Additional file 1: Supplementary Materials

Neuromuscular Control During Tai Chi in Individuals With Knee Osteoarthritis: Broadly Preserved Muscle Synergy Architecture With Selective Alterations in Functional Recruitment

Scope and guide to contents

Purpose and relationship to the main article. Additional file 1 provides the detailed evidence supporting the results reported in the main article. It expands the condensed main-text presentation with participant-level baseline characteristics, condition-level statistical results, the full series of movement-specific figures, and technical information on non-negative matrix factorization (NMF), rank selection, synergy matching, and statistical inference. Its purpose is to make the reported findings transparent and auditable at the participant, condition, synergy, and muscle levels.

Organisation of this file. The numbered sections follow the sequence of the corresponding Methods and Results subsections in the main article:

1. participant-level baseline characteristics for the 52 participants with knee osteoarthritis (KOA) and 17 healthy controls (HC);
2. methodological support for muscle-synergy extraction, comprising the NMF specification, consensus and matching procedures, and rank/VAF selection curves;
3. spatial-structure results in the main-text sequence: synergy number, similarity and variability, and muscle-weight comparisons;
4. recruitment results in main-text order: activation-profile inference, functional contribution, and the across-movement key-muscle profile;
5. the five-measure descriptive movement synthesis.

The typeset tables provide complete results where they remain compact and otherwise show prespecified summaries or FDR-significant subsets. The condition-level figures retain individual participant observations where applicable.

NMF reproducibility and matching. The following implementation details apply throughout the synergy analyses:

- **Objective / solver / initialisation:** Frobenius-norm NMF used coordinate descent with deterministic NNDSVD initialisation, eliminating factorisation randomness.
- **Shared basis:** consensus clustering of 50 restarts (k-means on L2-normalised W columns); the centroids formed the shared basis.
- **Cross-subject identity:** free-fit subject- and trial-level synergies were Hungarian-aligned to the shared basis, so index k identifies the same module across participants.
- **Rank:** smallest k with global VAF ≥ 0.90, else the $< 5\%$-incremental-VAF elbow (per-condition curves in Fig. S1).
- **Rank-diagnostic subsampling:** conditions exceeding 8000 time columns used a reproducible uniform sample without replacement (8000 columns) for VAF and cophenetic diagnostics; smaller conditions used all columns. Final NMF extraction always used the full pooled matrix.

Companion machine-readable results. Additional file 2, `Supplementary_Tables.xlsx`, is the authoritative machine-readable companion to this document. Its `README` sheet provides a contents guide and row counts for the included result tables. Worksheet prefixes match the numbered tables in this document: S2 contains the synergy-number results (17 rows); S3–S4, matched-synergy structure and variability (125 rows); S5, muscle-weight comparisons (1584 rows); S6, activation-profile summaries (99 rows); S7, activation-profile clusters (34 rows); S8, directional timing results (2 rows); S9, annotated activation-profile clusters (34 rows); S10–S11, functional-contribution comparisons (272 rows); and S12, the five-measure descriptive index (17 rows). The workbook should be used when complete machine-readable values or downstream reanalysis are required.

Analysis unit and inferential conventions. The participant, never the trial, is the unit of inference. Synergy-number and muscle-weight comparisons use Welch's t-test when both groups pass the Shapiro–Wilk normality check and the Mann–Whitney U test otherwise; BH-FDR is applied across the 17 conditions for synergy number and across the 16-muscle family within each condition–synergy for muscle weights. Participant-level deviations from the shared synergy reference are compared with Mann–Whitney U tests and BH-FDR across the 125 matched synergies. Functional contribution is analysed as a 16-part composition by a two-sided studentized permutation test on centered-log-ratio values (9,999 label permutations), with BH-FDR across all 272 muscle–condition comparisons as the primary multiplicity correction. The corresponding percentile-bootstrap 95% confidence intervals (2000 within-group resamples) are pointwise and are not multiplicity-adjusted. Activation-profile inference uses cluster-based permutation testing with cluster-level correction. Functional-contribution analyses use available cases without imputation.

Terminology, coding, and numbering. An *analysis condition* is one movement–side combination. Seven movements are analysed separately by left or right stance leg; QS, SS, and SZS are not split by side and are coded NA, yielding 17 conditions from 10 movements. Conditions use compact Pinyin-initial movement codes in the data and figures, whereas the main article uses the corresponding English names. Abbreviations are: KOA, knee osteoarthritis; HC, healthy controls; QS, Opening Form; DJG, Repulse Monkey; LXAB, Brush Knee and Twist Step; YMFZ, Part the Wild Horse's Mane; YS, Cloud Hands; JJDL, Golden Rooster Stands on One Leg; DJ, Heel Kick; LQW, Grasp the Sparrow's Tail; SZS, Cross Hands; SS, Closing Form; L/R, left/right stance leg; NA, no side-specific split; BF, biceps femoris; MG, medial gastrocnemius; GMx, gluteus maximus; GMd, gluteus medius; RF, rectus femoris; TA, tibialis anterior; VL, vastus lateralis; VM, vastus medialis; L/R prefixes denote left/right side. See main-text Fig. 1 for movement demonstrations and the full English–Pinyin mapping. Synergies are numbered from 1 ("Syn 1, Syn 2, ...") in this document to match figure-panel order; Additional file 2 also retains the 0-based `synergy_id` used by the analysis pipeline.

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S1 Per-participant baseline characteristics

Table S1 lists the baseline characteristics of all 69 participants (52 KOA, 17 HC) whose surface-EMG trials entered the synergy analysis, de-identified by sequential code. Each participant was matched to a record in the study baseline file. The main-text Table 1 reports the group-level descriptive statistics and the between-group comparison; these full participant-level baseline data provide the underlying per-participant values. Sex is coded M/F; BMI is computed as weight/height^2. KL grade, symptom duration and Tai Chi experience are clinical/exposure descriptors ("–" = not recorded or not applicable: HC have no KOA-specific measures). A substantial long-term Tai Chi practice history was recorded only for HC01–HC10 (10–27 years); the remaining seven controls (HC11–HC17) had no recorded long-term practice and were assigned 2 months (≈0.2 years).

Table S1: Per-participant baseline characteristics of all analysed participants. ID, de-identified sequential code; KOA, knee osteoarthritis; HC, healthy controls; Sex, M/F; Age in years; Height in m; Weight in kg; BMI, body-mass index in kg/m^2; KL, Kellgren–Lawrence radiographic grade; Duration, symptom duration in months; TC exp., Tai Chi practice experience in years. "–" denotes a value not recorded or not applicable.

ID	Group	Sex	Age	Height	Weight	BMI	KL	Duration	TC exp.
HC01	HC	M	57	1.70	55.0	19.0	–	–	27.0
HC02	HC	F	73	1.56	56.5	23.2	–	–	10.0
HC03	HC	M	55	1.62	66.0	25.1	–	–	11.0
HC04	HC	M	62	1.72	66.8	22.6	–	–	12.0
HC05	HC	M	63	1.73	75.0	25.1	–	–	24.0
HC06	HC	M	72	1.67	63.8	22.9	–	–	20.0
HC07	HC	F	56	1.60	75.0	29.3	–	–	23.0
HC08	HC	F	66	1.59	53.5	21.2	–	–	15.0
HC09	HC	F	66	1.56	45.0	18.5	–	–	15.0
HC10	HC	F	63	1.62	52.0	19.8	–	–	12.0
HC11	HC	M	52	1.62	62.5	23.8	–	–	0.2

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Table S1 continued

ID	Group	Sex	Age	Height	Weight	BMI	KL	Duration	TC exp.
HC12	HC	M	62	1.68	61.5	21.8	–	–	0.2
HC13	HC	M	70	1.69	71.7	25.1	–	–	0.2
HC14	HC	F	67	1.57	51.2	20.8	–	–	0.2
HC15	HC	F	70	1.49	48.7	21.9	–	–	0.2
HC16	HC	F	59	1.66	69.6	25.3	–	–	0.2
HC17	HC	F	54	1.65	61.0	22.4	–	–	0.2
KOA01	KOA	F	55	1.60	60.4	23.4	3	60	0.2
KOA02	KOA	F	69	1.57	51.3	20.7	3	120	0.2
KOA03	KOA	F	71	1.56	48.4	19.9	1	6	0.2
KOA04	KOA	F	51	1.58	51.1	20.5	1	120	0.2
KOA05	KOA	M	54	1.83	92.0	27.5	2	48	0.2
KOA06	KOA	F	51	1.47	51.9	24.0	3	60	0.2
KOA07	KOA	M	68	1.62	51.8	19.8	2	240	0.2
KOA08	KOA	F	66	1.60	46.5	18.2	3	120	0.2
KOA09	KOA	M	71	1.73	80.4	27.0	2	180	0.2
KOA10	KOA	F	57	1.59	50.2	19.9	2	120	0.2
KOA11	KOA	F	64	1.56	61.2	25.0	2	60	0.2
KOA12	KOA	F	51	1.63	74.2	27.9	1	204	0.2
KOA13	KOA	F	60	1.56	63.7	26.2	3	120	0.2
KOA14	KOA	M	61	1.72	76.8	26.1	3	24	0.2
KOA15	KOA	F	57	1.66	77.0	27.9	3	6	0.2
KOA16	KOA	F	68	1.67	70.3	25.4	2	120	0.2
KOA17	KOA	F	70	1.57	58.5	23.6	2	6	0.2
KOA18	KOA	M	68	1.59	63.9	25.3	2	60	0.2
KOA19	KOA	F	64	1.55	62.2	25.9	2	120	0.2
KOA20	KOA	F	61	1.66	77.0	27.9	2	120	0.2
KOA21	KOA	F	61	1.68	66.5	23.6	2	60	0.2
KOA22	KOA	M	60	1.76	73.1	23.5	2	84	0.2
KOA23	KOA	M	62	1.64	55.4	20.6	2	120	0.2
KOA24	KOA	F	60	1.54	60.4	25.3	2	84	0.2
KOA25	KOA	M	67	1.57	62.8	25.3	2	60	0.2
KOA26	KOA	F	69	1.56	56.3	23.0	2	60	0.2
KOA27	KOA	M	77	1.64	63.7	23.7	3	120	0.2
KOA28	KOA	F	56	1.64	65.2	24.3	3	36	0.2
KOA29	KOA	F	60	1.64	68.4	25.4	3	30	0.2
KOA30	KOA	M	60	1.71	72.4	24.8	3	12	0.2
KOA31	KOA	M	68	1.79	73.1	22.7	2	36	0.2
KOA32	KOA	F	64	1.59	48.1	19.0	2	36	0.2
KOA33	KOA	F	56	1.58	57.0	22.8	2	36	0.2
KOA34	KOA	F	55	1.54	52.0	21.9	2	24	0.2
KOA35	KOA	F	57	1.66	70.5	25.6	2	12	0.2
KOA36	KOA	F	64	1.57	52.5	21.3	2	240	0.2
KOA37	KOA	F	60	1.58	49.0	19.6	2	97	0.2
KOA38	KOA	F	64	1.53	54.5	23.3	2	84	0.2
KOA39	KOA	F	62	1.58	67.5	27.0	2	134	0.2
KOA40	KOA	F	70	1.56	60.5	24.9	3	120	0.2
KOA41	KOA	M	68	1.71	72.5	24.8	2	48	0.2
KOA42	KOA	F	55	1.60	61.0	23.8	2	3	0.2
KOA43	KOA	F	63	1.58	58.0	23.2	2	24	0.2

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Table S1 continued

ID	Group	Sex	Age	Height	Weight	BMI	KL	Duration	TC exp.
KOA44	KOA	F	62	1.60	65.0	25.4	3	324	0.2
KOA45	KOA	F	56	1.54	66.0	27.8	3	144	0.2
KOA46	KOA	F	58	1.51	55.0	24.1	2	36	0.2
KOA47	KOA	F	70	1.59	66.0	26.1	2	120	0.2
KOA48	KOA	F	57	1.55	60.5	25.2	3	24	0.2
KOA49	KOA	F	58	1.58	55.3	22.2	2	72	0.2
KOA50	KOA	F	60	1.62	52.0	19.8	2	240	0.2
KOA51	KOA	M	69	1.68	77.0	27.3	3	240	0.2
KOA52	KOA	F	66	1.45	44.0	20.9	2	24	0.2

S2 Rank / VAF selection curves

VAF-versus-k curves for each condition and group, documenting the rank-selection rule (smallest k with VAF ≥ 0.90, else the $< 5\%$-incremental-VAF elbow).

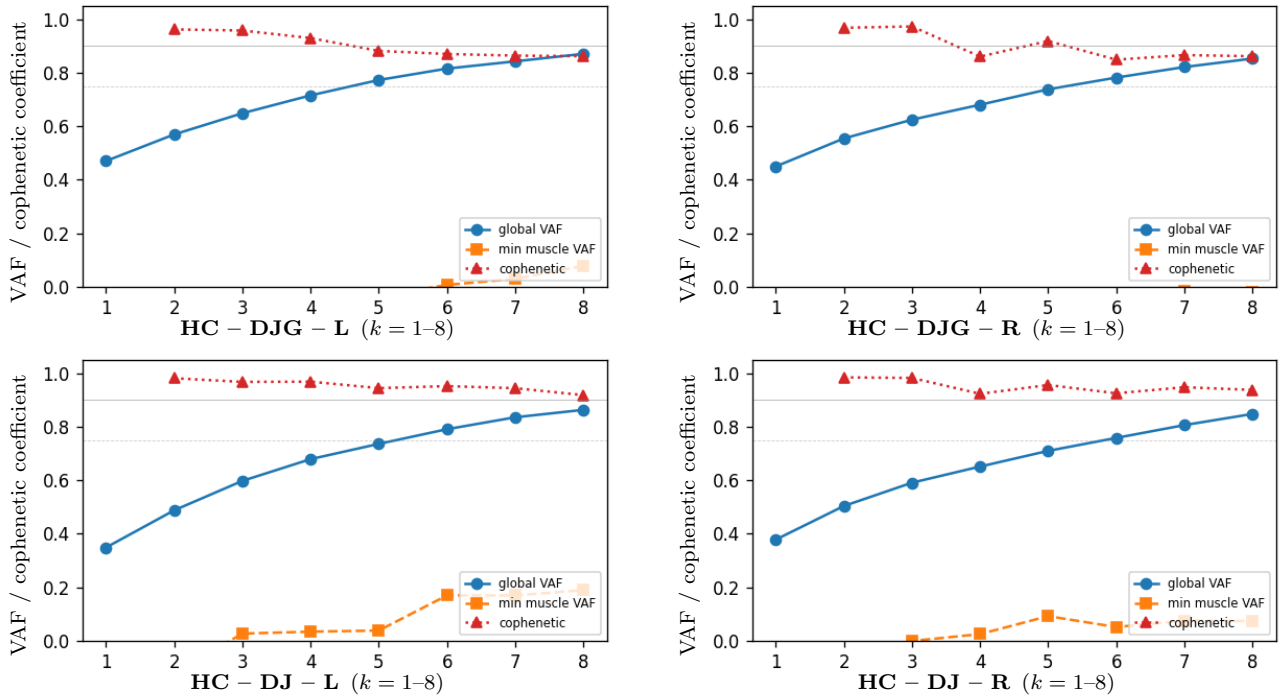


Figure S1: Variance-accounted-for (VAF) versus synergy rank k for each condition and group (34 panels). The y-axis reports global VAF, minimum-muscle VAF and the cophenetic coefficient, as identified in the legend. Each bottom label gives group, movement, stance and the displayed candidate-rank range. Continued on the next pages. Abbreviations: KOA, knee osteoarthritis; HC, healthy controls; VAF, variance accounted for; QS, Opening Form; DJG, Repulse Monkey; LXAB, Brush Knee and Twist Step; YMFZ, Part the Wild Horse's Mane; YS, Cloud Hands; JJDL, Golden Rooster Stands on One Leg; DJ, Heel Kick; LQW, Grasp the Sparrow's Tail; SZS, Cross Hands; SS, Closing Form; L/R, left/right stance leg; NA, no side-specific split.

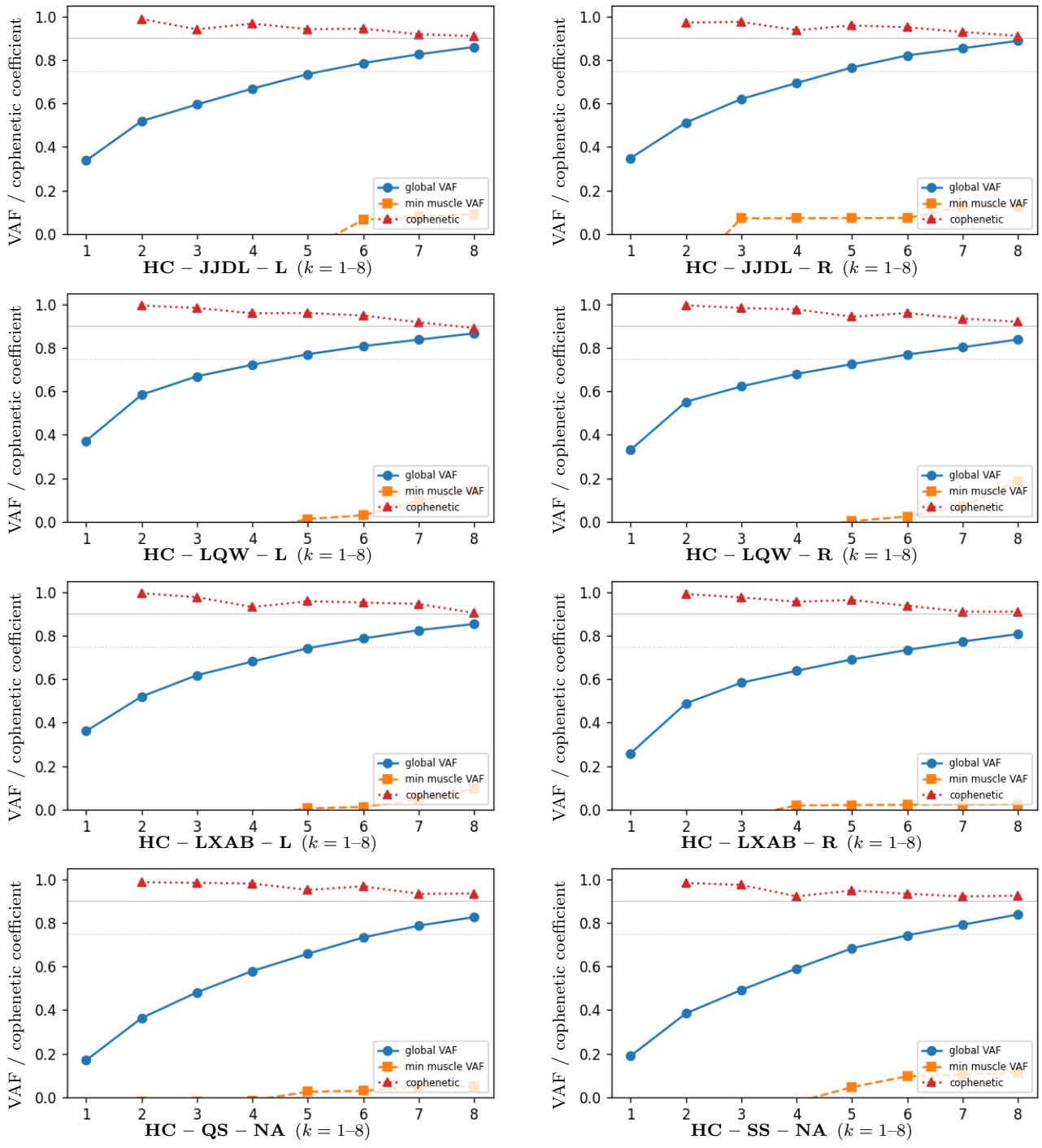


Figure S1: Variance-accounted-for curves (continued).

