Supplementary material

Supplementary Table 1

As described in the manuscript text, it provides the definitions and computational formulas for all EMG-derived variables used in your study. This table organizes the features into several domains. Feature extraction was automated with custom MATLAB scripts.

Features	Definition	Computational formula
Root Mean Square (RMS)	Represents the overall magnitude of the EMG signal, reflecting average muscle activation intensity.	$RMS = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i)^2}$ x_i: *filtered EMG signal at sample i* N: *number of samples*
Integrated EMG (iEMG)	Cumulative measure of total muscle activity over a period.	$iEMG = \int_0^T \lvert x(t)\rvert dt$ $iEMG \approx \sum_{n=1}^{N}\lvert x[n]\rvert \cdot \Delta t$ $iEMG \approx \Delta t\left(\frac{\lvert x[1]\rvert}{2} + \sum_{n=2}^{N-1}\lvert x[n]\rvert + \frac{\lvert x[N]\rvert}{2}\right)$ $x(t)$: *EMG signal as a function of time* T: *duration of the signal* $x[n]$: *EMG signal at sample n* N: *number of samples* Δt: *sampling interval*
Peak Amplitude	Maximum absolute amplitude of the EMG signal.	$Peak\ Amplitude = \max_{0 \le t \le T}\lvert x(t)\rvert$ $x(t)$: *EMG signal as a function of time* T: *duration of the signal*
Co-contraction Index (CCI)	Degree of simultaneous activation between agonist–antagonist muscle pairs (e.g., RF–BFs, TA–MG).	$x_{norm}(t) = \frac{x(t)}{\max(\lvert x(t)\rvert)}$ $CCI = \frac{\sum_t(\lvert EMGa_{norm}(t)\rvert \cdot \lvert EMGan_{norm}(t)\rvert)}{\sum_t(\lvert EMGa_{norm}(t)\rvert + \lvert EMGan_{norm}(t)\rvert)}$ $x(t)$: *EMG signal at time t* $x_{norm}(t)$: *normalized EMG signal* $\max(\lvert x(t)\rvert)$: *maximum absolute amplitude of the EMG signal over the entire duration* $EMGa_{norm}(t)$: *normalized agonist EMG signal* $EMGan_{norm}(t)$: *normalized antagonist EMG signal*
Median Frequency	Frequency below which 50% of the total EMG power spectrum is contained.	$x(f) = FFT\{x(t)\}$ $P(f) = \left\lvert\frac{X(f)}{N}\right\rvert$

		$$C(f) = \sum_{i=0}^{k} P(f_i)$$ $$P_{total} = C(f_{max})$$ $$f_{med} \text{ such that } C(f_{med}) \geq \frac{P_{total}}{2}$$ $x(t)$: EMG signal in the time domain $X(f)$: Fourier transform of $x(t)$ $x(t)$: EMG signal in the time domain N: number of samples $P(f)$: amplitude spectrum (magnitude normalized by N) $C(f_k)$: cumulative sum of spectral power up to frequency bin f_k P_{total}: cumulative spectral power across all frequency bins
Mean Frequency	Power-weighted average frequency of the EMG spectrum.	$$f_{mean} = \frac{\sum_{i=1}^{N} f_i \cdot P(f_i)}{\sum_{i=1}^{N} P(f_i)}$$ f_i: frequency at the i^{th} bin $P(f_i)$: power (or amplitude spectrum) at frequency f_i N: total number of frequency bins
Frequency Band Power (20–150 Hz)	Power of EMG within a specific frequency range, reflecting muscle recruitment dynamics.	$$P_{band} = \sum_{f=f_{20}}^{f_{150}} P(f)$$ $P(f)$: power spectrum at frequency f f_{20}: lower cutoff frequency (20 Hz) f_{150}: upper cutoff frequency (150 Hz)
Entropy	Complexity and irregularity of the EMG frequency spectrum.	$$H = -\sum_{i=1}^{N} P(f_i) \log (P(f_i) + \epsilon)$$ $P(f_i)$: power spectrum at frequency bin f_i N: total number of frequency bins ϵ: small constant to avoid taking the logarithm of zero
AP SD	The standard deviation (SD) of the EMG signal in the anteroposterior directions, quantifying variability in muscle activation, reflecting postural stability.	$$AP\_SD = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} (x_i - \bar{x})^2}$$ x_i: anteroposterior displacement at sample i $\bar{x}$: mean values of AP displacement N: number of samples
ML SD	The SD of the EMG signal in the mediolateral directions, quantifying variability in muscle activation, reflecting lateral stability.	$$ML\_SD = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} (y_i - \bar{y})^2}$$ y_i: midiolateral displacement at sample i $\bar{y}$: mean values of ML displacement N: number of samples