Analyzed muscle by muscle (Table 3, Fig. 3), the effect of variant was significant for the middle trapezius, the latissimus dorsi and the posterior deltoid, and non-significant for the biceps brachii and the lower trapezius.

The middle trapezius showed the largest effect ($\eta^2 = 0.422$): activation was higher with maintained scapular adduction than in either other execution (30.2 ± 12.3 versus $19.9 \pm 8.9\%$ MVC without adduction, mean difference 10.3% MVC, 95% CI 6.9 to 13.8, $d_z = 1.11, p < 0.001$; and versus $18.1 \pm 12.9\%$ MVC in the kyphotic execution, mean difference 12.1% MVC, 95% CI 7.4 to 16.8, $d_z = 0.95, p < 0.001$), the latter two not differing from each other ($p = 0.388$; Fig. 3B). The posterior deltoid showed the opposite pattern ($\eta^2 = 0.325$): the kyphotic execution lowered activation below both the adducted execution (16.7 ± 10.8 versus $30.9 \pm 18.3\%$ MVC, mean difference 14.2% MVC, 95% CI 7.6 to 20.7, $d_z = 0.81, p < 0.001$) and the non-adducted one (versus $26.5 \pm 17.1\%$ MVC, mean difference 9.8% MVC, 95% CI 5.2 to 14.5, $d_z = 0.79, p < 0.001$; Fig. 3E). The latissimus dorsi showed the smallest effect over the whole repetition ($\eta^2 = 0.137$), only the contrast between the adducted and the kyphotic execution surviving correction (37.2 ± 13.1 versus $43.0 \pm 17.7\%$ MVC, mean difference -5.8% MVC, 95% CI -9.9 to -1.7 , $d_z = -0.53, p = 0.021$; Fig. 3D). All pairwise comparisons, for every muscle and every outcome, are reported in Supplementary Table S2.

Table 3

Effect of variant on the activation of each muscle, in each of the three outcomes (mixed analysis of variance with sex as a between-subject factor; Greenhouse-Geisser corrected).

Outcome	Muscle	F	df1 (GG)	df2 (GG)	ϵ	p (GG)	ηp^2
TOT	Biceps brachii	1.52	1.95	54.65	0.976	0.229	0.051
TOT	Middle trapezius	20.45	1.75	49.12	0.877	< 0.001	0.422
TOT	Lower trapezius	0.03	1.74	48.76	0.871	0.955	0.001
TOT	Latissimus dorsi	4.46	1.44	40.21	0.718	0.028	0.137
TOT	Posterior deltoid	13.51	1.76	49.37	0.882	< 0.001	0.325
CON	Biceps brachii	0.40	1.98	55.39	0.989	0.672	0.014
CON	Middle trapezius	8.06	1.74	48.74	0.870	0.002	0.224
CON	Lower trapezius	0.30	1.84	51.66	0.922	0.726	0.011
CON	Latissimus dorsi	1.73	1.43	40.08	0.716	0.196	0.058
CON	Posterior deltoid	9.92	1.83	51.15	0.913	< 0.001	0.262
ECC	Biceps brachii	5.32	1.32	36.89	0.659	0.019	0.160
ECC	Middle trapezius	17.85	1.65	46.19	0.825	< 0.001	0.389
ECC	Lower trapezius	0.09	1.58	44.17	0.789	0.875	0.003
ECC	Latissimus dorsi	11.14	1.34	37.43	0.668	< 0.001	0.285
ECC	Posterior deltoid	12.41	1.44	40.41	0.722	< 0.001	0.307

3.4. Effect of variant in the concentric and eccentric phases

Because the effect of variant depended on the phase, the same analysis was repeated separately on the concentric and the eccentric value (Supplementary Table S1, Table 3, Fig. 4). The effect of variant was present in both phases for the middle trapezius ($\eta p^2 = 0.224$ concentrically and 0.389 eccentrically) and the posterior deltoid ($\eta p^2 = 0.262$ and 0.307), confined to the eccentric phase for the latissimus dorsi and the biceps brachii, and absent from both phases for the lower trapezius. In each of the four muscles in which an effect was detected it was larger eccentrically than concentrically. In both phases the contrasts surviving correction were ADP versus NAP and ADP versus KTP for the middle trapezius, and ADP versus KTP and NAP versus KTP for the posterior deltoid.

In the latissimus dorsi the effect of variant was absent during the concentric phase ($F(1.43, 40.08) = 1.73$, $p = 0.196$, $\eta p^2 = 0.058$) but large during the eccentric phase ($F(1.34, 37.43) = 11.14$, $p < 0.001$, $\eta p^2 = 0.285$), with the whole-repetition value intermediate ($F(1.44, 40.21) = 4.46$, $p = 0.028$, $\eta p^2 = 0.137$).