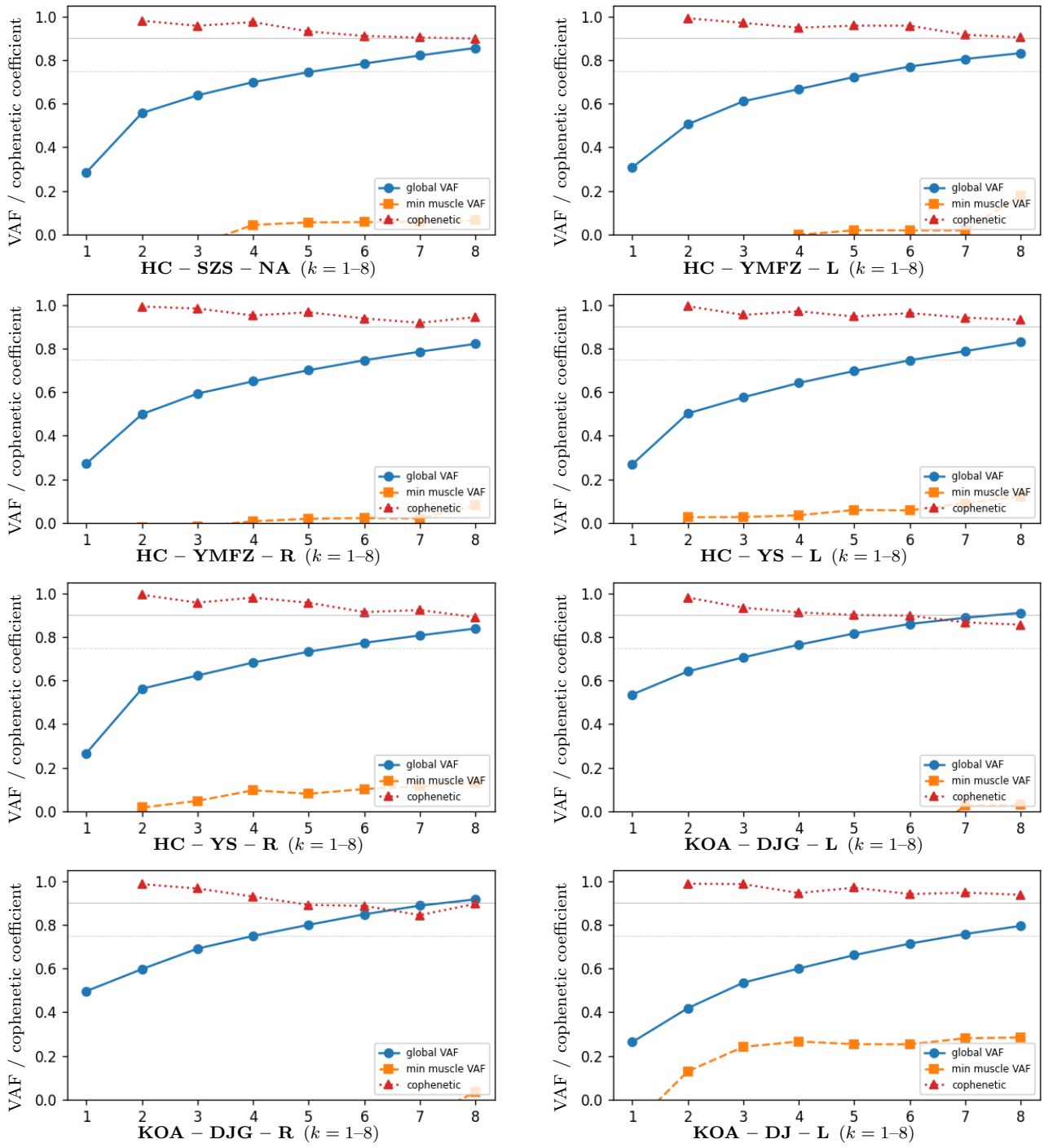


Figure S1: Variance-accounted-for curves (continued).

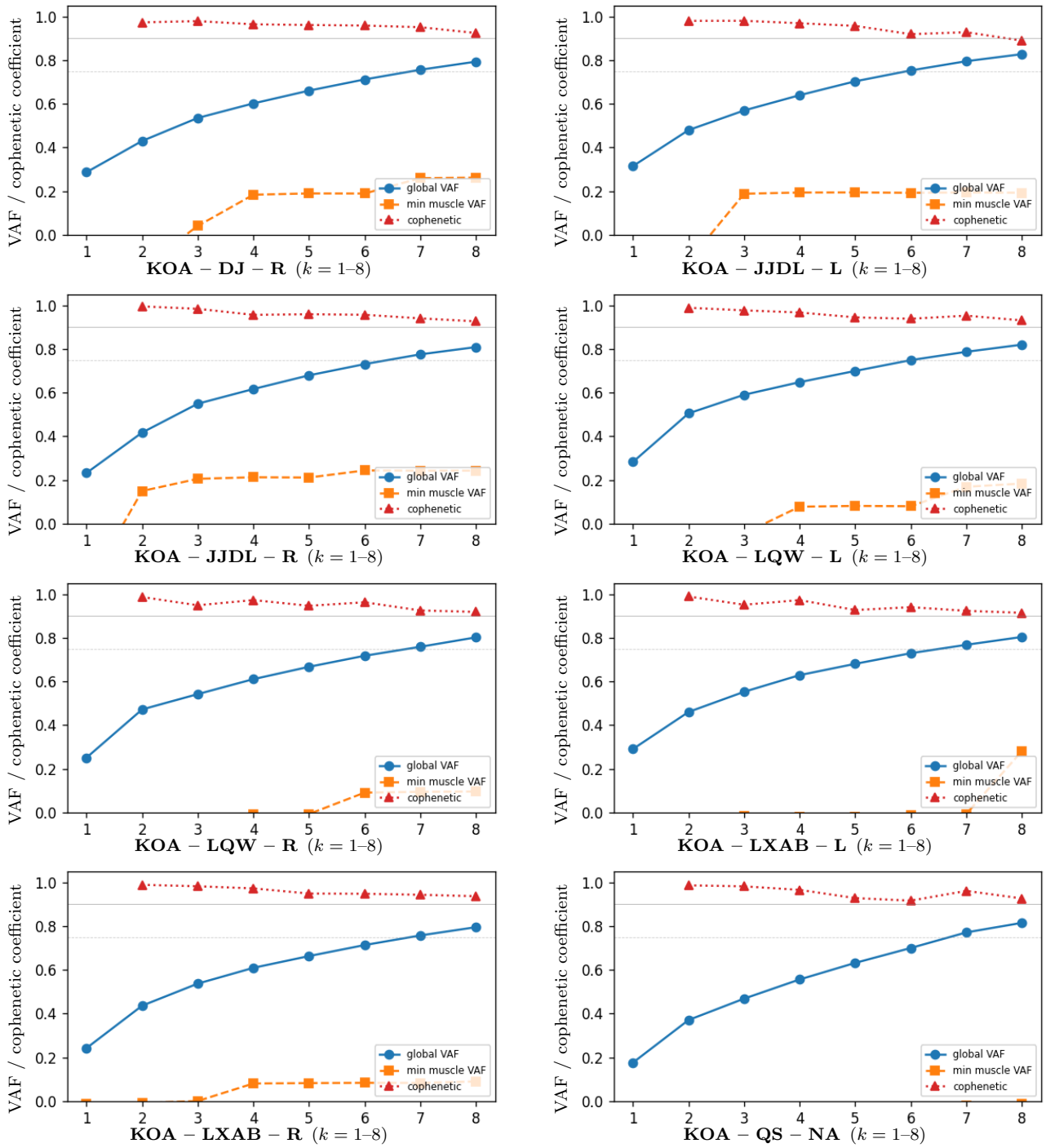


Figure S1: Variance-accounted-for curves (continued).

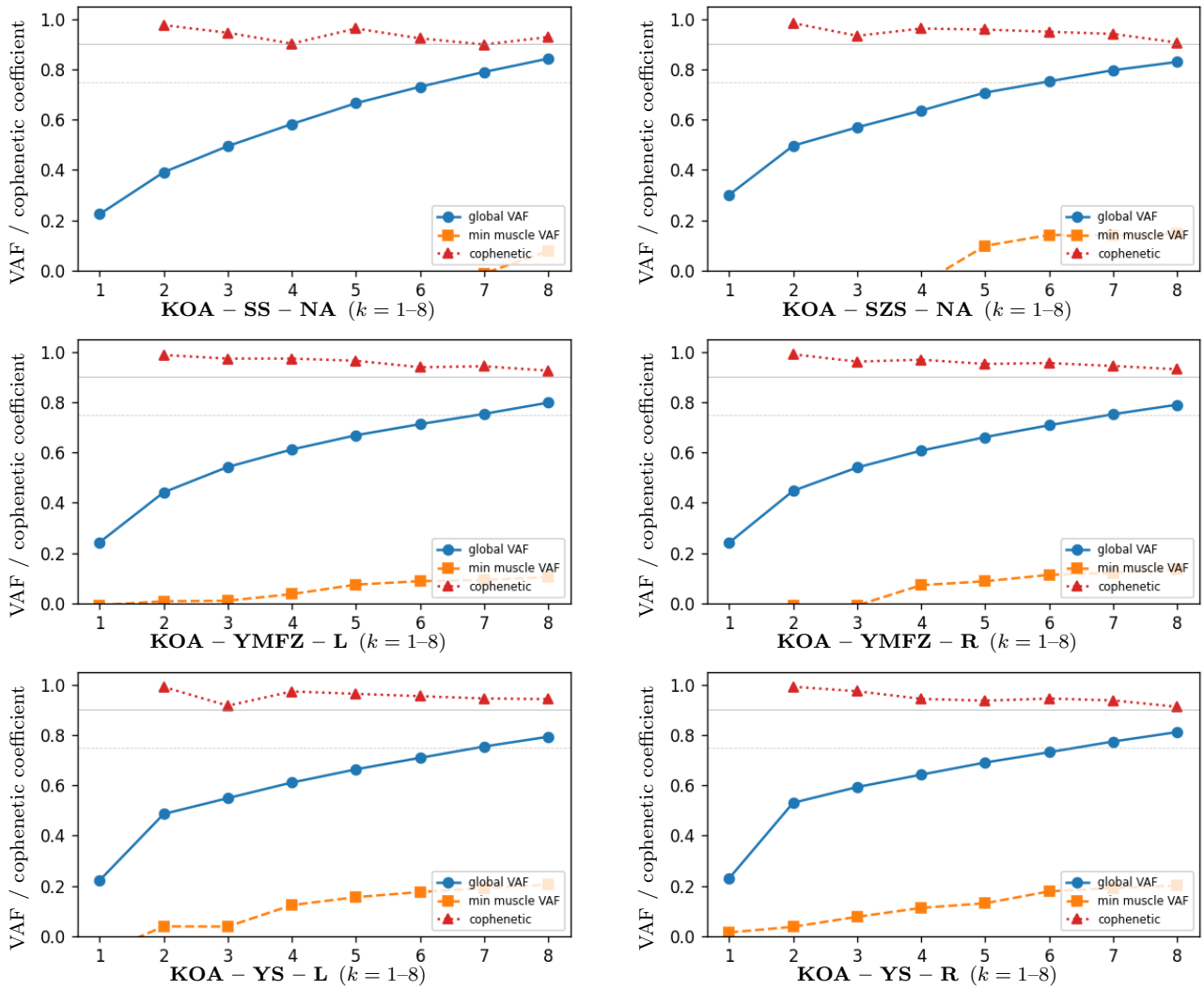


Figure S1: Variance-accounted-for curves (continued).

S3 Synergy number per condition

Table S2: Per-condition synergy number by group: per-subject selected count summary, test and p-values (0/17 conditions significant after FDR). Values are median (IQR). Abbreviations and marks: KOA, knee osteoarthritis; HC, healthy controls; FDR, false discovery rate; IQR, interquartile range; Mv, movement; Side "–", single-stance movement; QS, Opening Form; DJG, Repulse Monkey; LXAB, Brush Knee and Twist Step; YMFZ, Part the Wild Horse's Mane; YS, Cloud Hands; JJDL, Golden Rooster Stands on One Leg; DJ, Heel Kick; LQW, Grasp the Sparrow's Tail; SZS, Cross Hands; SS, Closing Form; L/R, left/right stance leg; NA, no side-specific split.

Mv	Side	n_{KOA}	n_{HC}	KOA	HC	Test	p	p_{FDR}
DJ	L	50	14	8.0 (8.0-8.0)	7.0 (5.0-8.0)	Mann-Whitney U	0.011	0.093
DJ	R	52	16	8.0 (7.0-8.0)	6.5 (6.0-8.0)	Mann-Whitney U	0.027	0.115
DJG	L	48	14	4.0 (4.0-5.0)	4.0 (4.0-4.8)	Mann-Whitney U	0.950	0.952
DJG	R	47	15	4.0 (3.0-5.0)	5.0 (4.5-6.5)	Mann-Whitney U	0.008	0.093
JJDL	L	52	16	6.0 (5.0-7.0)	5.5 (5.0-6.0)	Mann-Whitney U	0.076	0.231
JJDL	R	50	16	7.0 (7.0-8.0)	6.0 (4.0-7.2)	Mann-Whitney U	0.017	0.096
LQW	L	52	17	8.0 (7.0-8.0)	7.0 (6.0-8.0)	Mann-Whitney U	0.132	0.282
LQW	R	51	17	8.0 (7.0-9.0)	7.0 (6.0-9.0)	Mann-Whitney U	0.099	0.241
LXAB	L	51	17	7.0 (6.5-8.0)	7.0 (6.0-8.0)	Mann-Whitney U	0.237	0.402
LXAB	R	52	17	8.0 (7.0-9.0)	9.0 (8.0-9.0)	Mann-Whitney U	0.214	0.402
QS	–	42	12	7.0 (6.0-7.0)	6.0 (6.0-7.0)	Mann-Whitney U	0.763	0.865
SS	–	41	14	6.0 (5.0-7.0)	6.5 (6.0-7.0)	Mann-Whitney U	0.081	0.231
SZS	–	49	17	7.0 (6.0-8.0)	7.0 (6.0-8.0)	Mann-Whitney U	0.327	0.505
YMFZ	L	51	17	8.0 (7.0-8.0)	8.0 (7.0-8.0)	Mann-Whitney U	0.952	0.952
YMFZ	R	52	17	8.0 (7.0-9.0)	8.0 (7.0-8.0)	Mann-Whitney U	0.459	0.632
YS	L	50	17	8.0 (7.0-8.8)	8.0 (7.0-8.0)	Mann-Whitney U	0.483	0.632
YS	R	48	16	7.0 (6.0-8.0)	7.0 (6.0-7.2)	Mann-Whitney U	0.590	0.717

S4 Synergy similarity and inter-individual variability

Table S3 summarises synergy similarity per analysis condition: the distribution of matched-pair cosine similarity (KOA vs HC), the number of synergies exceeding the prespecified similarity threshold (cosine ≥ 0.80), and the median deviation of individual participants' synergies from the shared reference in each group. Across all conditions, 95/125 matched synergies exceeded the threshold (median cosine 0.95), and the inter-individual deviation did not differ between groups for any synergy (0/125 after FDR). Table S4 lists the sub-threshold matched synergies to make the main-text Fig. 4 counts transparent; all 125 per-synergy values are provided in `Supplementary_Tables.xlsx`, sheet `S3-S4_structure_variability`.

Table S3: Per-condition synergy-similarity summary. Cosine: median (min–max) of matched-pair similarity. ≥ 0.80: pairs exceeding the prespecified similarity threshold. KOA/HC dev.: median deviation of individual synergies from the shared reference. Abbreviations: KOA, knee osteoarthritis; HC, healthy controls; dev., deviation; QS, Opening Form; DJG, Repulse Monkey; LXAB, Brush Knee and Twist Step; YMFZ, Part the Wild Horse's Mane; YS, Cloud Hands; JJDL, Golden Rooster Stands on One Leg; DJ, Heel Kick; LQW, Grasp the Sparrow's Tail; SZS, Cross Hands; SS, Closing Form; L/R, left/right stance leg; NA, no side-specific split.

Condition	Cosine median (range)	≥ 0.80	KOA dev.	HC dev.
DJ-L	0.96 (0.04–0.99)	6/8	0.90	0.92
DJ-R	0.93 (0.65–0.98)	6/7	0.83	0.88
DJG-L	0.60 (0.20–0.97)	1/4	0.78	0.77
DJG-R	0.76 (0.18–0.92)	2/5	0.80	0.65
JJDL-L	0.97 (0.85–0.98)	7/7	0.91	0.85
JJDL-R	0.99 (0.67–0.99)	5/7	0.92	0.90
LQW-L	0.96 (0.59–1.00)	6/8	0.94	0.91
LQW-R	0.98 (0.30–1.00)	8/9	0.88	0.90
LXAB-L	0.95 (0.17–1.00)	6/8	0.88	0.90
LXAB-R	0.95 (0.31–1.00)	6/9	0.96	0.88
QS	0.95 (0.04–1.00)	5/7	0.83	0.82
SS	0.96 (0.46–0.99)	5/6	0.76	0.76
SZS	0.98 (0.81–0.99)	8/8	0.94	0.94
YMFZ-L	0.97 (0.18–1.00)	6/8	0.90	0.92
YMFZ-R	0.92 (0.81–1.00)	8/8	0.93	0.92
YS-L	0.92 (0.09–0.99)	5/8	0.92	0.93
YS-R	0.86 (0.37–0.99)	5/8	0.82	0.81

Table S4: Sub-threshold matched synergies underlying the synergy-similarity counts. Rows list the matched synergy pairs with KOA–HC group-pattern cosine similarity below the prespecified similarity threshold (< 0.80). Synergy numbers are 1-based to match the figures. The complete set of 125 matched-pair cosine values is provided in `Supplementary_Tables.xlsx`, sheet `S3-S4_structure_variability`. Abbreviations: QS, Opening Form; DJG, Repulse Monkey; LXAB, Brush Knee and Twist Step; YMFZ, Part the Wild Horse's Mane; YS, Cloud Hands; JJDL, Golden Rooster Stands on One Leg; DJ, Heel Kick; LQW, Grasp the Sparrow's Tail; SZS, Cross Hands; SS, Closing Form; L/R, left/right stance leg; NA, no side-specific split.

Condition	Syn	Total matched	Cosine
DJ-L	3	8	0.781
DJ-L	8	8	0.036
DJ-R	7	7	0.653
DJG-L	1	4	0.724
DJG-L	3	4	0.483
DJG-L	4	4	0.197
DJG-R	2	5	0.756
DJG-R	4	5	0.183
DJG-R	5	5	0.205
JJDL-R	4	7	0.665
JJDL-R	5	7	0.724
LQW-L	7	8	0.737
LQW-L	8	8	0.592
LQW-R	7	9	0.297
LXAB-L	6	8	0.175
LXAB-L	8	8	0.692
LXAB-R	5	9	0.314
LXAB-R	6	9	0.630
LXAB-R	7	9	0.771
QS	5	7	0.256
QS	7	7	0.036
SS	6	6	0.458
YMFZ-L	7	8	0.492
YMFZ-L	8	8	0.177
YS-L	1	8	0.752
YS-L	3	8	0.743
YS-L	8	8	0.086
YS-R	1	8	0.768
YS-R	6	8	0.376
YS-R	7	8	0.374

S5 Muscle-weight comparisons and per-condition figures

Table S5 lists the 25/1584 muscle weights that differed between groups after FDR correction.

Table S5: Muscle weights significant after FDR correction (25/1584). Descriptives are mean (SD) (Welch) or median (IQR) (MWU). Effect size (ES): Cohen's d (Welch) or rank-biserial r (MWU). Abbreviations and marks: KOA, knee osteoarthritis; HC, healthy controls; FDR, false discovery rate; SD, standard deviation; IQR, interquartile range; MWU, Mann–Whitney U; Mv, movement; Syn, synergy; Side "–", single-stance movement; BF, biceps femoris; MG, medial gastrocnemius; GMx, gluteus maximus; GMd, gluteus medius; RF, rectus femoris; TA, tibialis anterior; VL, vastus lateralis; VM, vastus medialis; L/R prefixes denote left/right side; QS, Opening Form; DJG, Repulse Monkey; LXAB, Brush Knee and Twist Step; YMFZ, Part the Wild Horse's Mane; YS, Cloud Hands; JJDL, Golden Rooster Stands on One Leg; DJ, Heel Kick; LQW, Grasp the Sparrow's Tail; SZS, Cross Hands; SS, Closing Form; L/R, left/right stance leg; NA, no side-specific split.