Eccentrically all three pairwise comparisons were significant, activation increasing from the adducted

through the non-adducted to the kyphotic execution (32.1 ± 12.3 , 35.6 ± 15.0 and $42.0 \pm 18.2\%$ MVC): ADP versus NAP, mean difference -3.5% MVC (95% CI -6.2 to -0.7), $d_z = -0.47$, $p = 0.015$; ADP versus KTP, -9.9% MVC (95% CI -15.3 to -4.4), $d_z = -0.68$, $p = 0.003$; NAP versus KTP, -6.4% MVC (95% CI -10.6 to -2.2), $d_z = -0.57$, $p = 0.008$. The advantage of the kyphotic execution for the latissimus dorsi was therefore largely confined to the eccentric phase (Fig. 4F–4J). The biceps brachii showed the same phase dependence more weakly, the effect being absent concentrically ($F(1.98, 55.39) = 0.40$, $p = 0.672$, $\eta^2 = 0.014$) and significant eccentrically ($F(1.32, 36.89) = 5.32$, $p = 0.019$, $\eta^2 = 0.160$), with the eccentric contrast between the adducted and the non-adducted execution surviving correction (mean difference 3.3% MVC, 95% CI 1.2 to 5.4 , $d_z = 0.58$, $p = 0.011$).

The non-parametric sensitivity analysis agreed with the parametric one on 43 of the 45 contrasts and led to the same conclusion for every muscle in which an effect of variant was detected. Both exceptions occurred in the eccentric phase. For ADP versus KTP in the biceps brachii the two corrected p-values fell either side of the threshold (parametric 0.055, Wilcoxon 0.049). For ADP versus NAP in the posterior deltoid (parametric 0.062, Wilcoxon 0.002) the discrepancy was attributable to a single participant whose difference ran counter to the group: 27 of the 30 participants showed higher activation in the adducted than in the non-adducted execution, and the resulting departure of the difference scores from normality ($p < 0.001$) makes the rank-based test the more reliable of the two in this instance.

3.5. Activation profile within each variant

Within each variant the latissimus dorsi was the most activated of the five muscles, at $37.2 \pm 13.1\%$ MVC with maintained scapular adduction (Supplementary Fig. S1A), $39.4 \pm 16.3\%$ MVC without scapular adduction (Supplementary Fig. S1B) and $43.0 \pm 17.7\%$ MVC in the kyphotic thoracic position (Supplementary Fig. S1C); means for every combination of variant, outcome and muscle are given in Supplementary Table S3. The least activated muscle differed between executions: the biceps brachii with maintained adduction ($22.4 \pm 12.5\%$ MVC), the middle trapezius without adduction ($19.9 \pm 8.9\%$ MVC) and the posterior deltoid in the kyphotic execution ($16.7 \pm 10.8\%$ MVC). These between-muscle comparisons are descriptive, since each muscle is normalized to its own maximal voluntary contraction and the values therefore express the proportion of each muscle's own maximum rather than placing the muscles on a common scale. The inferential comparisons reported above are accordingly restricted to comparisons between variants within the same muscle.

3.6. Latissimus dorsi selectivity

The proportion of the total recorded activation attributable to the latissimus dorsi differed between variants in all three outcomes, and the effect was considerably larger during the eccentric phase ($F(1.57, 43.86) = 56.35$, $p < 0.001$, $\eta^2 = 0.668$) than during the concentric one ($F(1.29, 36.23) = 6.53$, $p = 0.010$, $\eta^2 = 0.189$), with the whole repetition intermediate ($F(1.31, 36.81) = 22.17$, $p < 0.001$, $\eta^2 = 0.442$; Fig. 5). Over the whole repetition the share rose from $24.7 \pm 7.5\%$ in the pull with maintained scapular adduction to $28.7 \pm 8.9\%$ in the pull without scapular adduction and $33.9 \pm 9.5\%$ in the pull in a kyphotic thoracic position, every pairwise comparison being significant after correction (ADP versus NAP, mean difference

– 4.0%, 95% CI – 5.6 to – 2.5, $d_z = -0.96$, $p < 0.001$; ADP versus KTP, – 9.3%, 95% CI – 12.6 to – 6.0, $d_z = -1.06$, $p < 0.001$; NAP versus KTP, – 5.2%, 95% CI – 8.8 to – 1.7, $d_z = -0.55$, $p = 0.006$). Eccentrically the same ordering ran from $23.0 \pm 7.8\%$ to $34.8 \pm 9.5\%$, again with all three comparisons significant after correction (Fig. 5C). This was the largest effect observed in the study.

Because the index is a ratio, its change between variants was decomposed into its two components. Over the whole repetition the numerator rose from 37.2%MVC in the pull with maintained scapular adduction to 43.0%MVC in the pull in a kyphotic thoracic position, while the denominator, the summed activation of the five recorded muscles, fell from 152.3 to 128.4%MVC, principally through the middle trapezius (30.2 to 18.1%MVC) and the posterior deltoid (30.9 to 16.7%MVC). The two components did not contribute equally in the two phases. Eccentrically, between the same two executions, the latissimus dorsi rose by 9.9%MVC while the other four muscles fell by 29.9%MVC; concentrically the latissimus dorsi was essentially unchanged (+ 0.7%MVC) and the whole of the rise in the index rested on the fall of the other four muscles (– 26.0%MVC). The index therefore describes how the recorded muscular effort is distributed among the five muscles and not, on its own, the amount of latissimus dorsi activation.

The index was also compared across the three outcomes. In the mixed model with variant and phase (concentric, eccentric) as within-subject factors and sex as a between-subject factor, the main effect of phase was absent ($F(1, 28) = 0.01$, $p = 0.944$, $\eta^2 = 0.000$), as expected for a quantity expressed as a share of a total, whereas the variant by phase interaction was significant ($F(1.61, 44.98) = 8.93$, $p = 0.001$, $\eta^2 = 0.242$; Fig. 5D). Within the pull with maintained scapular adduction the latissimus dorsi accounted for a larger share concentrically than eccentrically (25.2 versus 23.0%, $d_z = 0.46$, $p = 0.037$); within the pull without scapular adduction the two phases did not differ (29.9 versus 28.9%, $d_z = 0.17$, $p = 0.364$); and within the pull in a kyphotic thoracic position the ordering was reversed, the eccentric share exceeding the concentric one (31.4 versus 34.8%, $d_z = 0.58$, $p = 0.011$). The kyphotic execution therefore did not simply raise latissimus dorsi selectivity but shifted the moment of greatest selective recruitment from the shortening to the lengthening portion of the repetition.

The only test involving sex to reach nominal significance in the study was the variant by sex interaction on the eccentric selectivity index ($F(1.57, 43.86) = 4.79$, $p = 0.020$, $\eta^2 = 0.146$). It did not survive the correction applied within the sex family (smallest corrected $p = 0.117$) and was not significant in the combined model with phase as an explicit factor ($F(1.36, 38.12) = 2.38$, $p = 0.122$, $\eta^2 = 0.078$). The stratified analysis further indicates a difference of magnitude rather than of direction: the effect of variant was present and large in both sexes (men, $\eta^2 = 0.755$; women, $\eta^2 = 0.533$), the index rising from 21.6% to 36.8% between the adducted and the kyphotic execution in men and from 24.3% to 32.8% in women.

3.7. Comparison of the whole repetition, the concentric phase and the eccentric phase

The three outcomes were compared for every variant and muscle (Supplementary Table S4, Supplementary Fig. S2). The inferential comparison is the one between the concentric and the eccentric value: it was significant after correction for 7 of the 15 variant–muscle combinations, in every case with activation higher during the concentric phase, and in none was eccentric activation significantly higher. The comparisons involving the whole-repetition value are reported in the same table for completeness, but because that value is computed over a window containing both phases they describe the relationship between a composite and its own components and are not independent tests of a phase effect; a descriptive repeated-measures model treating the three outcomes as levels of a single factor returned a difference for the same 7 combinations, the largest being the biceps brachii in the pull in a kyphotic thoracic position ($F(1.02, 28.61) = 89.63, p < 0.001, \eta^2 = 0.762$).

The variant by phase interaction reached significance in the latissimus dorsi ($F(1.75, 48.87) = 6.06, p = 0.006, \eta^2 = 0.178$). In that muscle the concentric value exceeded the eccentric one in the pull with maintained scapular adduction (38.4 versus 32.1%MVC, $dz = 0.63, p = 0.004$) and in the pull without scapular adduction (42.9 versus 35.6%MVC, $dz = 0.68, p = 0.003$), whereas in the pull in a kyphotic thoracic position this ordering disappeared and the two phases no longer differed (39.1 versus 42.0%MVC, $dz = -0.20, p = 0.274$). The kyphotic execution therefore altered not only the amount of latissimus dorsi activation but its distribution between the shortening and the lengthening portion of the movement.

The phase was finally examined on the between-muscle profile itself, by fitting within each variant a mixed model with muscle and phase (concentric, eccentric) as within-subject factors and sex as a between-subject factor (Supplementary Table S5). The main effect of phase was significant in the pull with maintained scapular adduction ($F(1, 28) = 12.98, p = 0.001, \eta^2 = 0.317$) and in the pull without scapular adduction ($F(1, 28) = 22.47, p < 0.001, \eta^2 = 0.445$) but not in the pull in a kyphotic thoracic position ($F(1, 28) = 2.26, p = 0.144, \eta^2 = 0.075$). The muscle by phase interaction was significant in the pull with maintained scapular adduction ($F(2.82, 78.90) = 4.91, p = 0.004, \eta^2 = 0.149$) and in the pull in a kyphotic thoracic position ($F(2.98, 83.54) = 4.30, p = 0.007, \eta^2 = 0.133$) and absent in the pull without scapular adduction ($F(2.53, 70.77) = 1.89, p = 0.148, \eta^2 = 0.063$). No effect involving sex approached significance in any of the three models.