Mv	Side	Syn	Muscle	KOA	HC	Test	ES	p_{FDR}
JJDL	L	4	L VM	0.00 (0.00–0.06)	0.11 (0.05–0.29)	MWU	0.62	0.002
SZS	–	3	R VM	0.00 (0.00–0.03)	0.09 (0.02–0.25)	MWU	0.56	0.004
LQW	L	1	R GMx	0.04 (0.02–0.09)	0.01 (0.00–0.03)	MWU	-0.59	0.004
DJG	L	8	L VM	0.00 (0.00–0.00)	0.01 (0.00–0.10)	MWU	0.57	0.005
YS	L	1	L TA	0.02 (0.00–0.11)	0.13 (0.07–0.17)	MWU	0.56	0.010
LQW	L	1	L RF	0.03 (0.01–0.07)	0.00 (0.00–0.02)	MWU	-0.51	0.013
JJDL	L	3	L BF	0.74 (0.07–0.93)	0.95 (0.84–0.98)	MWU	0.52	0.015
JJDL	L	3	L RF	0.07 (0.04–0.14)	0.02 (0.00–0.05)	MWU	-0.53	0.015
LQW	L	1	R GMd	0.06 (0.02–0.13)	0.02 (0.00–0.05)	MWU	-0.48	0.016
DJ	R	5	R BF	0.39 (0.14–0.62)	0.09 (0.02–0.24)	MWU	-0.53	0.019
DJ	R	5	L RF	0.14 (0.09–0.18)	0.04 (0.02–0.07)	MWU	-0.51	0.019
DJG	R	9	L GMx	0.08 (0.01–0.64)	0.01 (0.00–0.02)	MWU	-0.55	0.023
DJ	R	5	R MG	0.41 (0.14–0.58)	0.09 (0.01–0.28)	MWU	-0.47	0.025
LQW	L	1	L GMx	0.04 (0.02–0.06)	0.02 (0.01–0.04)	MWU	-0.44	0.027
DJ	L	5	L MG	0.39 (0.17–0.50)	0.05 (0.00–0.27)	MWU	-0.55	0.030
DJ	L	5	L GMx	0.33 (0.12–0.49)	0.13 (0.03–0.19)	MWU	-0.49	0.031
DJ	L	5	L BF	0.26 (0.14–0.39)	0.07 (0.01–0.21)	MWU	-0.49	0.031
YMFZ	R	3	L MG	0.18 (0.07–0.54)	0.03 (0.02–0.09)	MWU	-0.50	0.037
JJDL	L	3	R GMx	0.02 (0.01–0.04)	0.00 (0.00–0.01)	MWU	-0.45	0.037
YMFZ	R	5	L RF	0.10 (0.05–0.17)	0.04 (0.00–0.07)	MWU	-0.47	0.038
YMFZ	R	5	R GMd	0.05 (0.01–0.15)	0.01 (0.00–0.02)	MWU	-0.43	0.038
YMFZ	R	5	L VL	0.16 (0.09–0.29)	0.03 (0.01–0.09)	MWU	-0.44	0.038
YS	R	1	R GMx	0.09 (0.05–0.15)	0.04 (0.02–0.07)	MWU	-0.51	0.041
JJDL	L	4	R RF	0.21 (0.02–0.47)	0.03 (0.00–0.08)	MWU	-0.46	0.041
JJDL	R	2	L GMx	0.18 (0.09–0.33)	0.07 (0.02–0.11)	MWU	-0.50	0.043

Per-condition figures

Each condition is shown as a separate, larger figure so the muscle weights, participant datapoints, error bars and significance annotations can be inspected directly. These subject-level plots complement the pooled global basis in main-text Fig. 2. In each figure, bars show group means, error bars show SD, dots show individual participants, and brackets mark KOA–HC tests (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ raw; † also FDR-significant). Exact test statistics and FDR-corrected p values are listed in Table S5. Abbreviations: KOA, knee osteoarthritis; HC, healthy controls; FDR, false discovery rate; BF, biceps femoris; MG, medial gastrocnemius; GMx, gluteus maximus; GMd, gluteus medius; RF, rectus femoris; TA, tibialis anterior; VL, vastus lateralis; VM, vastus medialis; L/R prefixes denote left/right side; QS, Opening Form; DJG, Repulse Monkey; LXAB, Brush Knee and Twist Step; YMFZ, Part the Wild Horse's Mane; YS, Cloud Hands; JJDL, Golden Rooster Stands on One Leg; DJ, Heel Kick; LQW, Grasp the Sparrow's Tail; SZS, Cross Hands; SS, Closing Form; L/R, left/right stance leg; NA, no side-specific split.

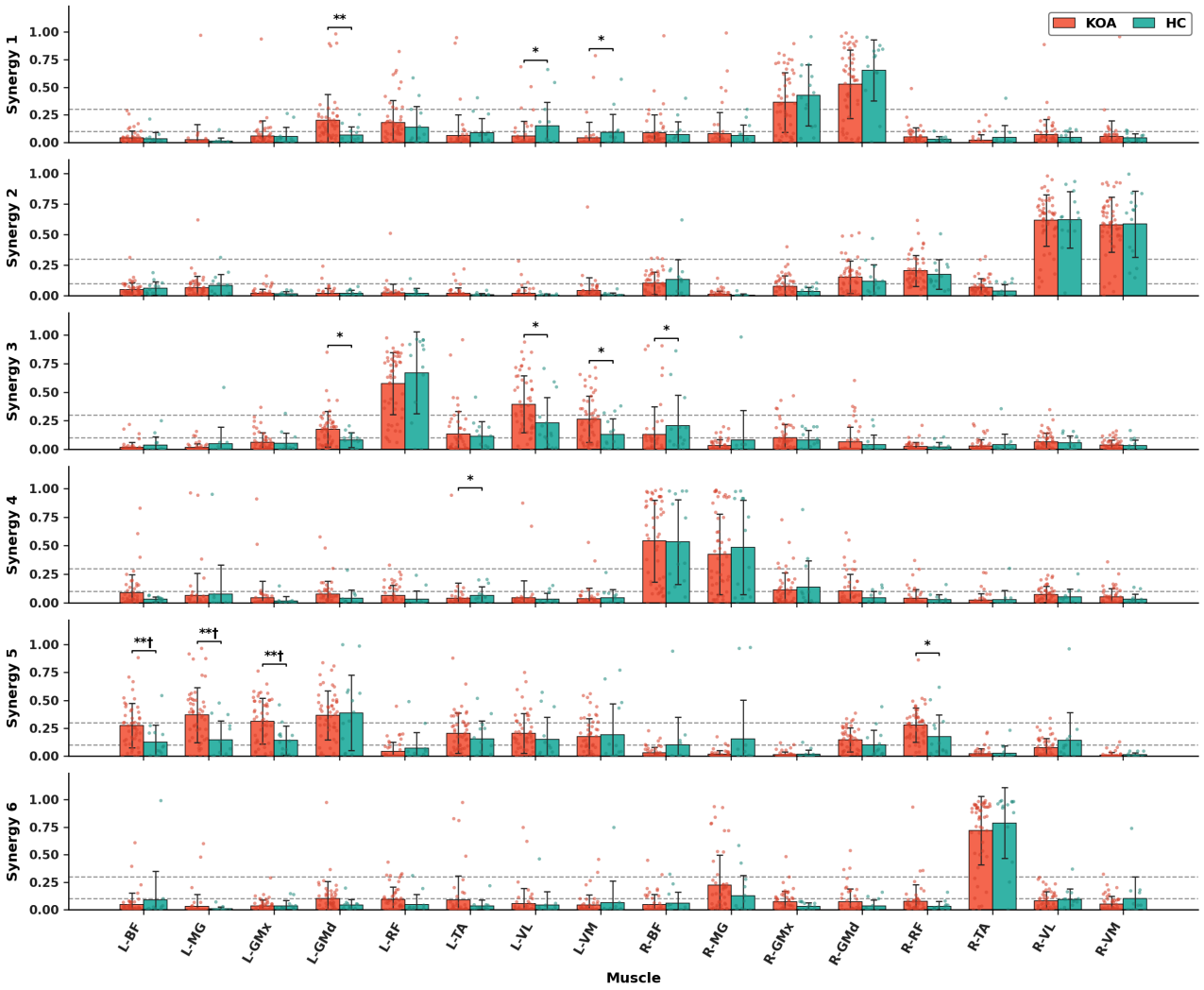


Figure S2: DJ-L muscle-weight distributions by synergy, KOA versus HC. Subject-level muscle weights in the shared basis are shown as group means (bars), SD (error bars), and individual participants (dots). Brackets mark raw KOA–HC tests (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$); † denotes FDR-corrected $p < 0.05$. Exact test statistics and FDR-corrected p values are listed in Table S5.

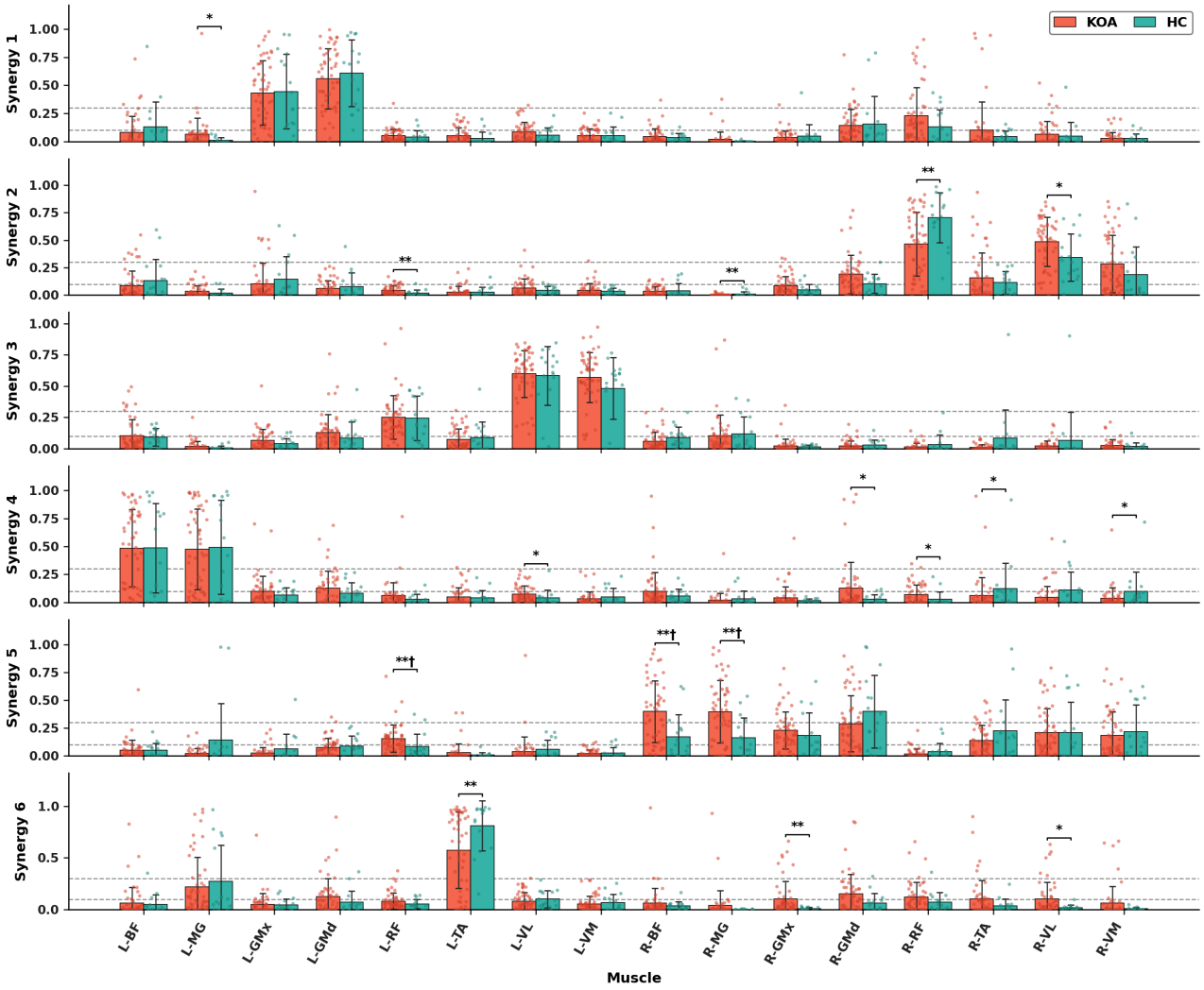


Figure S3: DJ-R muscle-weight distributions by synergy, KOA versus HC. Subject-level muscle weights in the shared basis are shown as group means (bars), SD (error bars), and individual participants (dots). Brackets mark raw KOA–HC tests (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$); † denotes FDR-corrected $p < 0.05$. Exact test statistics and FDR-corrected p values are listed in Table S5.

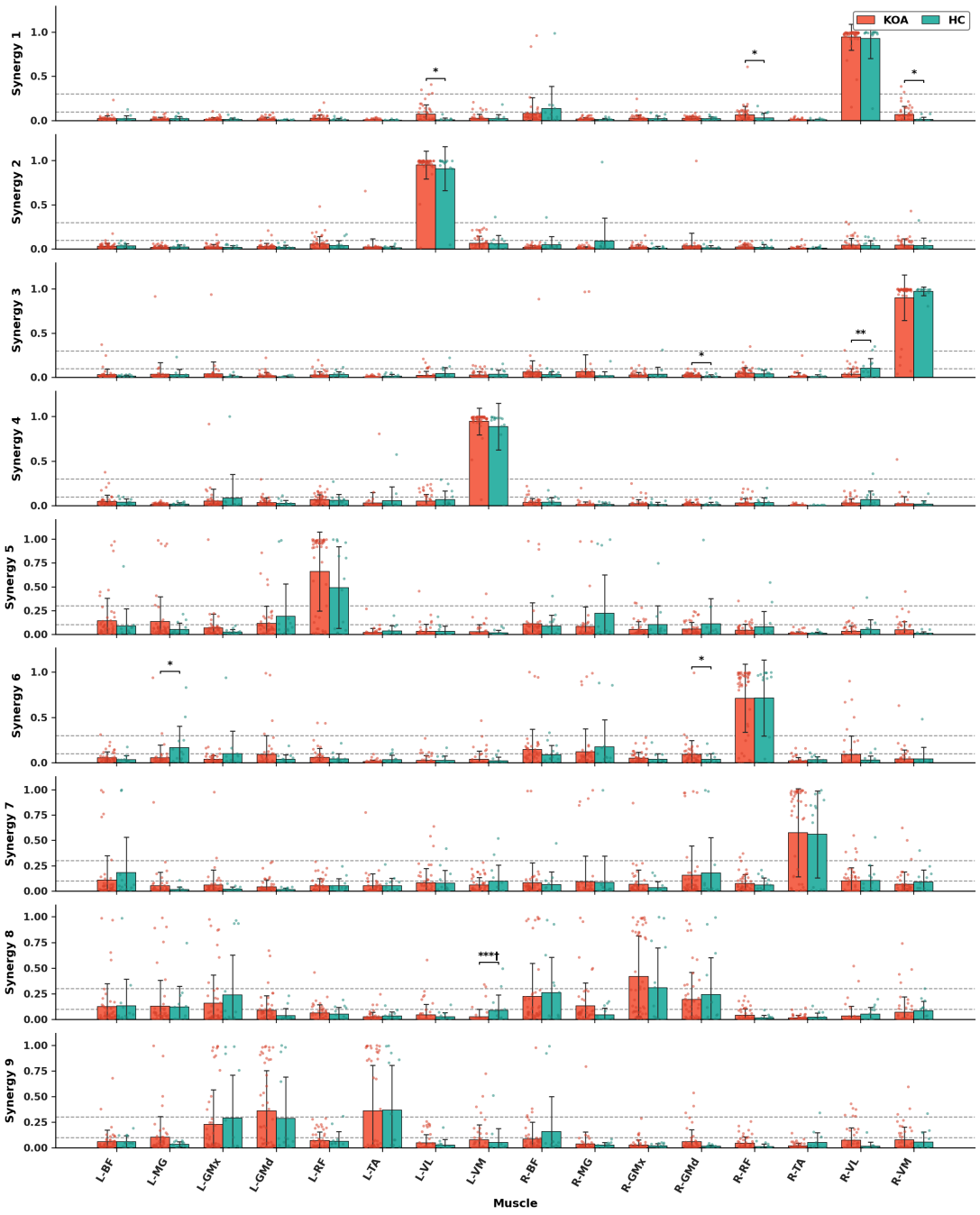


Figure S4: DJG-L muscle-weight distributions by synergy, KOA versus HC. Subject-level muscle weights in the shared basis are shown as group means (bars), SD (error bars), and individual participants (dots). Brackets mark raw KOA–HC tests (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$); † denotes FDR-corrected $p < 0.05$. Exact test statistics and FDR-corrected p values are listed in Table S5.

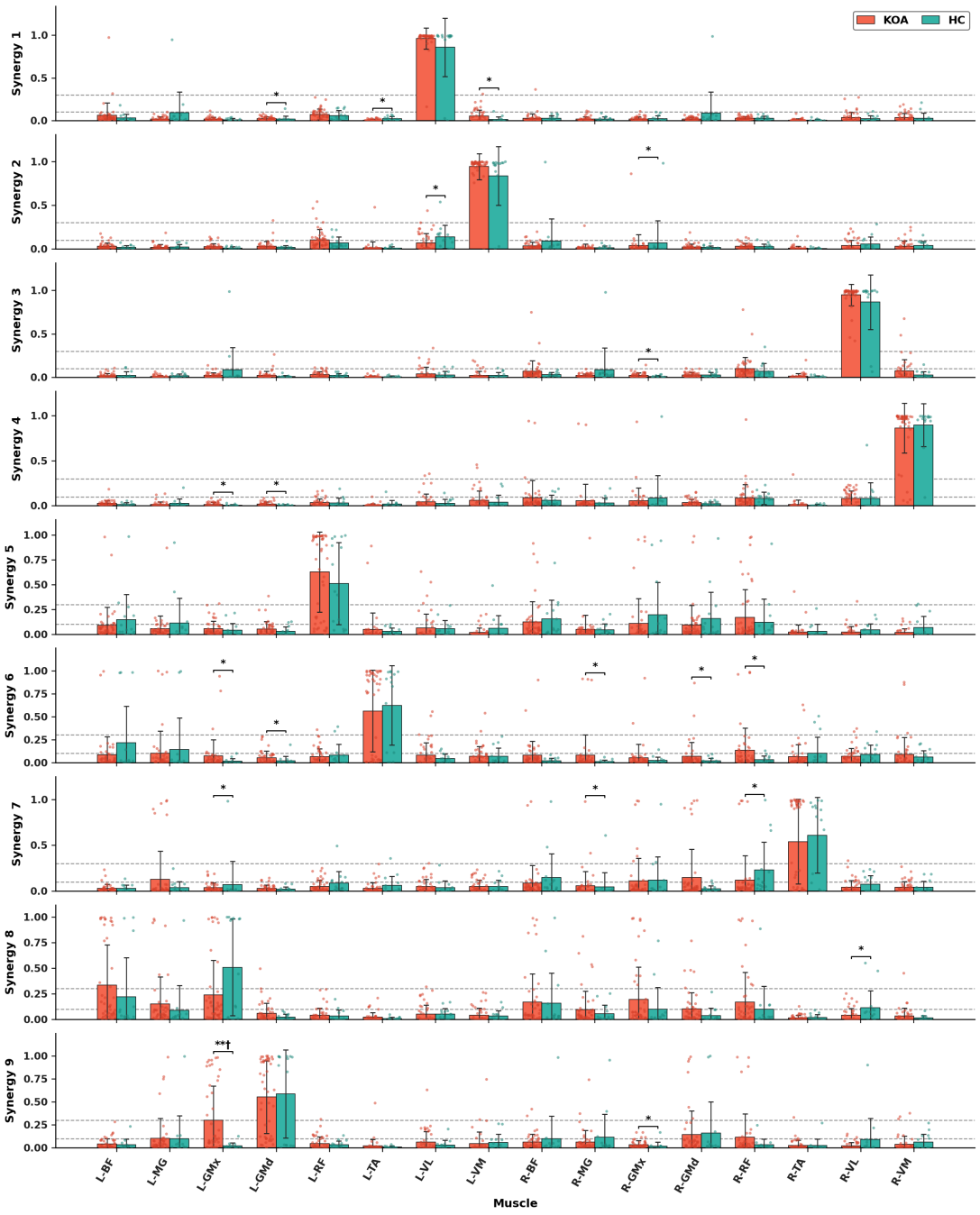


Figure S5: DJG-R muscle-weight distributions by synergy, KOA versus HC. Subject-level muscle weights in the shared basis are shown as group means (bars), SD (error bars), and individual participants (dots). Brackets mark raw KOA–HC tests (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$); † denotes FDR-corrected $p < 0.05$. Exact test statistics and FDR-corrected p values are listed in Table S5.