3.8. Sex

Sex entered every model in the design as a between-subject factor and was in addition compared directly between men and women on the level of activation in each variant, phase and muscle, on the size of the phase effect and on every anthropometric association; the complete set of tests is listed in Supplementary Table S6, grouped by the family within which the correction was applied. None was significant after correction.

In the overall model neither the main effect of sex ($F(1, 28) = 1.86, p = 0.184, \eta^2 = 0.062$) nor any of its interactions reached significance, the largest being the phase by sex interaction ($F(1, 28) = 2.82, p = 0.104, \eta^2 = 0.092$), and the same held in the primary, muscle-specific, variant-specific and phase-

specific models. Of the 45 direct comparisons between men and women, 3 were nominally significant and none survived the false-discovery-rate correction; the largest difference observed was in the biceps brachii during the concentric phase of the pull in a kyphotic thoracic position ($18.6 \pm 7.6\%$ MVC in men versus $26.6 \pm 11.8\%$ MVC in women, $d = -0.80$, $p = 0.036$, corrected $p = 0.581$). None of the comparisons on the phase effect itself survived correction (largest, middle trapezius in the pull with maintained scapular adduction, corrected $p = 0.726$), and none of the anthropometric correlations differed between the sexes when compared with Fisher's z test (smallest corrected $p = 0.137$). Recomputed separately within each sex, the effect of variant and the effect of phase had the same sign in men and in women for every muscle and every outcome (Supplementary Fig. S3).

The study was not powered to detect sex differences: with 15 participants of each sex the direct comparisons between men and women could detect only differences of Cohen's $d \geq 1.06$ at 80% power and $\alpha = 0.05$, and the power available against a moderate difference of $d = 0.50$ was 26%. These negative findings therefore indicate an absence of evidence of a sex difference within the sensitivity of the design, and not evidence that men and women respond in the same way.

3.9. Anthropometry

No anthropometric variable moderated the electromyographic response to technical variation in any of the three outcomes. Of the 360 correlations between the anthropometric variables and the within-participant change in activation between pairs of variants, 9 reached nominal significance (3 per outcome) and none survived false discovery rate correction. This is fewer than the 18 expected by chance at an α of 0.05, although the tests are not independent and the comparison is therefore only indicative. The strongest whole-repetition association was between the humerus-to-trunk ratio and the change in lower trapezius activation between the kyphotic pull and the pull without scapular adduction ($r = -0.46$, $p = 0.010$, corrected $p = 0.891$). Supplementary Fig. S4A shows all coefficients against the thresholds for significance and for 80% power. Supplementary Fig. S4B shows that the observed p-values followed the uniform distribution expected in the absence of any effect.

The same held for the absolute level of activation. Of the 360 correlations between the anthropometric variables and activation within each variant and outcome, a single one reached nominal significance, the largest coefficient in the set was $|r| = 0.36$, and none survived correction. Two further analyses led to the same conclusion: partial correlations on the raw segment lengths with sex as a covariate, and the two principal components extracted from the four standardized lengths (together 81.7% of the anthropometric variance). The strongest association involving the latissimus dorsi, the muscle of primary interest, is shown in Supplementary Fig. S4C.

These null findings should be read against the sensitivity of the design. With 30 participants, correlations of $|r| \geq 0.49$ were detectable with 80% power, so weak to moderate associations between body proportions and the electromyographic response cannot be excluded. What can be said is that no association strong enough to support individualized exercise prescription based on segment lengths was present in this sample.

4. Discussion

With respect to the aim of the study, the results provide three answers. The three execution techniques did not uniformly increase or decrease activation but redistributed it among the muscles. This redistribution was phase-dependent and, for the latissimus dorsi, was almost entirely confined to the lengthening phase of the repetition. Neither anthropometric proportions nor sex moderated these effects in any phase.

For the latissimus dorsi, the kyphotic execution was distinguished by greater activation during lengthening, but not during shortening. Although whole-repetition analysis showed moderately greater activation than the execution with scapular adduction, when the phases were analysed separately, differences emerged exclusively during the eccentric phase. These findings confirm those of Padovan et al. (8), who reported greater latissimus dorsi excitation with a narrow grip than with a wide grip, and show that the influence of execution technique may be specific to the eccentric phase.

The spinal component of the execution had not previously been examined. Studies that recorded trunk musculature during rowing exercises did not analyse any scapular muscles (6, 26), whereas those that modified hand position (7, 8) or scapular position (10) maintained the spine in a neutral position. Park and Kim (9) compared an upright trunk with 30° forward and 20° backward inclinations during a modified seated cable row in 23 healthy participants; however, trunk alignment was maintained under all conditions, and only the trapezius was analysed. To our knowledge, this is the first study to compare seated-row executions with the spine in kyphotic and neutral positions and the first to demonstrate that the effect of a spinal variable on the latissimus dorsi is confined to the lengthening phase of the movement.

The selectivity index, defined as the proportion of total recorded activity attributable to the latissimus dorsi, reproduced this pattern and showed the largest effect observed in the study. This index increased from the execution with scapular adduction to that without adduction and, finally, to the kyphotic execution, with markedly greater differences during lengthening than during shortening. The interaction between variant and phase provides even more relevant information. The latissimus dorsi was proportionally more involved during shortening in the execution with adduction, during lengthening in the kyphotic execution, and equally involved in both phases in the execution without adduction. Thus, the kyphotic position not only increases the relative involvement of the target muscle but also changes the point in the repetition at which this involvement reaches its peak.

As a ratio, the index may increase because of increased latissimus dorsi activity, reduced activity of the other muscles, or both. During the eccentric phase, both occurred, indicating a genuine increase in latissimus dorsi activation during the kyphotic execution; during the concentric phase, however, the increase in the index almost exclusively reflected the lower activity of the other muscles. The index therefore describes the distribution of activity among the five muscles, rather than the absolute activation of the latissimus dorsi or a ranking of the muscles, because values normalized to maximal voluntary contraction do not express the relative neural drive to the different synergists (27).

Maintaining scapular adduction increased activation of the middle trapezius and posterior deltoid, whereas the kyphotic execution reduced posterior deltoid activation during both phases. The greater involvement of the middle trapezius than the lower trapezius is consistent with Kara et al. (28), according to whom scapular retraction places greater demands on the former. The reciprocal relationship among the latissimus dorsi, middle trapezius, and posterior deltoid is also consistent with Vasconcelos et al. (7), suggesting that these differences depend more on the orientation of the humerus and scapula relative to the line of pull than on the effort required.

The comparison with Padovan et al. (10) is only partially concordant. As in the present study, the authors observed that restricting scapular movement increased posterior deltoid activation during the concentric phase and middle trapezius activation during the eccentric phase, supporting the view that such a constraint redistributes rather than increases muscle activation. In contrast, they reported greater eccentric activation of the latissimus dorsi with the scapula constrained, whereas in our study it was greater without adduction. This discrepancy may depend on the different experimental conditions: the scapula was held stationary in a neutral position in their study and actively adducted in ours. Indeed, sustained retraction brings the humeral insertion of the latissimus dorsi closer to its spinal attachments, thereby reducing its change in length.

No significant associations emerged between anthropometric measurements and the effects of the seated-row execution techniques. To our knowledge, no previous study has examined whether segment lengths influence muscle activation across different seated-row executions. Our findings therefore provide no evidence supporting the advantage of a specific technique based on anthropometric characteristics. The same applies to sex: the effect of the variant showed the same direction in men and women for every muscle and in each phase.

Several limitations should be acknowledged. Measurements were obtained during a single session and describe only the acute response. Thoracic and scapular angles were not objectively quantified. Although the kyphotic position was imposed through instruction and supervised, the degree of thoracic flexion may have varied among participants. Spinal loading was not measured. The sample comprised 30 resistance-trained adults aged 18–30 years, with at least two years of experience and familiarity with the exercise. This limits the generalizability of the findings to untrained individuals, older adults, and people with a history of shoulder injury. Sex-specific analyses, conducted with 15 participants per group, should be considered exploratory. Finally, the safety implications of the kyphotic execution remain uncertain. Previous evidence on spinal flexion under load does not directly reflect the sustained thoracic and lumbar flexion examined in the present study; therefore, no conclusions can be drawn regarding injury risk.

5. Conclusions

The three technical variants of the seated row altered the distribution of muscle activation rather than its overall magnitude. The kyphotic execution produced the greatest latissimus dorsi activation and the

highest relative contribution of this muscle to the total recorded activity, almost exclusively during the eccentric phase; by contrast, no differences among the three executions emerged during the concentric phase. The execution with maintained scapular adduction elicited greater involvement of the middle trapezius and posterior deltoid, whereas lower trapezius activation was similar across executions and phases. This pattern is consistent with the hypothesis that thoracic flexion places the latissimus dorsi closer to the lengthened end of its operating range at maximum reach, which is the position towards which the limb returns during the eccentric phase. Within the sensitivity limits of a sample of thirty participants, neither anthropometric proportions nor sex moderated the observed effects.

Practitioners may therefore select the execution technique according to the muscle they intend to load and the phase in which they wish to load it, rather than according to the individual's anthropometry: the kyphotic execution to emphasize the latissimus dorsi during a controlled return phase; the execution without maintained adduction to achieve the same emphasis while maintaining a neutral spine; and the execution with maintained adduction to load the scapular retractors. Because these data describe muscle activation recorded during a single session rather than training adaptations, and because maintaining a flexed spine under load raises concerns that an electromyographic comparison cannot resolve, the findings should guide exercise selection without being interpreted as evidence that one execution is superior in inducing training adaptations.