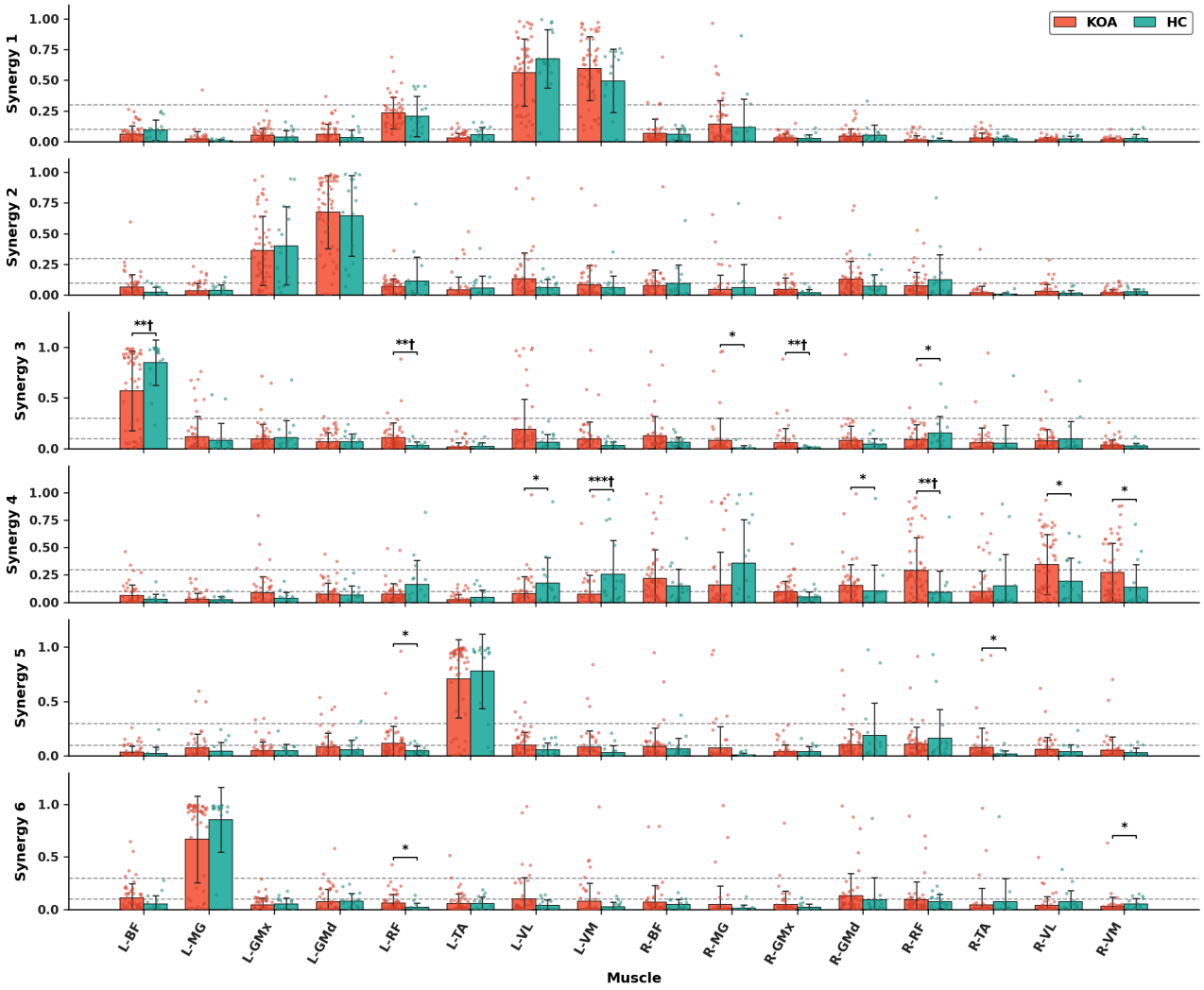


Figure S6: JJDL-L muscle-weight distributions by synergy, KOA versus HC. Subject-level muscle weights in the shared basis are shown as group means (bars), SD (error bars), and individual participants (dots). Brackets mark raw KOA–HC tests (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$); † denotes FDR-corrected $p < 0.05$. Exact test statistics and FDR-corrected p values are listed in Table S5.

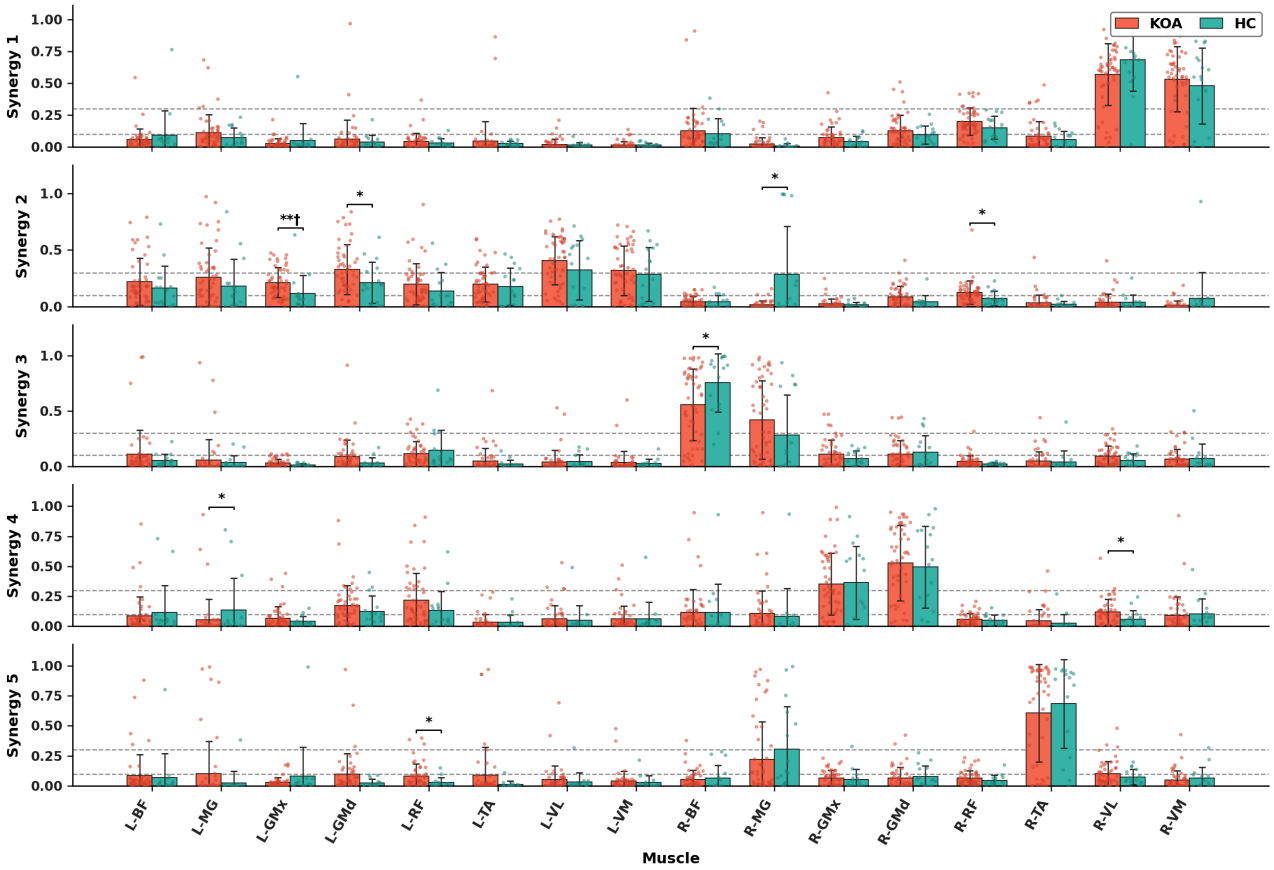


Figure S7: JJDL-R muscle-weight distributions by synergy, KOA versus HC. Subject-level muscle weights in the shared basis are shown as group means (bars), SD (error bars), and individual participants (dots). Brackets mark raw KOA–HC tests (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$); † denotes FDR-corrected $p < 0.05$. Exact test statistics and FDR-corrected p values are listed in Table S5.

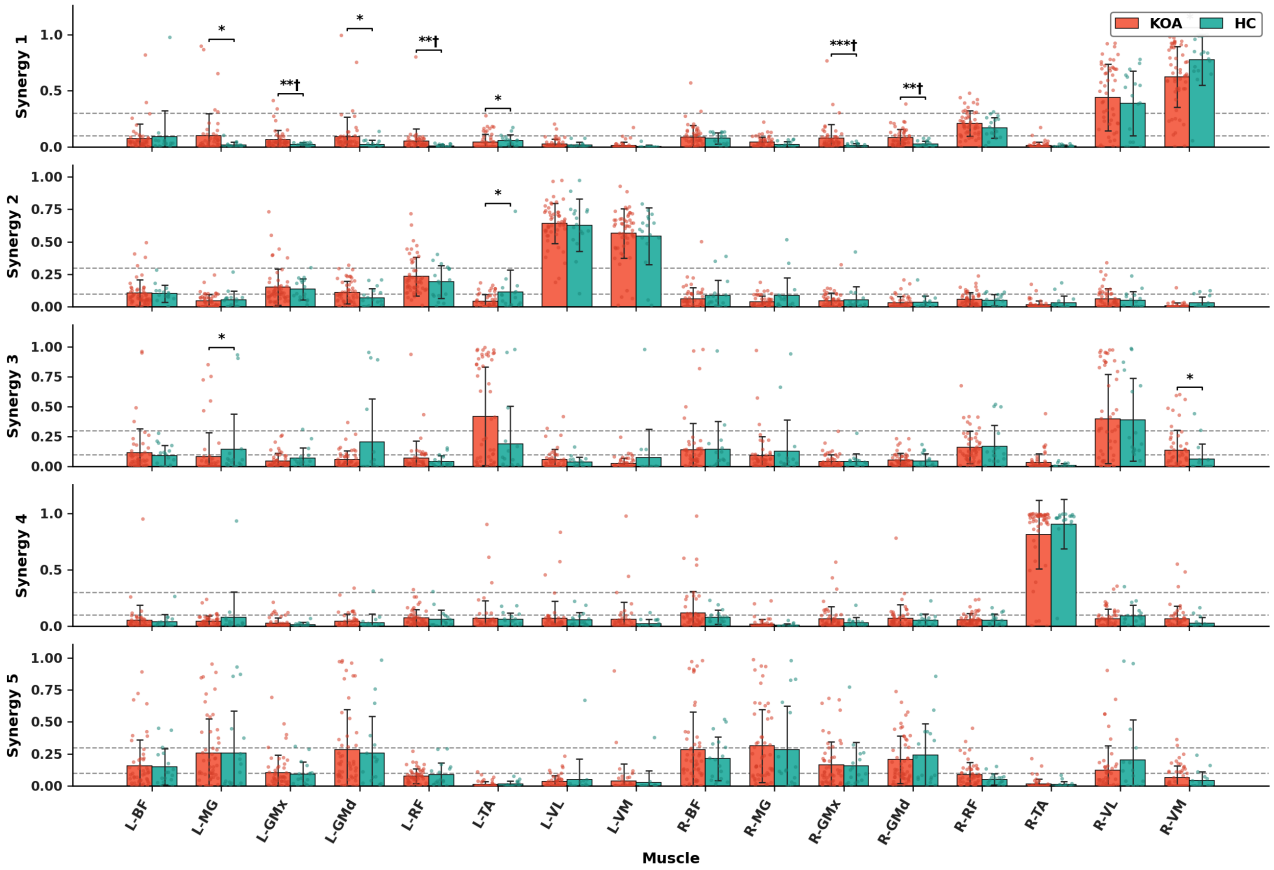


Figure S8: LQW-L muscle-weight distributions by synergy, KOA versus HC. Subject-level muscle weights in the shared basis are shown as group means (bars), SD (error bars), and individual participants (dots). Brackets mark raw KOA–HC tests (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$); † denotes FDR-corrected $p < 0.05$. Exact test statistics and FDR-corrected p values are listed in Table S5.

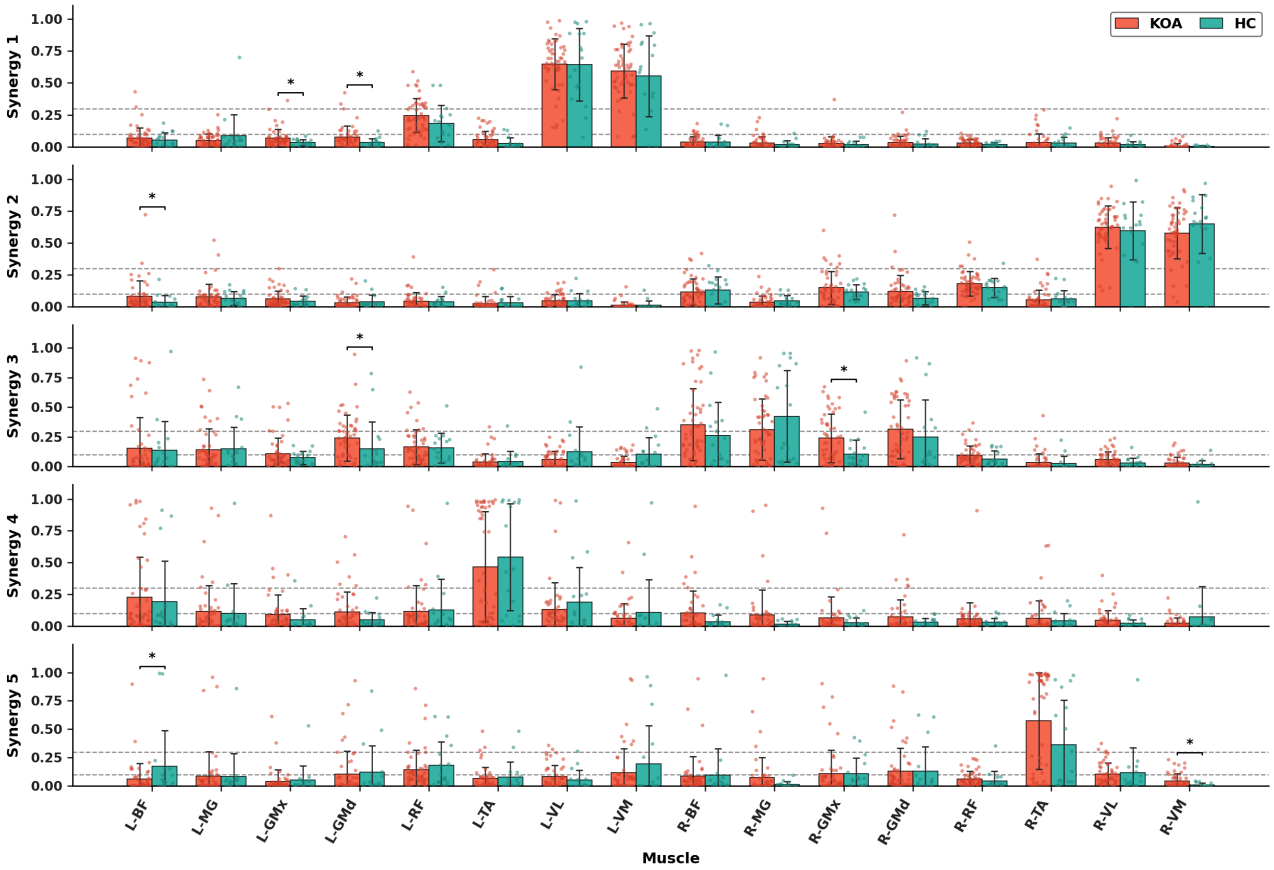


Figure S9: LQW-R muscle-weight distributions by synergy, KOA versus HC. Subject-level muscle weights in the shared basis are shown as group means (bars), SD (error bars), and individual participants (dots). Brackets mark raw KOA–HC tests (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$); † denotes FDR-corrected $p < 0.05$. Exact test statistics and FDR-corrected p values are listed in Table S5.

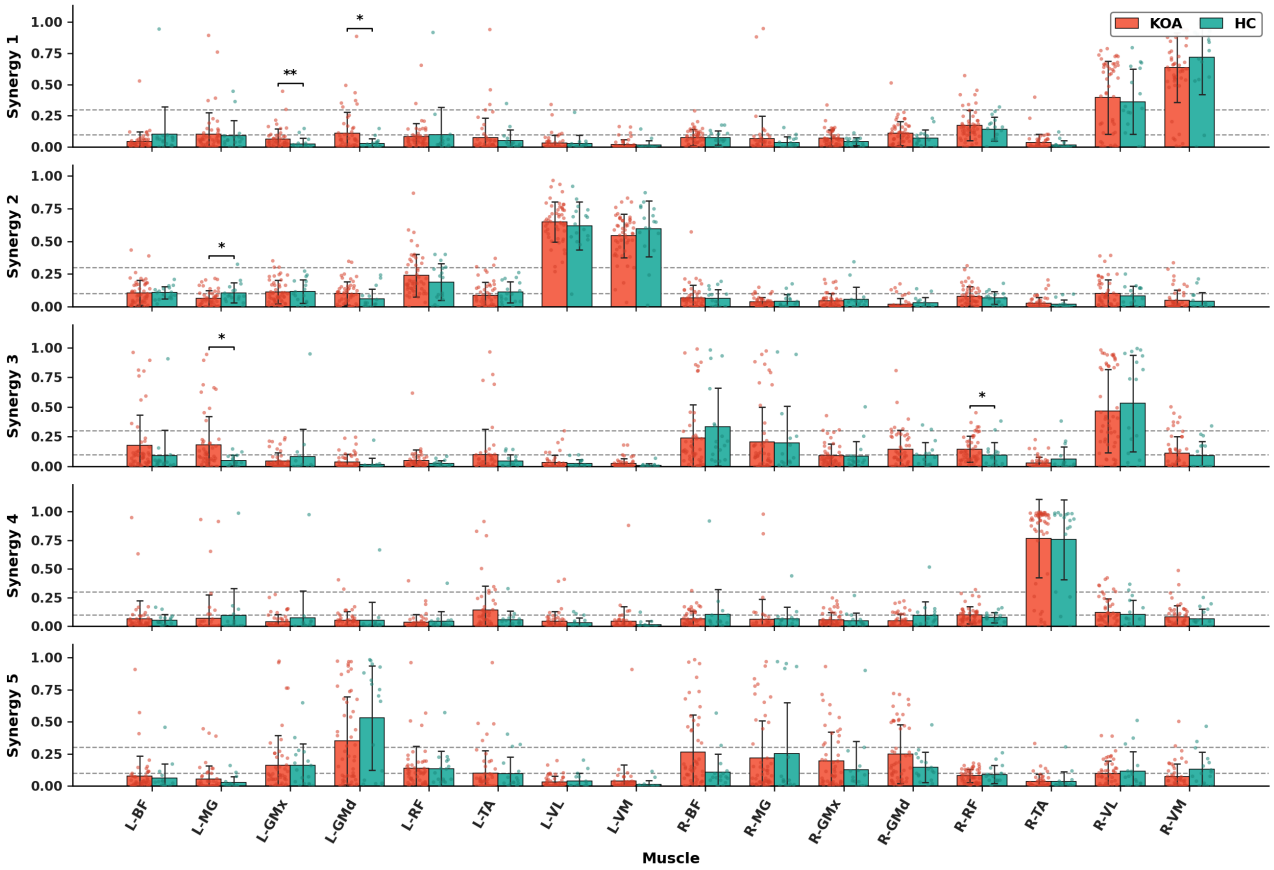


Figure S10: LXAB-L muscle-weight distributions by synergy, KOA versus HC. Subject-level muscle weights in the shared basis are shown as group means (bars), SD (error bars), and individual participants (dots). Brackets mark raw KOA–HC tests (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$); † denotes FDR-corrected $p < 0.05$. Exact test statistics and FDR-corrected p values are listed in Table S5.