Declarations

Conflicts of Interest and Source of Funding: This study received no external funding. For all authors, no conflicts of interest were declared. The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation. The results of the present study do not constitute endorsement by the American College of Sports Medicine.

Data Availability Statement: The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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Competing interests: The authors declare that they have no conflict of interest.

Ethics approval: The study was approved by the Local Bioethical Committee of the University of Molise (protocol 6306/2025) and was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

Consent to participate: Written informed consent was obtained from all individual participants prior to their inclusion in the study.

Author contributions (CRediT):

D.F.D: Conceptualization, Writing – original draft, Methodology, Software. G.D.C: Methodology, Visualization, Software. L.G: Software, Writing – review & editing. N.C: Visualization, Software M.A. Visualization. A.B: Writing – review & editing, Conceptualization. G.C: Supervision, Validation, Project administration. A.d.C: Supervision, Project administration, Writing – review & editing, Conceptualization, Validation. G.F: Supervision, Project administration, Writing – review & editing, Conceptualization, Validation

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Figures



Figure 1

The three variants of the seated cable row examined in the study, each shown at the start and at the end of the movement. (A1, A2) Pull performed while maintaining scapular adduction throughout the movement (ADP): (A1) start of the movement, (A2) end of the movement. (B1, B2) Pull performed without maintaining scapular adduction (NAP): (B1) start of the movement, (B2) end of the movement. (C1, C2) Pull performed in a kyphotic thoracic position (KTP): (C1) start of the movement, (C2) end of the movement.

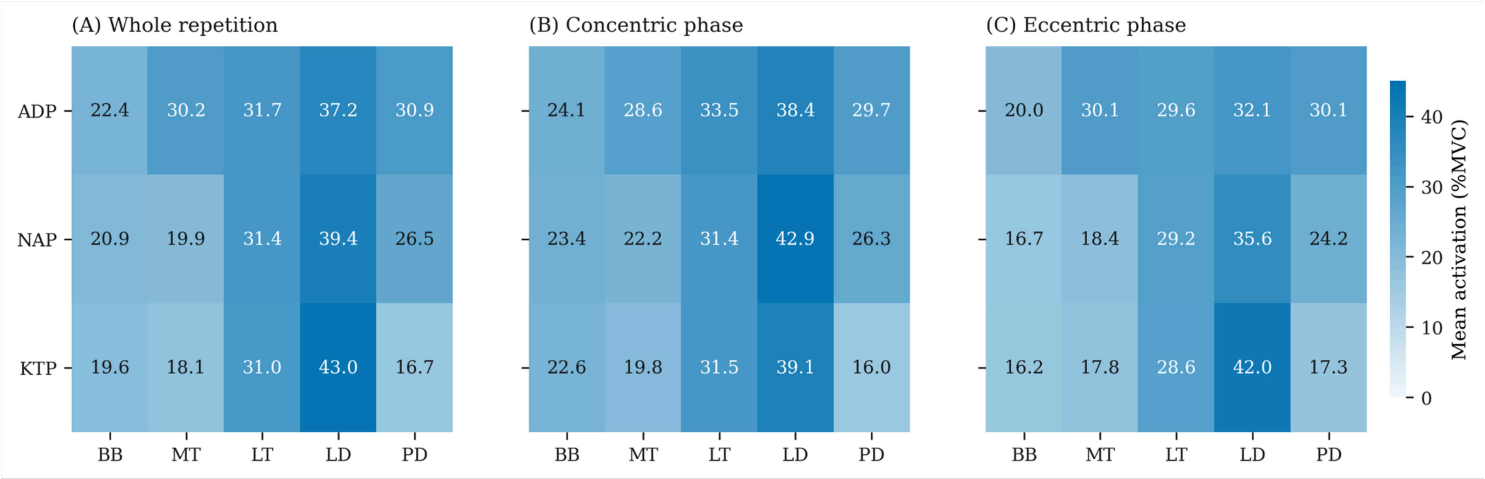


Figure 2

Mean activation (%MVC, n = 30) for every combination of muscle and variant, shown separately for (A) the whole repetition, (B) the concentric phase and (C) the eccentric phase. ADP, pull with maintained scapular adduction; NAP, pull without scapular adduction; KTP, pull in a kyphotic thoracic position. BB, biceps brachii; MT, middle trapezius; LT, lower trapezius; LD, latissimus dorsi; PD, posterior deltoid.