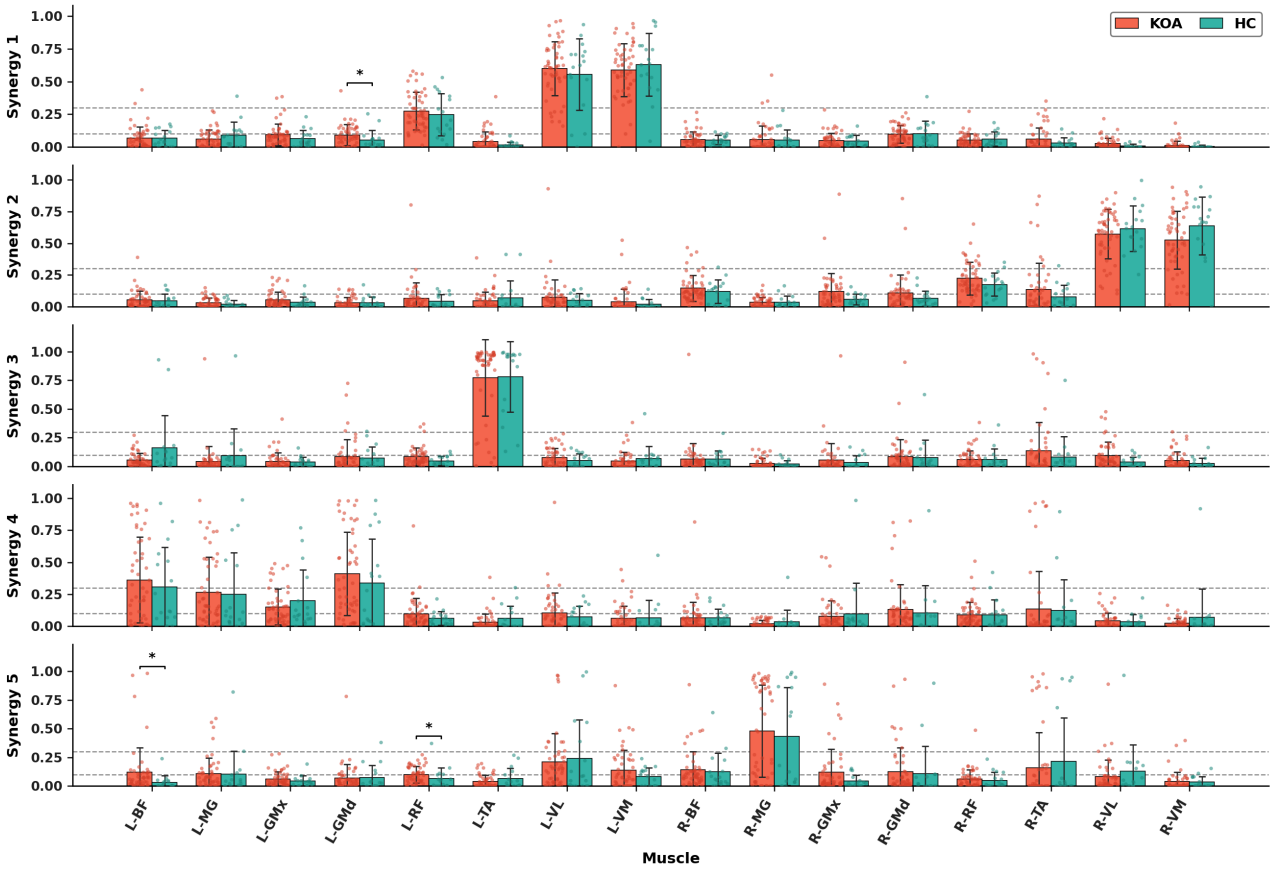


Figure S11: LXAB-R muscle-weight distributions by synergy, KOA versus HC. Subject-level muscle weights in the shared basis are shown as group means (bars), SD (error bars), and individual participants (dots). Brackets mark raw KOA–HC tests (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$); † denotes FDR-corrected $p < 0.05$. Exact test statistics and FDR-corrected p values are listed in Table S5.

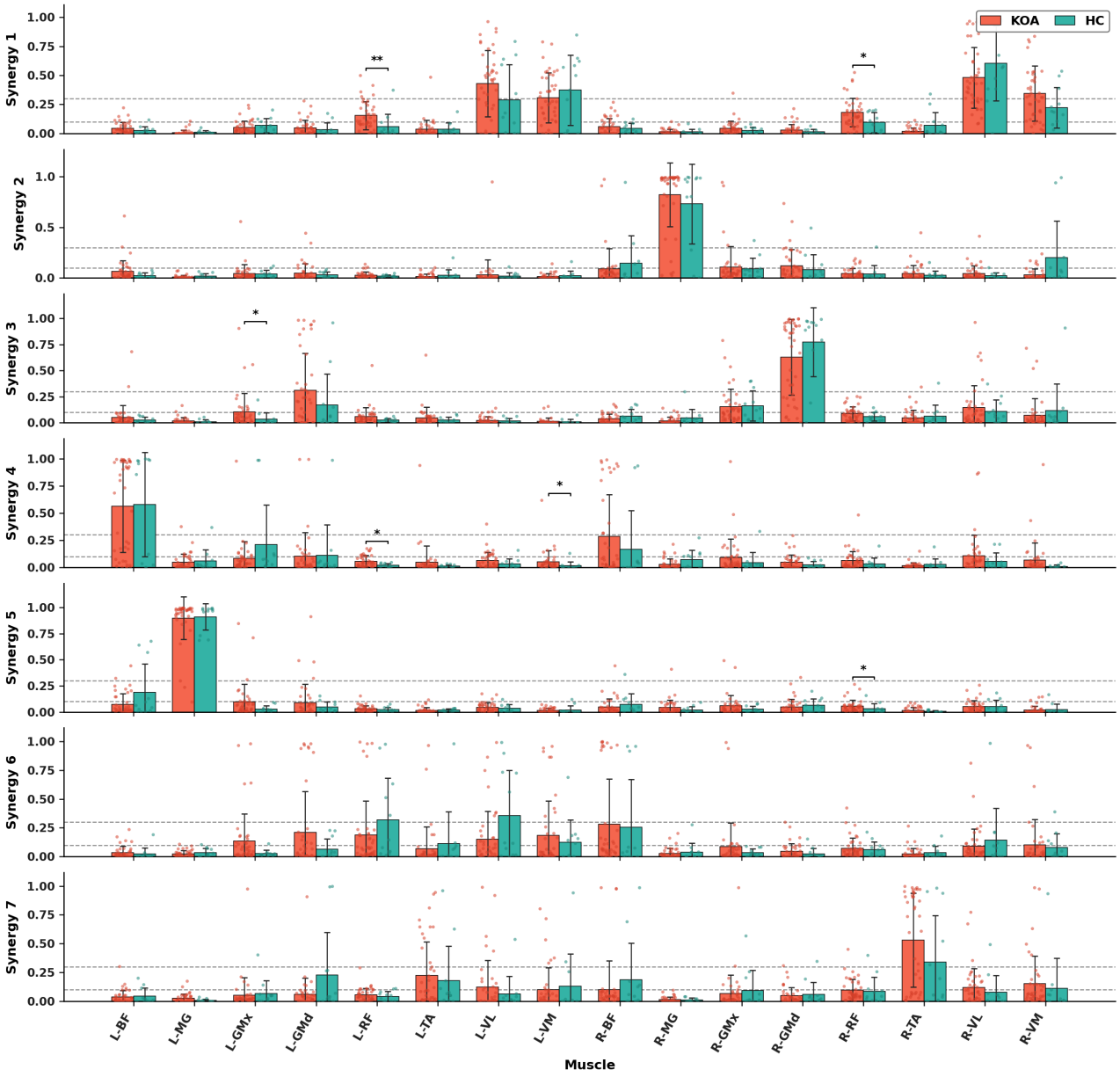


Figure S12: QS muscle-weight distributions by synergy, KOA versus HC. Subject-level muscle weights in the shared basis are shown as group means (bars), SD (error bars), and individual participants (dots). Brackets mark raw KOA–HC tests (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$); † denotes FDR-corrected $p < 0.05$. Exact test statistics and FDR-corrected p values are listed in Table S5.

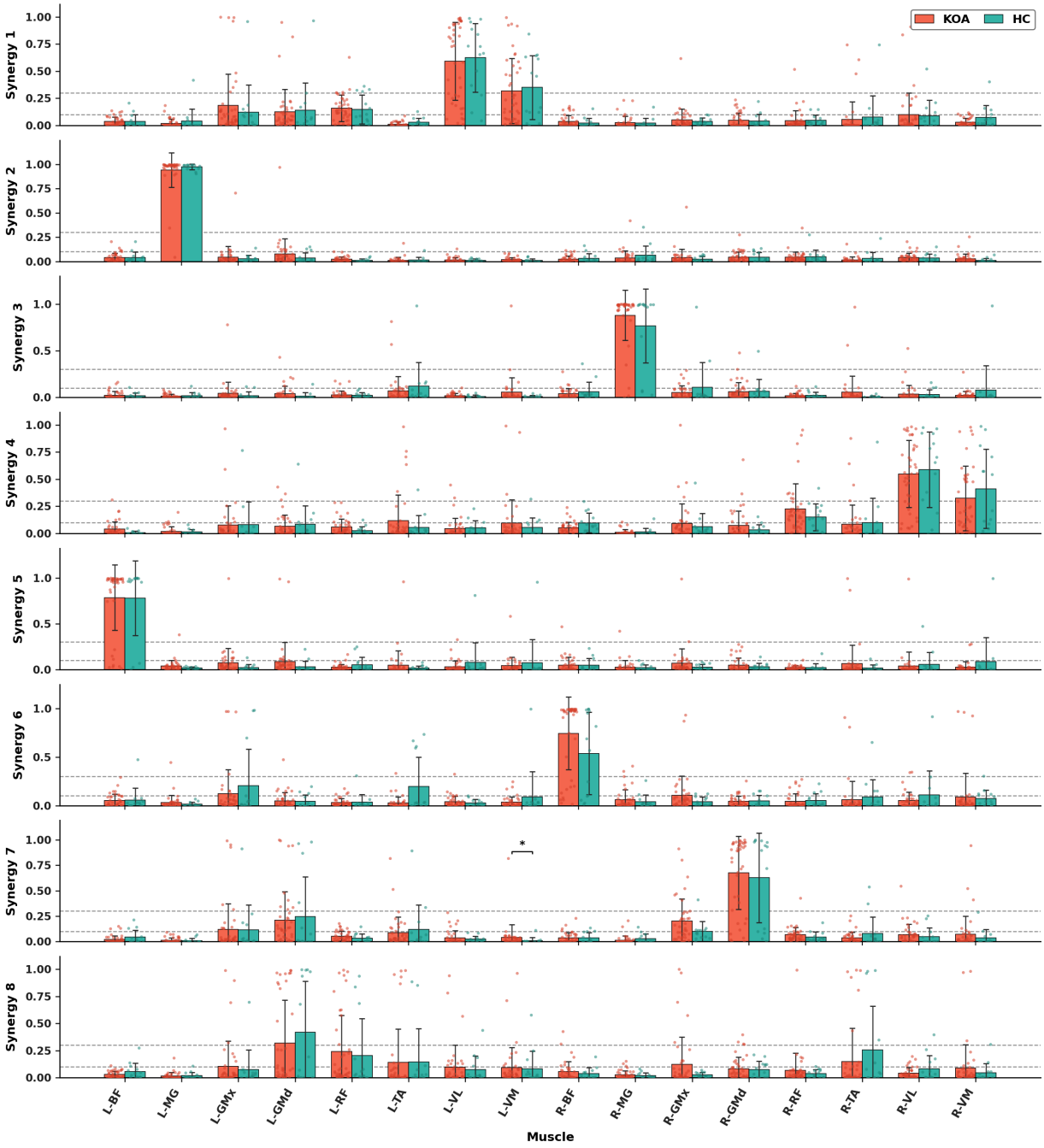


Figure S13: SS muscle-weight distributions by synergy, KOA versus HC. Subject-level muscle weights in the shared basis are shown as group means (bars), SD (error bars), and individual participants (dots). Brackets mark raw KOA–HC tests (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$); † denotes FDR-corrected $p < 0.05$. Exact test statistics and FDR-corrected p values are listed in Table S5.

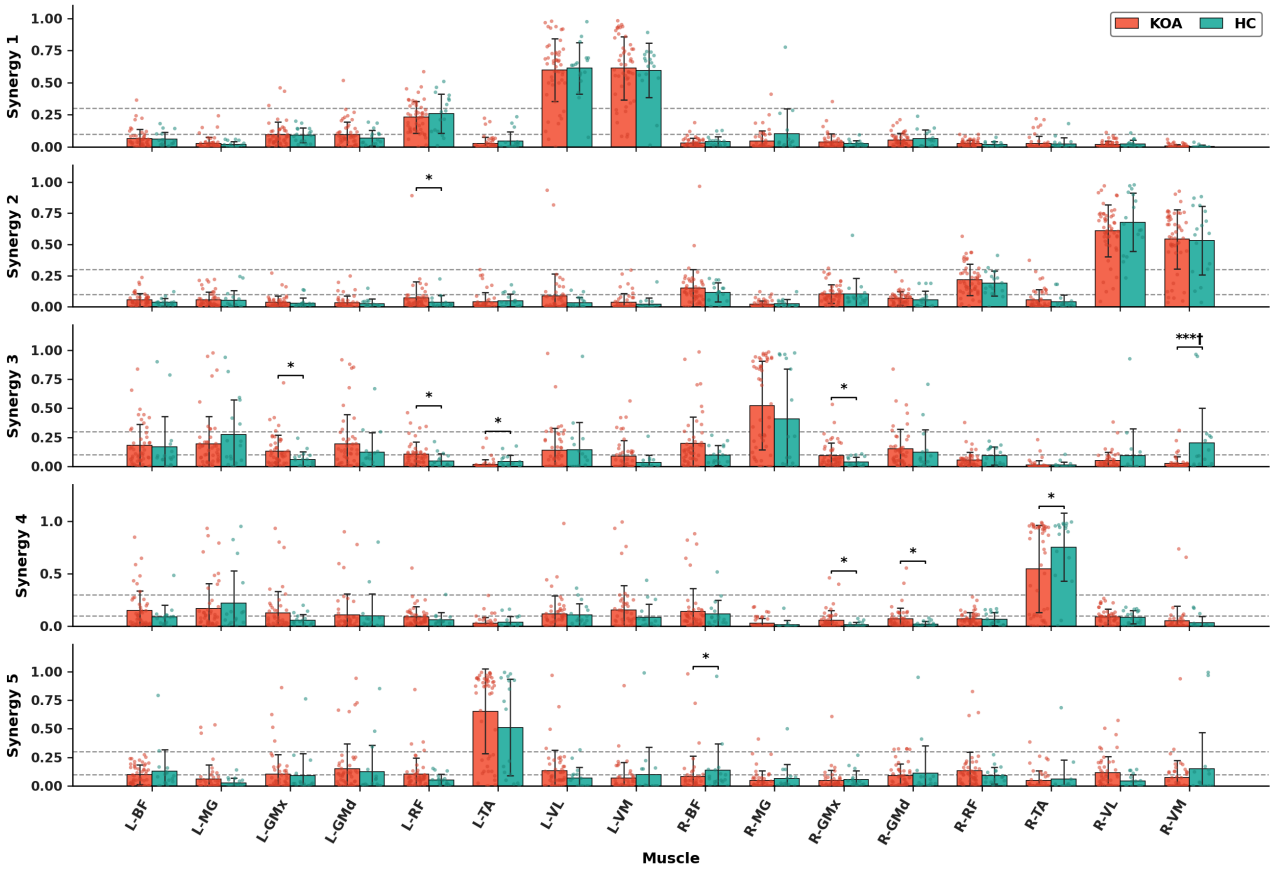


Figure S14: SZS muscle-weight distributions by synergy, KOA versus HC. Subject-level muscle weights in the shared basis are shown as group means (bars), SD (error bars), and individual participants (dots). Brackets mark raw KOA–HC tests (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$); † denotes FDR-corrected $p < 0.05$. Exact test statistics and FDR-corrected p values are listed in Table S5.

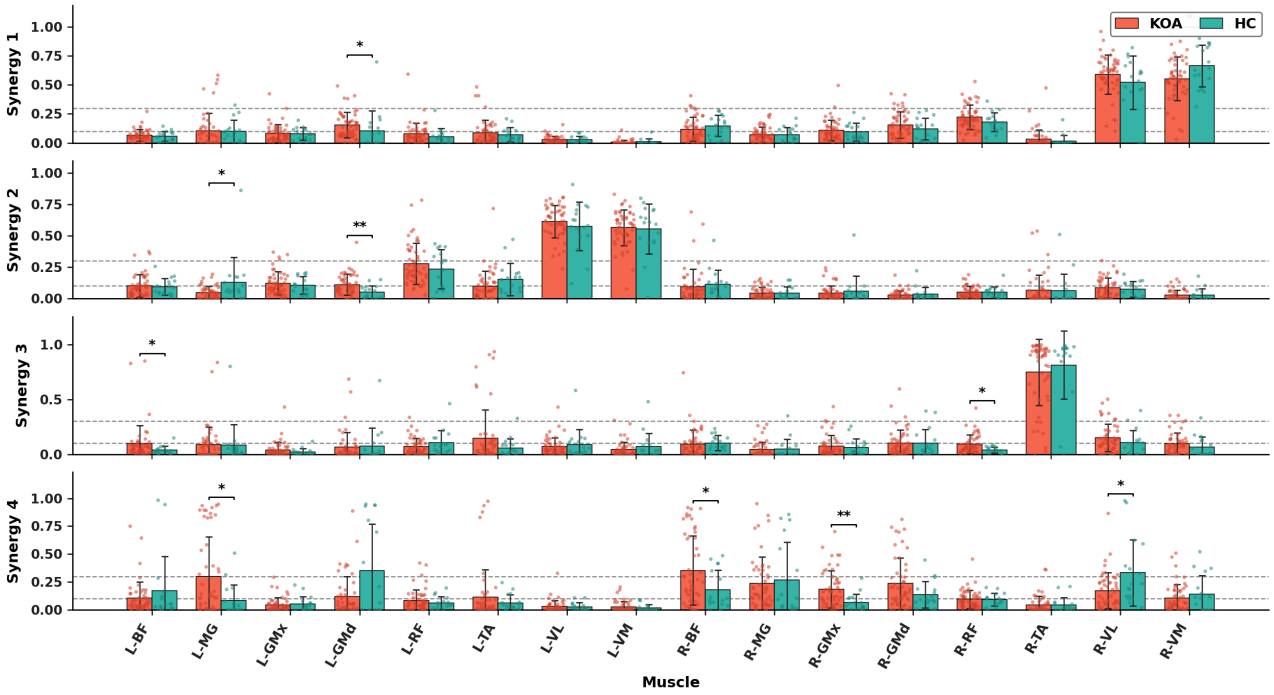


Figure S15: YMFZ-L muscle-weight distributions by synergy, KOA versus HC. Subject-level muscle weights in the shared basis are shown as group means (bars), SD (error bars), and individual participants (dots). Brackets mark raw KOA–HC tests (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$); † denotes FDR-corrected $p < 0.05$. Exact test statistics and FDR-corrected p values are listed in Table S5.

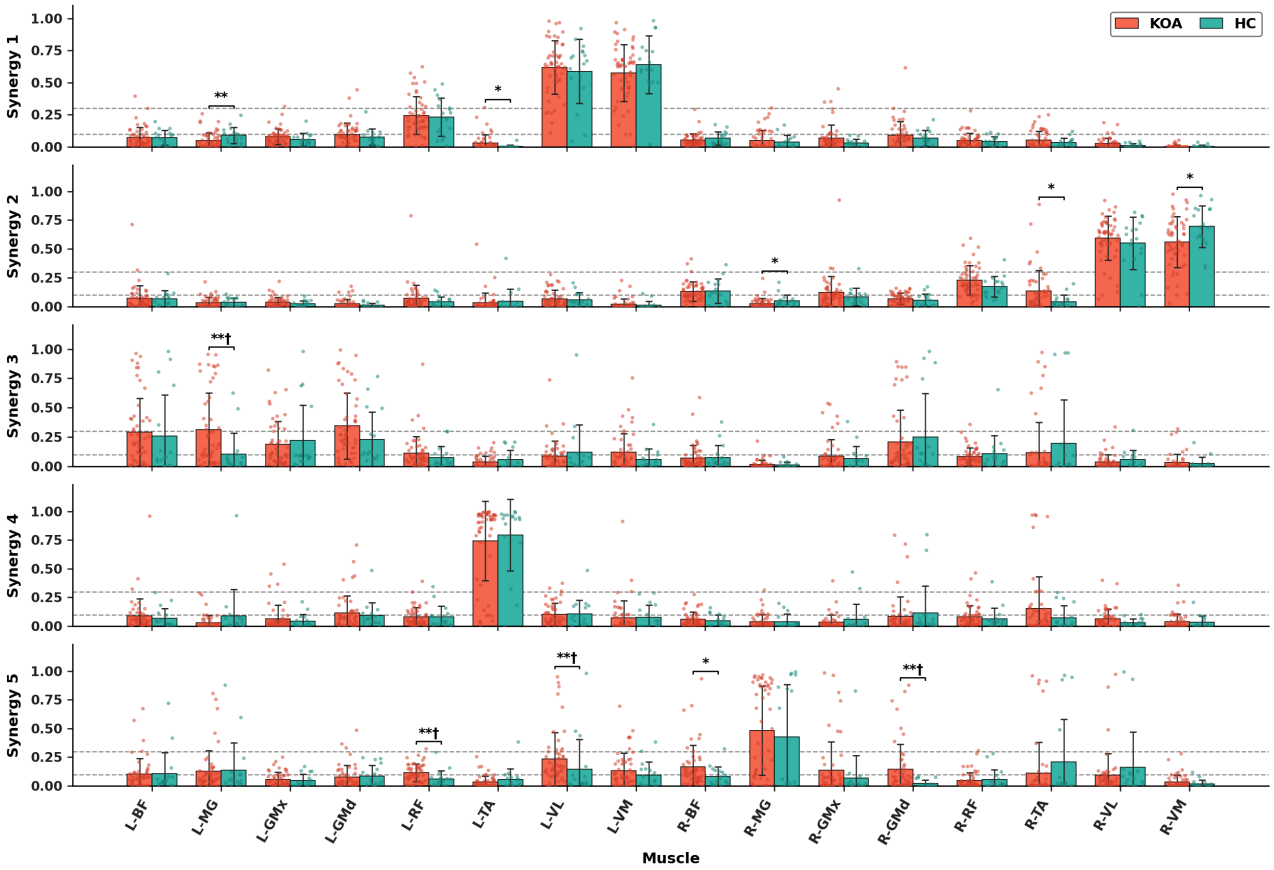


Figure S16: YMFZ-R muscle-weight distributions by synergy, KOA versus HC. Subject-level muscle weights in the shared basis are shown as group means (bars), SD (error bars), and individual participants (dots). Brackets mark raw KOA–HC tests (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$); † denotes FDR-corrected $p < 0.05$. Exact test statistics and FDR-corrected p values are listed in Table S5.

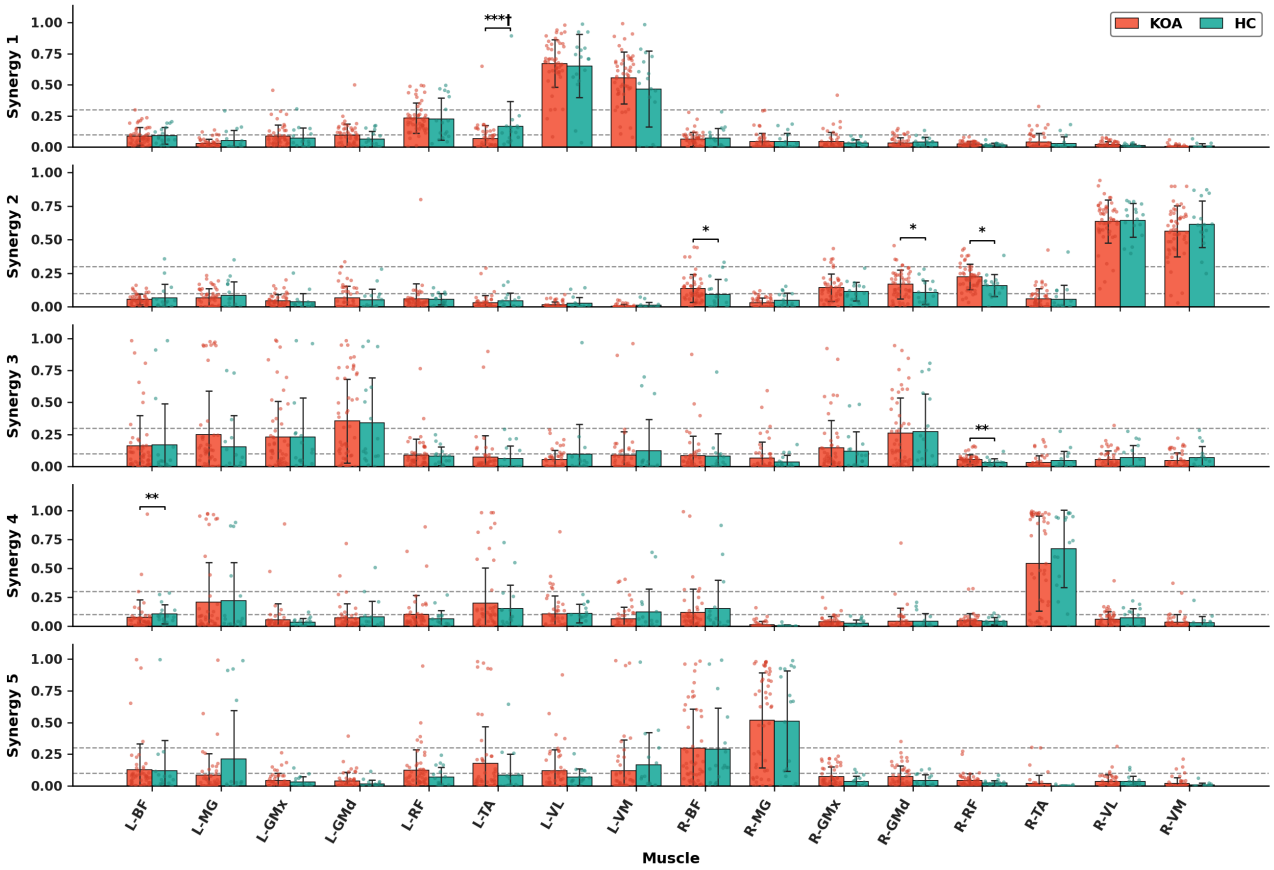


Figure S17: YS-L muscle-weight distributions by synergy, KOA versus HC. Subject-level muscle weights in the shared basis are shown as group means (bars), SD (error bars), and individual participants (dots). Brackets mark raw KOA–HC tests (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$); † denotes FDR-corrected $p < 0.05$. Exact test statistics and FDR-corrected p values are listed in Table S5.

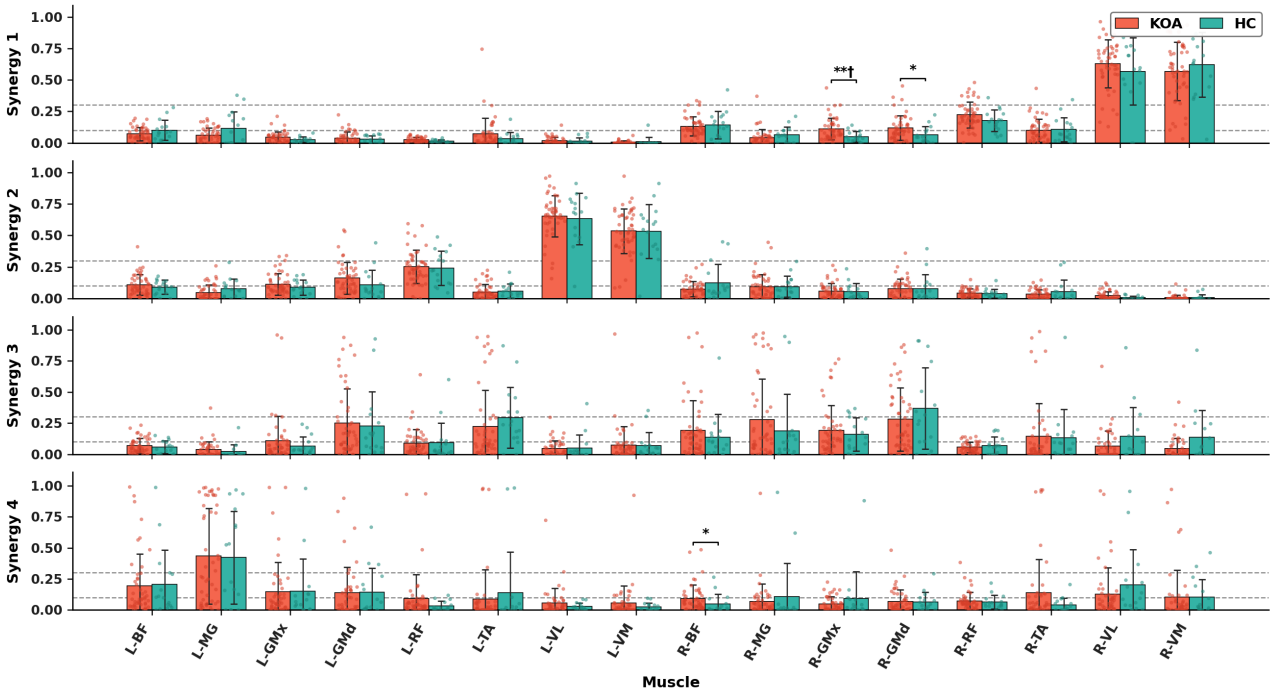


Figure S18: YS-R muscle-weight distributions by synergy, KOA versus HC. Subject-level muscle weights in the shared basis are shown as group means (bars), SD (error bars), and individual participants (dots). Brackets mark raw KOA–HC tests (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$); † denotes FDR-corrected $p < 0.05$. Exact test statistics and FDR-corrected p values are listed in Table S5.

S6 Activation profiles: all conditions and clusters

Main-text Fig. 5 shows representative DJG and YS activation profiles. Table S6 lists the 26 condition–synergy pairs with at least one cluster-corrected significant activation-profile window, and Table S7 lists all 34 individual windows; Fig. S20 shows the activation profiles for every condition.

Table S6: Affected condition–synergy pairs underlying the activation-profile result (26/99 synergies). Windows gives the number of cluster-corrected significant windows for that condition–synergy pair; KOA/HC windows gives the number higher in KOA or HC, respectively. Total duration is the summed significant duration in % of the movement cycle, and minimum p_{corr} is the smallest cluster-corrected p value among the pair's windows. Windows may reflect amplitude, profile shape or phase. Abbreviations: KOA, knee osteoarthritis; HC, healthy controls; Mv, movement; Syn, synergy; QS, Opening Form; DJG, Repulse Monkey; LXAB, Brush Knee and Twist Step; YMFZ, Part the Wild Horse's Mane; YS, Cloud Hands; JJDL, Golden Rooster Stands on One Leg; DJ, Heel Kick; LQW, Grasp the Sparrow's Tail; SZS, Cross Hands; SS, Closing Form; L/R, left/right stance leg; NA, no side-specific split.

Mv	Side	Syn	Windows	KOA/HC	Total dur.	Min. p_{corr}	Module
DJ	L	3	1	0/1	25.6	0.010	Knee-extension
DJ	R	2	1	0/1	28.0	0.008	Knee-extension
DJG	L	2	1	1/0	7.8	0.012	Knee-extension
DJG	L	8	3	3/0	15.6	0.024	Hip/posterior-chain
DJG	L	9	2	2/0	14.8	0.026	Hip/posterior-chain
DJG	R	5	2	2/0	8.7	0.015	Knee-extension
DJG	R	6	1	1/0	14.8	0.008	Ankle-dorsiflexion
DJG	R	7	1	1/0	6.1	0.034	Ankle-dorsiflexion
JJDL	L	3	1	0/1	10.6	0.024	Hip/posterior-chain
JJDL	R	1	1	0/1	14.1	0.018	Knee-extension
LQW	L	1	1	0/1	7.2	0.011	Knee-extension
LQW	L	2	2	2/0	15.2	0.004	Knee-extension
LQW	R	1	1	0/1	7.7	0.016	Knee-extension
LQW	R	2	2	2/0	19.2	0.005	Knee-extension
LXAB	L	5	1	1/0	9.7	0.008	Hip/posterior-chain
LXAB	R	1	2	2/0	17.9	0.004	Knee-extension
LXAB	R	2	1	1/0	14.5	0.009	Knee-extension
YMFZ	L	2	1	1/0	8.0	0.049	Knee-extension
YMFZ	L	4	1	1/0	8.0	0.021	Hip/posterior-chain
YMFZ	R	1	1	0/1	12.0	0.008	Knee-extension
YMFZ	R	2	1	1/0	13.3	0.013	Knee-extension
YS	L	1	1	0/1	27.2	0.001	Knee-extension
YS	L	2	1	1/0	32.8	0.001	Knee-extension
YS	L	3	1	1/0	5.6	0.025	Hip/posterior-chain
YS	R	1	1	0/1	19.4	0.009	Knee-extension
YS	R	2	2	1/1	40.0	0.006	Knee-extension

Table S7: All cluster-corrected significant activation-profile windows (34 clusters; 24 KOA↑, 10 HC↑). Window and duration are in % of the movement cycle; t-mass is the cluster mass; p_{corr} is the cluster-corrected p-value. A window may reflect amplitude, profile shape or phase and does not by itself establish retiming. Abbreviations and marks: KOA, knee osteoarthritis; HC, healthy controls; Mv, movement; Syn, synergy; Dur., duration; KOA↑/HC↑, higher activation in KOA/HC; QS, Opening Form; DJG, Repulse Monkey; LXAB, Brush Knee and Twist Step; YMFZ, Part the Wild Horse's Mane; YS, Cloud Hands; JJDL, Golden Rooster Stands on One Leg; DJ, Heel Kick; LQW, Grasp the Sparrow's Tail; SZS, Cross Hands; SS, Closing Form; L/R, left/right stance leg; NA, no side-specific split.

Mv	Side	Syn	Window (%)	Dur.	Direction	t-mass	p_{corr}
DJ	L	3	50–75	26	HC↑	-93.0	0.010
DJ	R	2	55–83	28	HC↑	-107.8	0.008
DJG	L	2	39–47	8	KOA↑	26.7	0.012
DJG	L	8	64–70	6	KOA↑	25.0	0.024
DJG	L	8	79–84	4	KOA↑	18.9	0.042
DJG	L	8	95–100	5	KOA↑	19.6	0.039
DJG	L	9	5–13	8	KOA↑	27.5	0.026
DJG	L	9	14–21	7	KOA↑	22.0	0.043
DJG	R	5	64–67	4	KOA↑	11.5	0.040
DJG	R	5	76–82	5	KOA↑	19.6	0.015
DJG	R	6	64–78	15	KOA↑	64.7	0.008
DJG	R	7	10–16	6	KOA↑	21.3	0.034
JJDL	L	3	73–84	11	HC↑	-24.3	0.024
JJDL	R	1	18–32	14	HC↑	-37.7	0.018
LQW	L	1	80–87	7	HC↑	-86.3	0.011
LQW	L	2	44–52	8	KOA↑	95.2	0.013
LQW	L	2	79–87	8	KOA↑	123.5	0.004
LQW	R	1	2–9	8	HC↑	-87.2	0.016
LQW	R	2	42–52	10	KOA↑	134.4	0.005
LQW	R	2	75–84	9	KOA↑	120.4	0.008
LXAB	L	5	84–94	10	KOA↑	46.1	0.008
LXAB	R	1	14–26	12	KOA↑	51.4	0.004
LXAB	R	1	74–80	6	KOA↑	29.5	0.026
LXAB	R	2	36–50	14	KOA↑	70.7	0.009
YMFZ	L	2	33–41	8	KOA↑	33.5	0.049
YMFZ	L	4	8–16	8	KOA↑	37.2	0.021
YMFZ	R	1	27–39	12	HC↑	-60.9	0.008
YMFZ	R	2	28–41	13	KOA↑	64.0	0.013
YS	L	1	62–89	27	HC↑	-159.6	0.001
YS	L	2	64–97	33	KOA↑	225.5	0.001
YS	L	3	39–44	6	KOA↑	35.4	0.025
YS	R	1	58–78	19	HC↑	-106.0	0.009
YS	R	2	10–33	23	HC↑	-119.1	0.006
YS	R	2	81–98	17	KOA↑	112.9	0.007

Big-picture characterisation of the activation-profile differences

Table S8 contrasts the two directions. KOA-higher windows are more numerous but brief, whereas HC-higher windows are fewer but about twice as long (duration: Mann–Whitney $p = 0.007$). The duration-normalised absolute cluster statistic is slightly higher for KOA-higher windows (median 3.3 versus 3.1; exploratory Mann–Whitney $p = 0.030$), while HC-higher windows have larger absolute mass because they are longer. These statistics describe standardised group separation, not activation intensity. KOA-higher windows sum to 229 cycle-percent units versus 175 for HC-higher windows; these are summed durations of between-group differences, not group-specific activation durations. Window count and summed duration highlight different movements (Fig. S21): DJG has the most windows (all KOA-higher) but the shortest, whereas Cloud Hands (YS) has the greatest bidirectional activation-profile burden.

Table S8: Activation-profile windows by direction. Duration is % of the movement cycle (median (IQR)); total duration sums all windows; $|t|$-mass is the median absolute cluster mass; t/time-point is the duration-normalised median absolute difference. Abbreviations: KOA, knee osteoarthritis; HC, healthy controls; IQR, interquartile range; dur., duration.

Direction	n	Duration	Total dur.	Median $\|t\|$-mass	t/time-point
KOA higher	24	7.8 (6.1–10.5)	229	36	3.3
HC higher	10	16.8 (10.9–24.9)	175	90	3.1

Labelling each affected synergy by its dominant module (Table S9), hip/posterior-chain activation-profile differences are almost exclusively KOA-higher (8/9), whereas knee-extension synergies show bidirectional differences. These directions should not be assumed to mirror the cycle-integrated compositional contribution contrasts, which measure a different estimand.

Table S9: Significant activation-profile windows by dominant synergy module and direction. KOA higher and HC higher denote windows with higher activation in knee osteoarthritis or healthy controls, respectively.

Module	KOA higher	HC higher	Total
Ankle-dorsiflexion	2	0	2
Hip/posterior-chain	8	1	9
Knee-extension	14	9	23
Total	24	10	34

Activation-profile–contribution convergence. Movements with significant activation-profile windows (DJ, DJG, JJDL, LQW, LXAB, YMFZ, YS) only partly overlap those with significant functional-contribution differences (DJ, JJDL, LQW, SZS), with Jaccard index 0.38. DJG, the most activation-profile-affected movement, shows no contribution difference, whereas SZS shows the converse, indicating that cycle-localised activation-profile and cycle-integrated contribution measures are partly dissociable readouts.

Per-subject peak-timing shift. As a complementary, per-subject test, the location of each synergy's peak activation (% of cycle) was compared between groups. Because peak location is periodic (0% $\equiv$ 100%), a linear rank test would treat peaks near opposite cycle boundaries as maximally distant; we therefore used a permutation test on the circular mean direction (1000 group-label permutations, fixed seed), Benjamini–Hochberg FDR-corrected across the 99 testable condition–synergy

pairs. After correction no synergy showed a significant peak-location shift (0/99; the strongest case was Cloud Hands, YS-L synergy 4, KOA circular-mean peak 35% versus HC 72% of cycle, $p_{\text{uncorr}} = 0.006$, $q = 0.099$). The per-subject peak location therefore did not differ between groups, indicating that the activation-profile differences identified by the cluster-based test (Fig. S19) are localised to specific cycle windows rather than wholesale shifts in when each synergy peaks. Because the peak of a broad or multimodal profile is in any case unstable, this per-subject analysis is exploratory and is reported here only for completeness; a linear Mann–Whitney U on the same data (retained as an audit column) had flagged this same synergy at $q = 0.001$, an artefact of within-group peaks straddling the 0/100% boundary that the circular test removes.