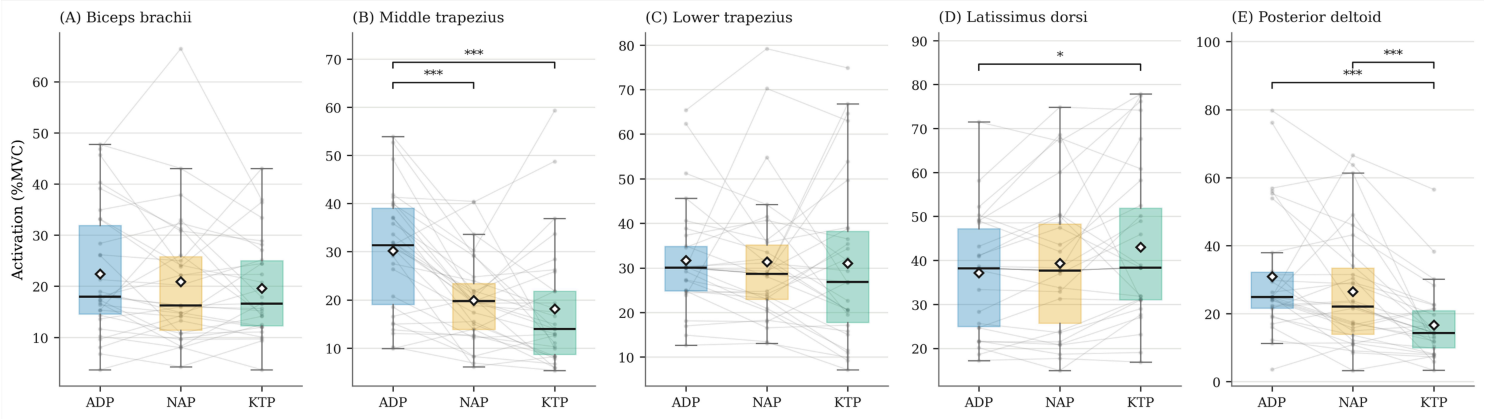


Figure 3

Activation of each muscle over the whole repetition in the three variants: (A) biceps brachii, (B) middle trapezius, (C) lower trapezius, (D) latissimus dorsi, (E) posterior deltoid. Boxes show the median and the interquartile range, whiskers the 1.5 interquartile range, open diamonds the mean, and the faint grey lines the individual participants, whose pairing across conditions is the basis of the statistical

comparison. Horizontal bars connect the two conditions being compared and mark comparisons that remained significant after the Holm-Bonferroni correction (* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$). Vertical scales differ between panels because each muscle is normalized to its own maximal voluntary contraction. ADP, pull with maintained scapular adduction; NAP, pull without scapular adduction; KTP, pull in a kyphotic thoracic position.