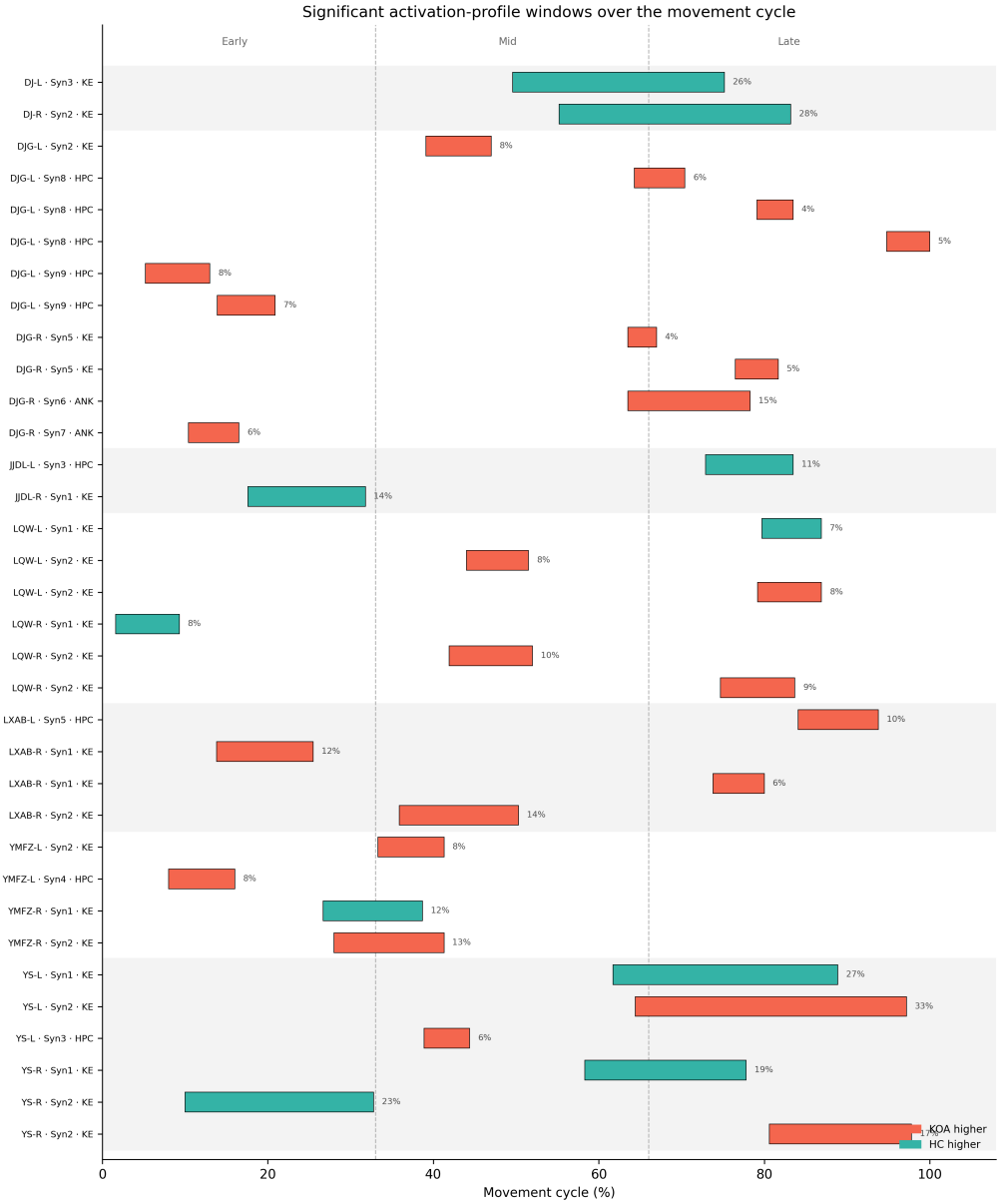


Figure S19: Significant activation-profile windows over the movement cycle (red, KOA higher; teal, HC higher). Rows identify movement–stance, synergy and dominant module; differences concentrate in the mid-to-late cycle. Movement abbreviations are defined in Tables S6 and S7.

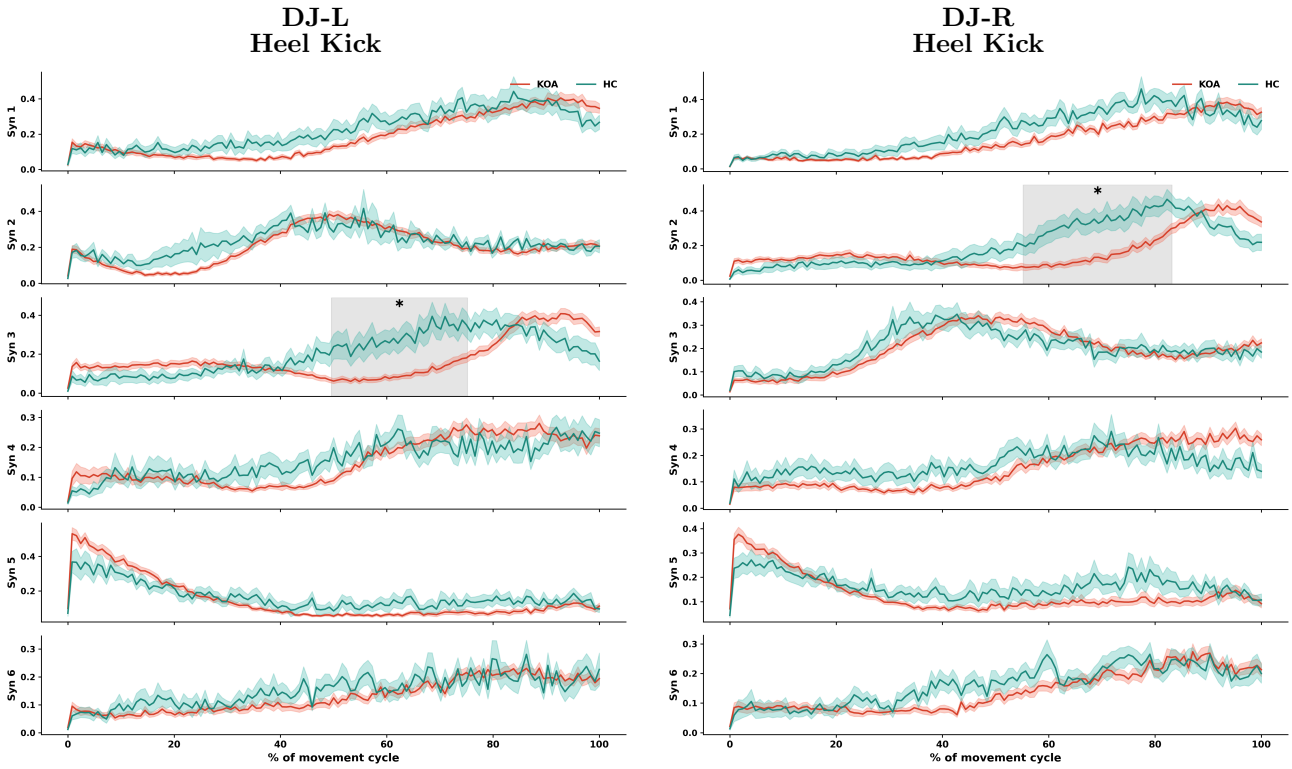


Figure S20: Synergy activation profiles (mean ± SE) for all 17 movement–side conditions. Shaded regions with asterisks mark cluster-corrected significant windows ($p < 0.05$). Left/right stance conditions remain adjacent; panel headings give the condition code and full movement name. Continued on the following pages. Abbreviations: KOA, knee osteoarthritis; HC, healthy controls; SE, standard error. Movement abbreviations are defined in Tables S6 and S7.

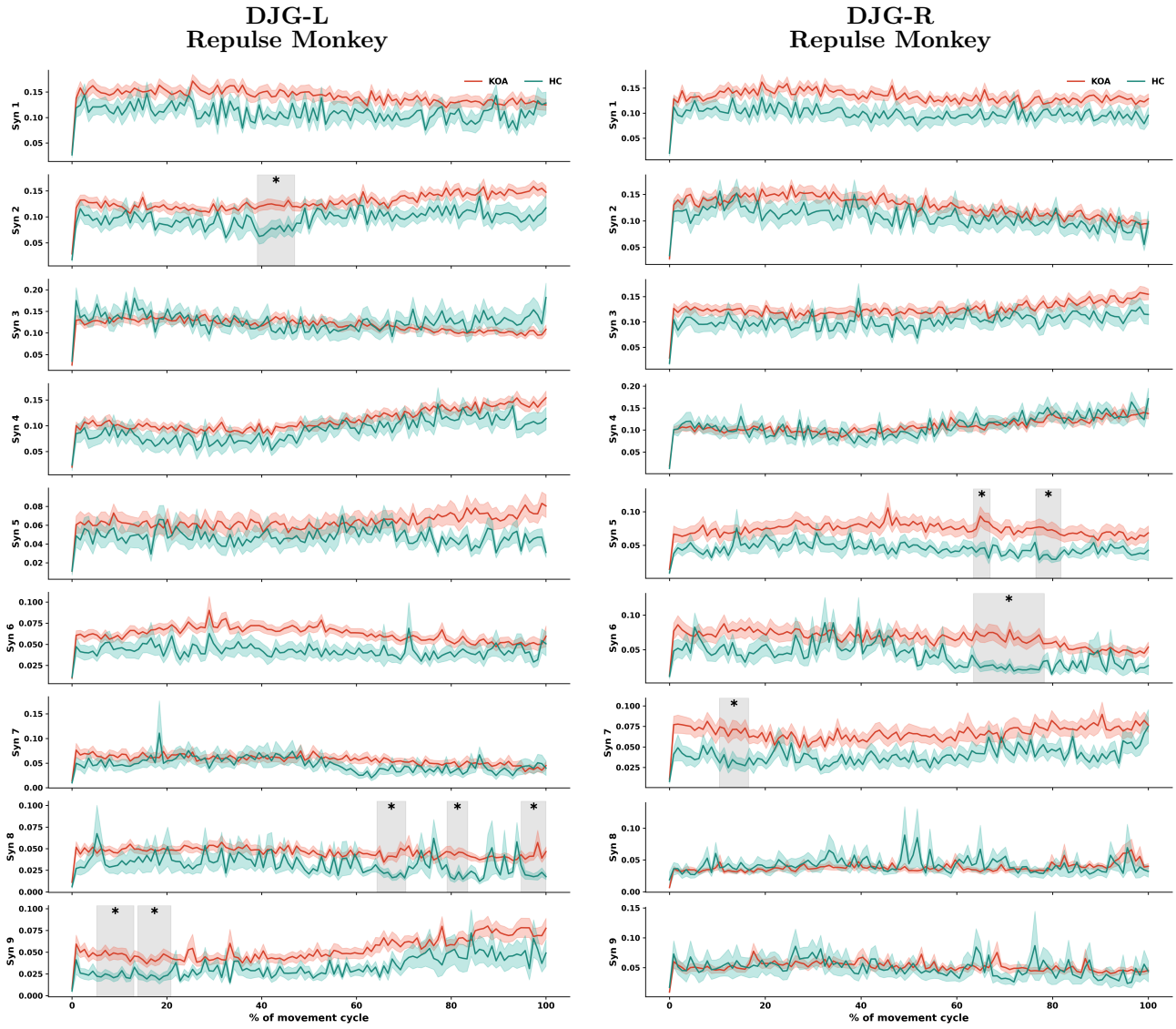


Figure S20: Synergy activation profiles (continued): Repulse Monkey (DJG).

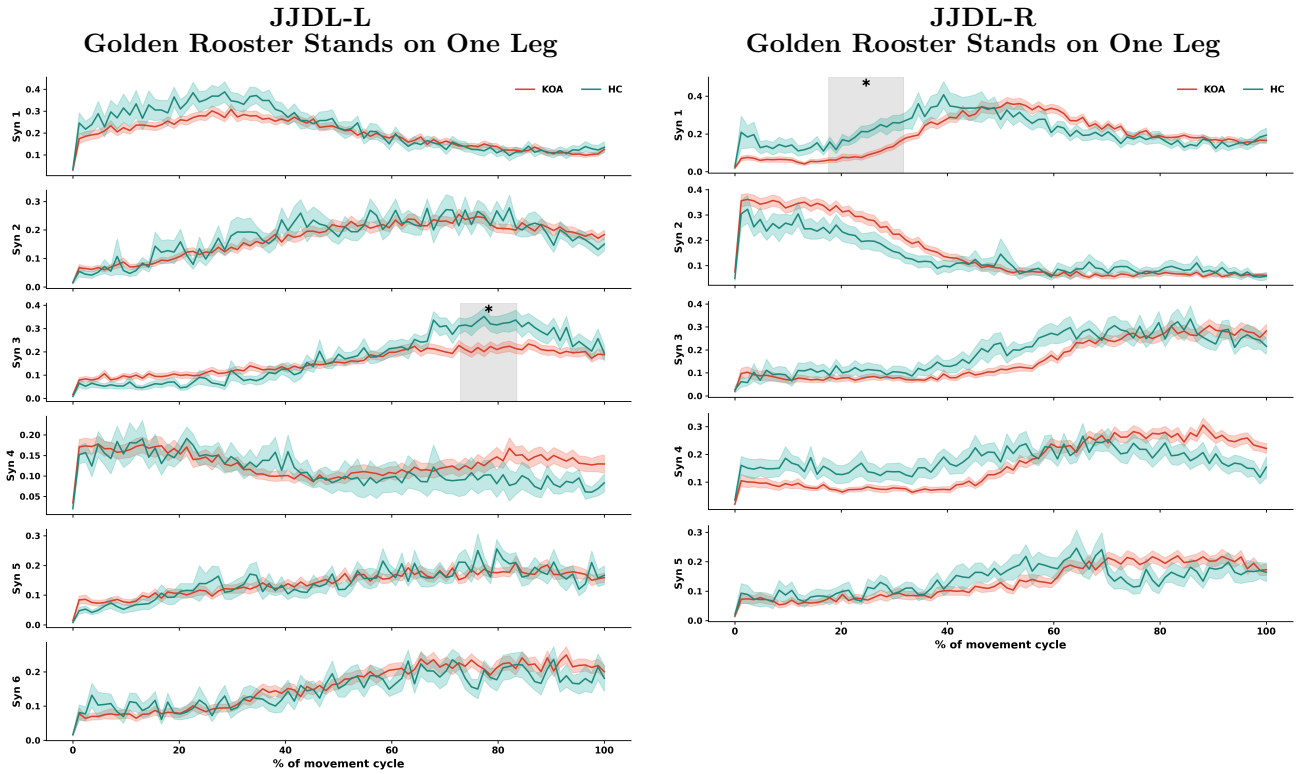


Figure S20: Synergy activation profiles (continued): Golden Rooster Stands on One Leg (JJDL).

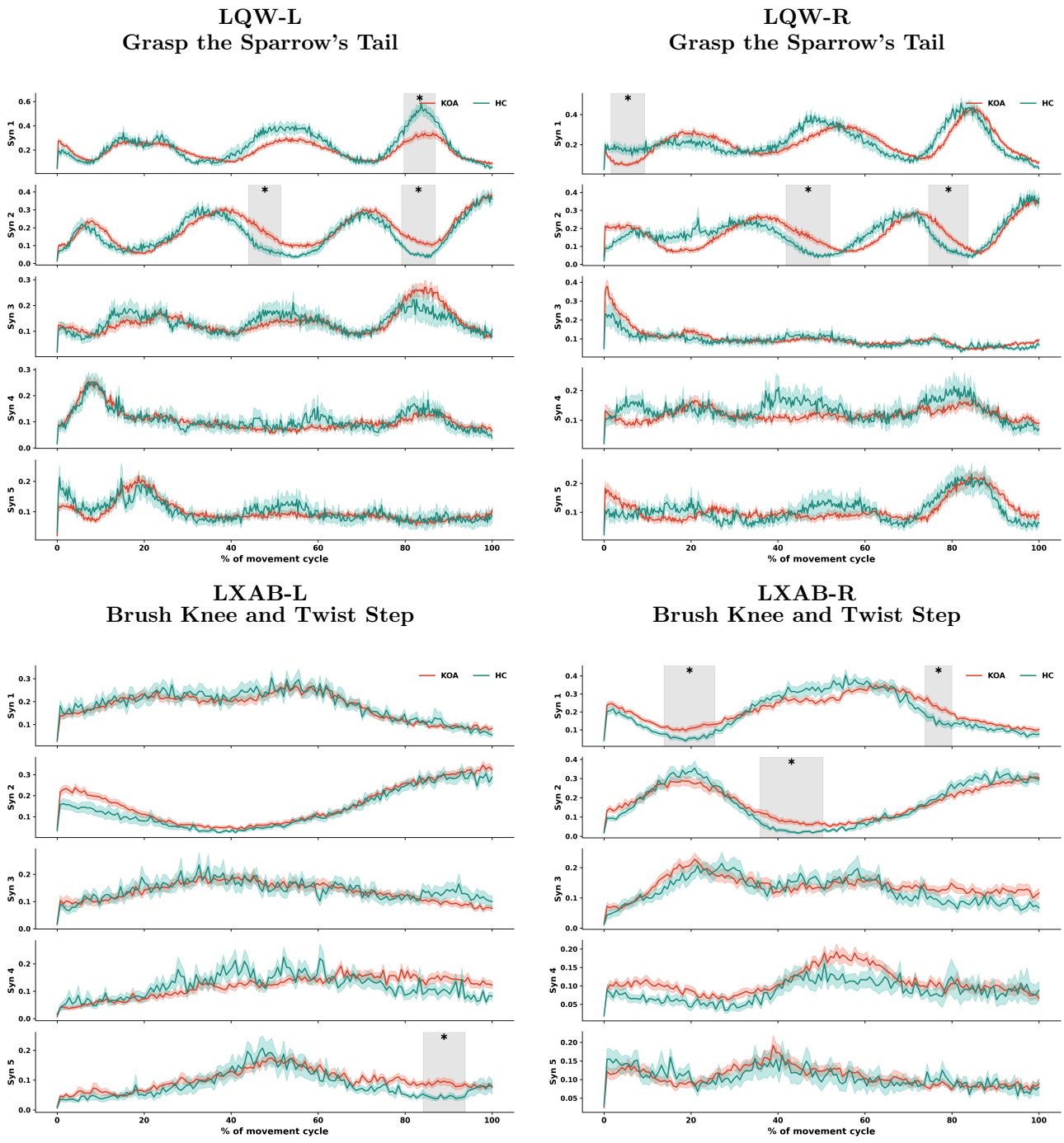


Figure S20: Synergy activation profiles (continued): Grasp the Sparrow's Tail (LQW) and Brush Knee and Twist Step (LXAB).