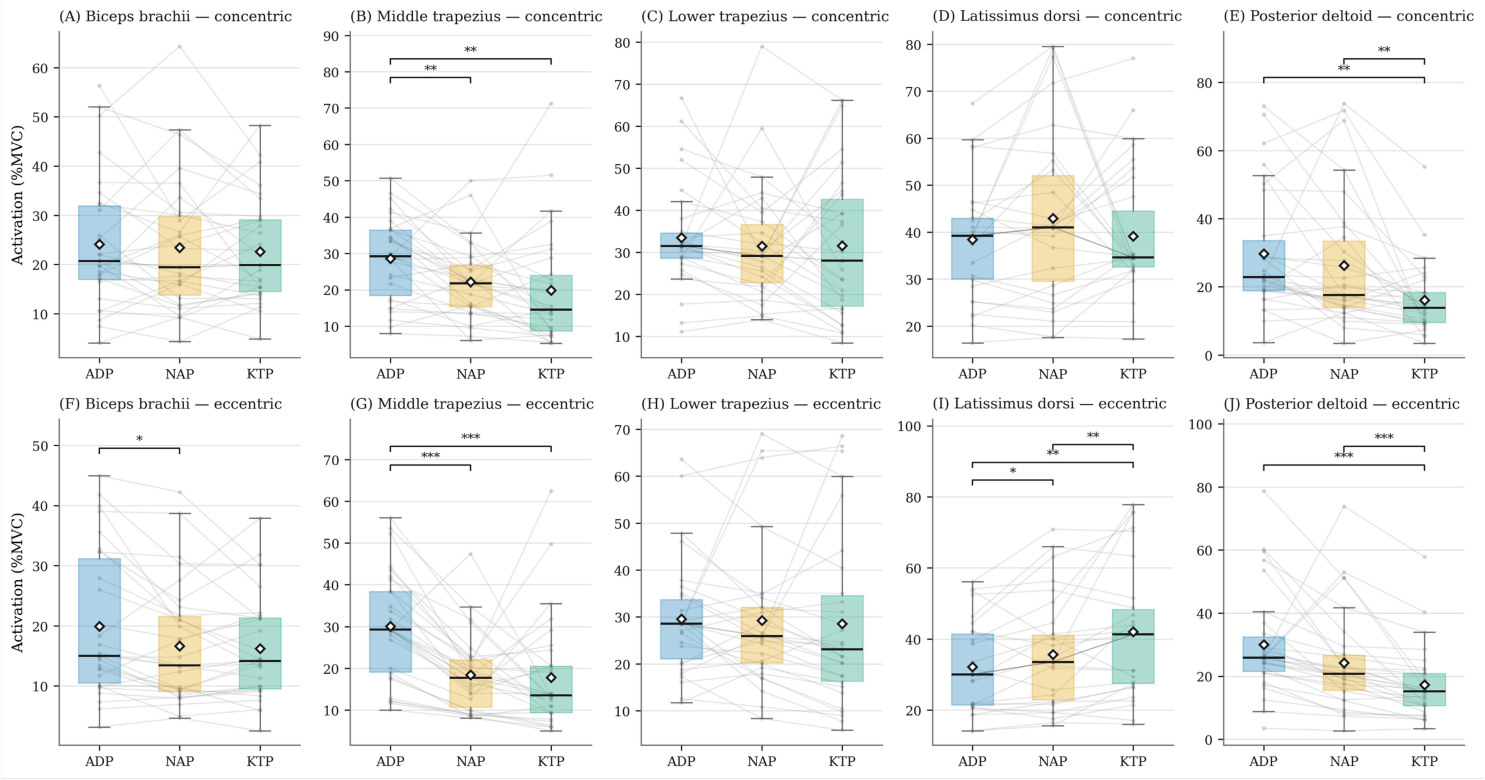


Figure 4

Activation of each muscle in the three variants, shown separately for the concentric phase (A–E) and the eccentric phase (F–J): (A, F) biceps brachii, (B, G) middle trapezius, (C, H) lower trapezius, (D, I) latissimus dorsi, (E, J) posterior deltoid. Plotting conventions and significance notation as in Fig. 3. ADP, pull with maintained scapular adduction; NAP, pull without scapular adduction; KTP, pull in a kyphotic thoracic position.

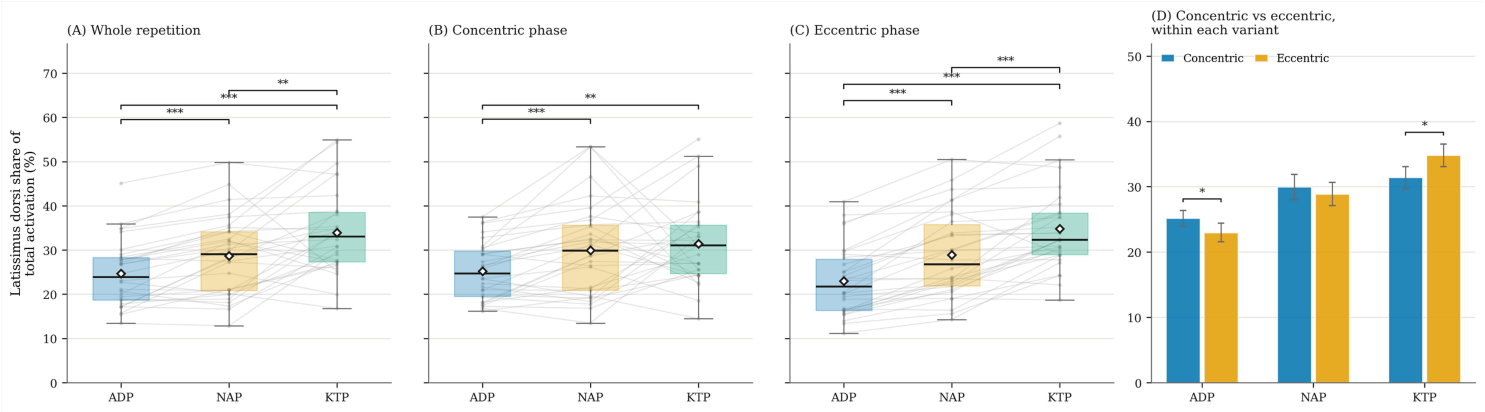


Figure 5

Latissimus dorsi selectivity, defined for each participant and variant as the activation of the latissimus dorsi expressed as a percentage of the summed activation of the five recorded muscles, shown for (A) the whole repetition, (B) the concentric phase and (C) the eccentric phase; plotting conventions and significance notation as in Fig. 3. (D) The same index in the concentric and the eccentric phase within each variant, as mean $\pm$ standard error of the mean, which is the comparison underlying the variant by phase interaction; horizontal bars connect the two phases and report the paired comparison after the Holm-Bonferroni correction applied within each variant (* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$). Note that panel D has its own vertical scale because it shows means rather than distributions. ADP, pull with maintained scapular adduction; NAP, pull without scapular adduction; KTP, pull in a kyphotic thoracic position.

Supplementary Files

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