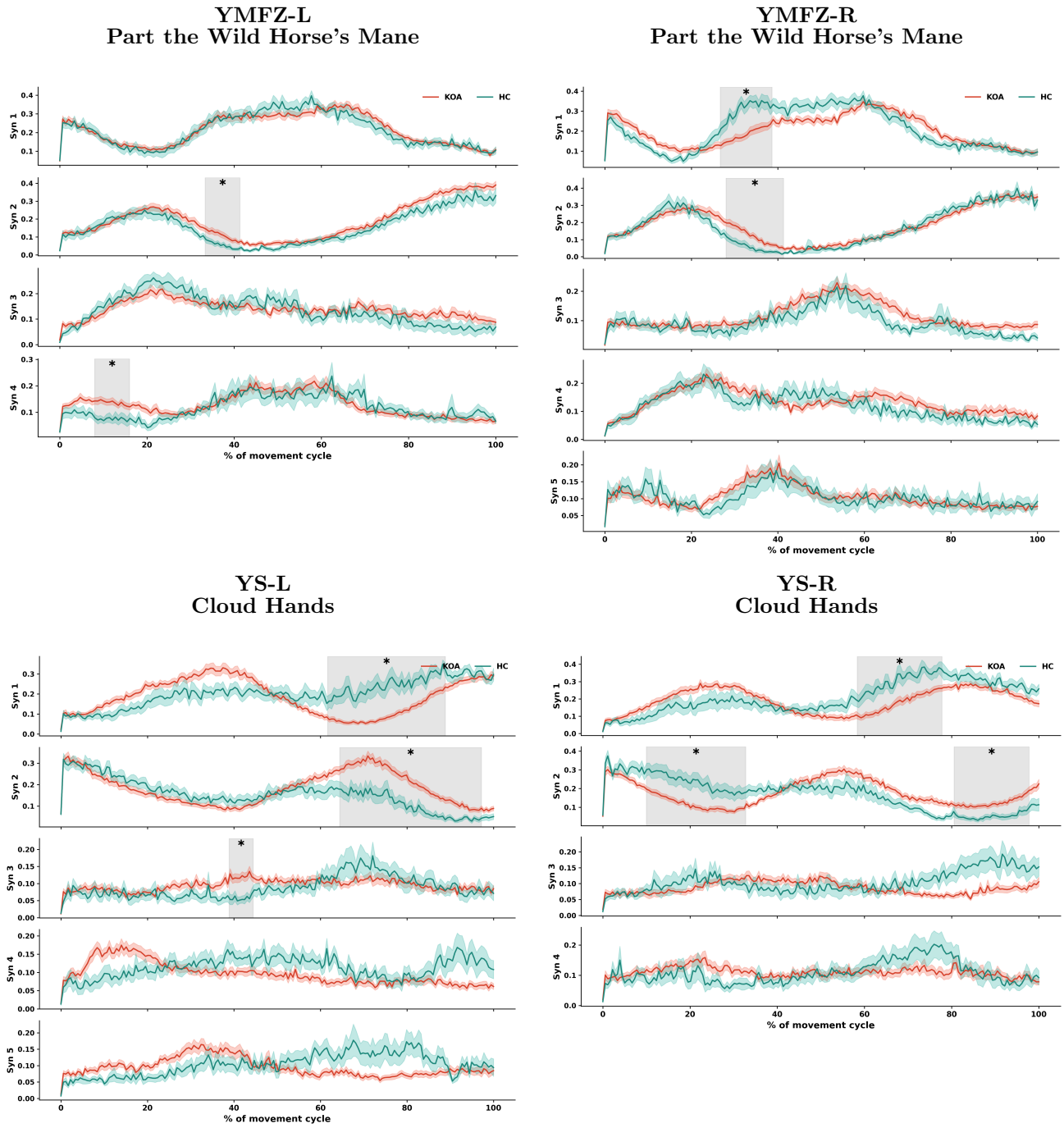


Figure S20: Synergy activation profiles (continued): Part the Wild Horse's Mane (YMFZ) and Cloud Hands (YS).

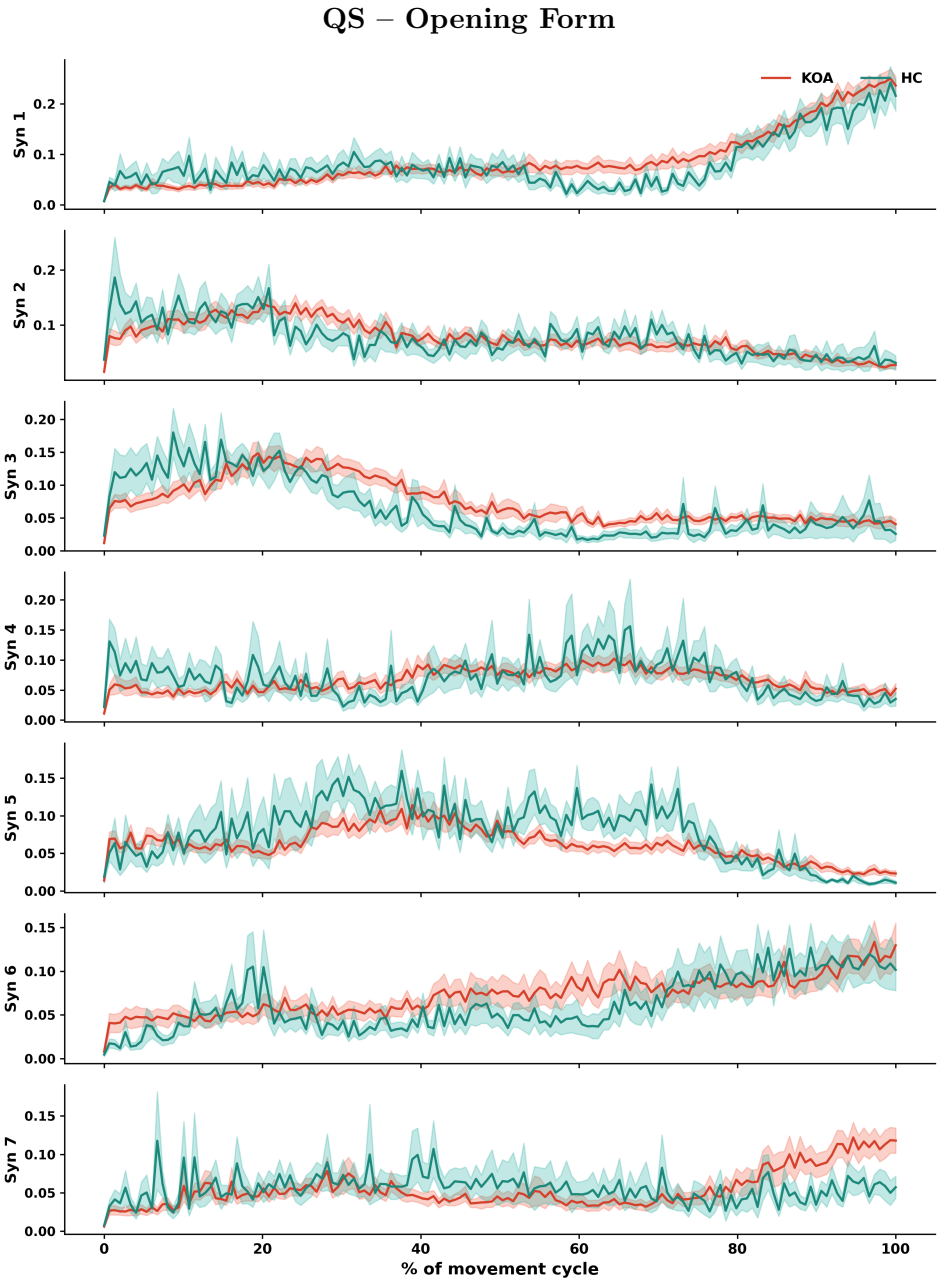


Figure S20: Synergy activation profiles (continued): Opening Form (QS).

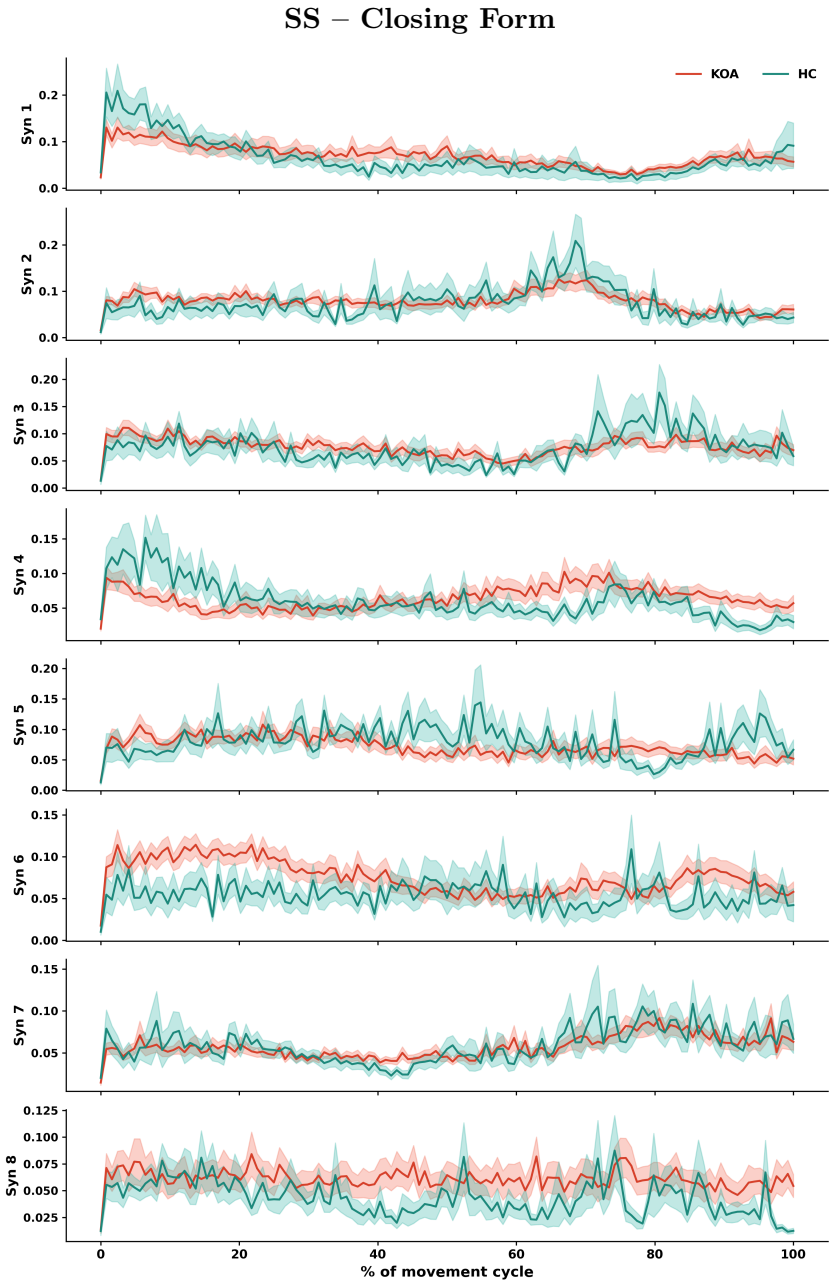


Figure S20: Synergy activation profiles (continued): Closing Form (SS).

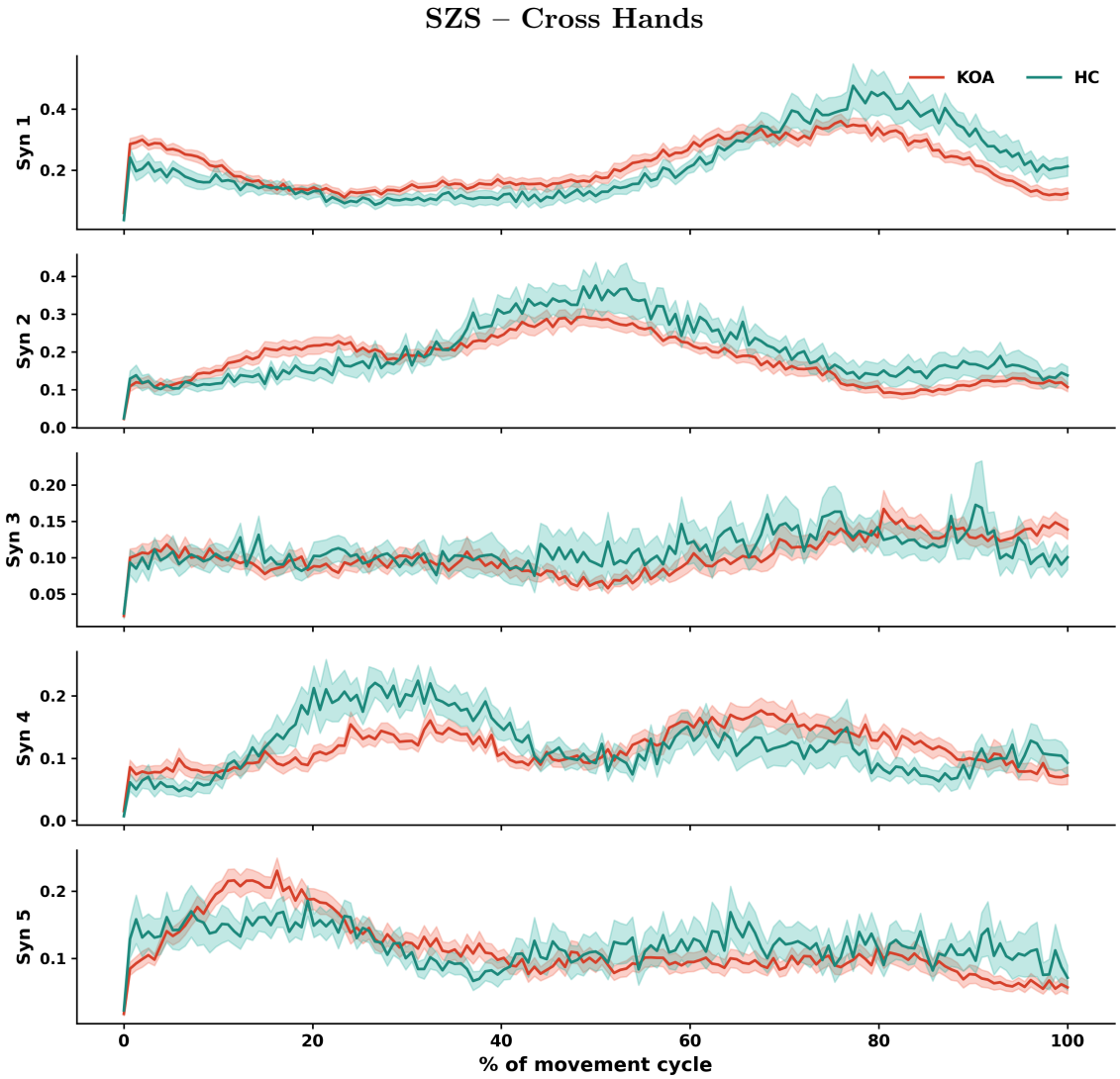


Figure S20: Synergy activation profiles (continued): Cross Hands (SZS).

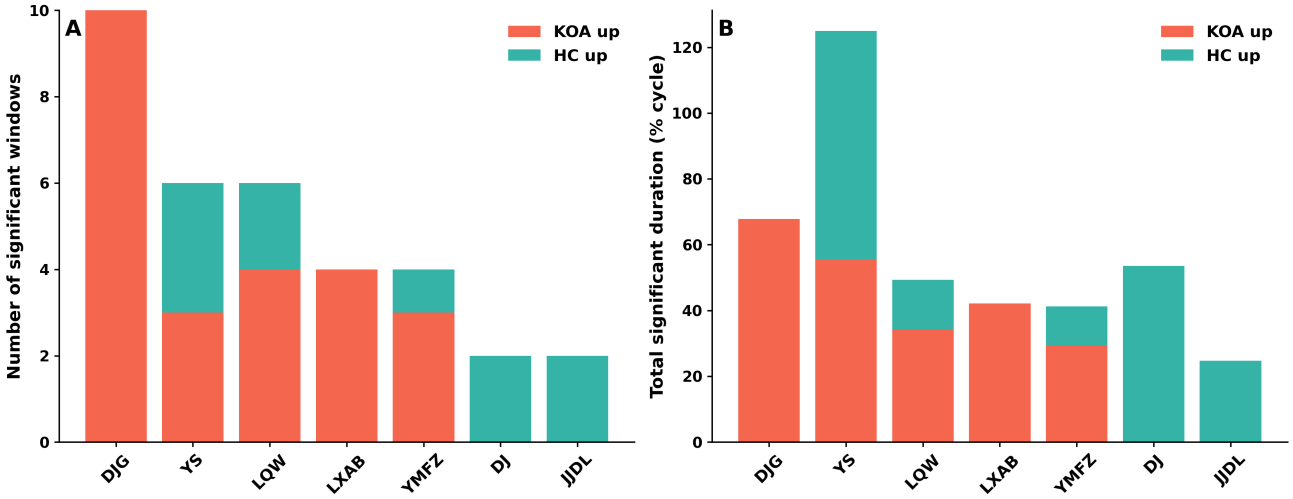
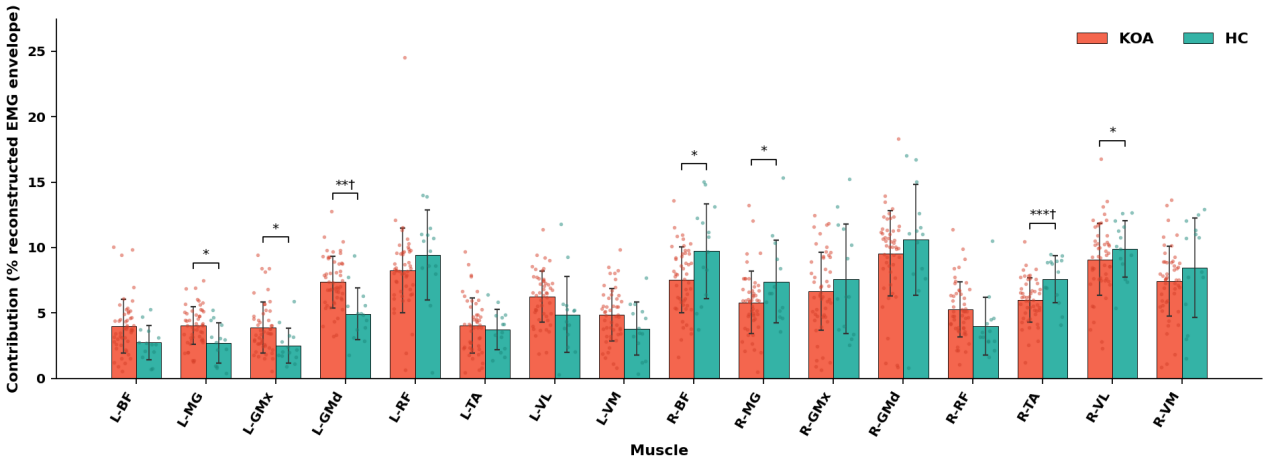


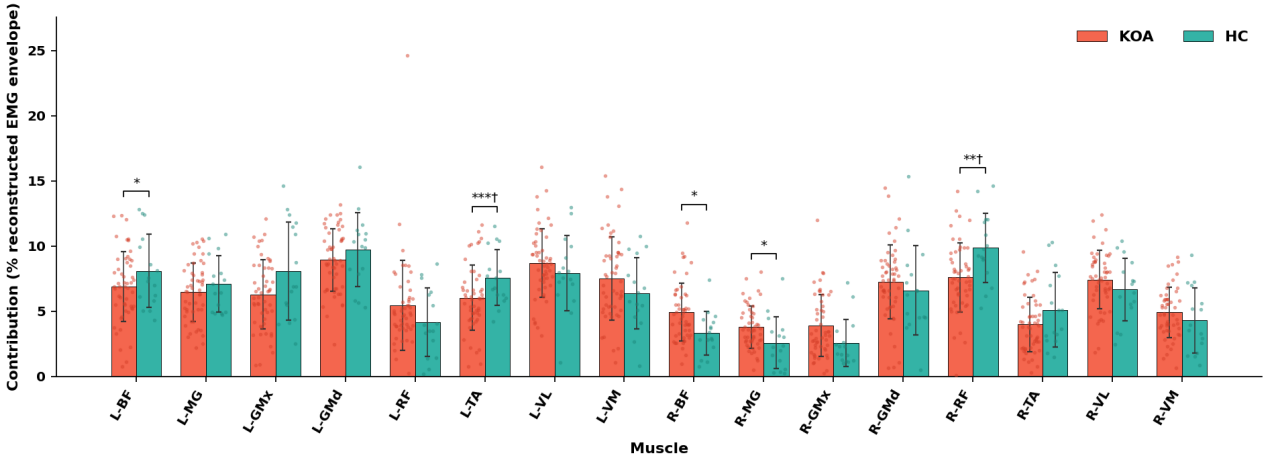
Figure S21: Activation-profile differences by movement and direction (coral, KOA > HC; teal, HC > KOA). Direction indicates which group had higher mean synergy activation within a significant cluster window. **(A)** Number of cluster-corrected significant windows; DJG has the most windows (10), all KOA > HC. **(B)** Total significant duration (% of the movement cycle); Cloud Hands (YS) carries the greatest cumulative duration (125% cycle), with bidirectional effects. Values are aggregated across movement-side conditions and synergies; consequently, total duration can exceed 100% of one movement cycle. Windows may reflect amplitude, profile shape or phase. Only movements with at least one significant window are shown. No additional across-synergy FDR correction was applied. Abbreviations: KOA, knee osteoarthritis; HC, healthy controls; FDR, false discovery rate; DJG, Repulse Monkey; YS, Cloud Hands; LQW, Grasp the Sparrow's Tail; LXAB, Brush Knee and Twist Step; YMFZ, Part the Wild Horse's Mane; DJ, Heel Kick; JJDL, Golden Rooster Stands on One Leg.

S7 Functional contribution: per-condition maps and muscle ranking

Per-condition functional-contribution profiles (KOA vs HC) underlying the discrimination overview in main-text Fig. 6 are shown below. For readability, each page contains one bilateral movement with its L/R conditions stacked at full width, or up to two movements without a side-specific split.

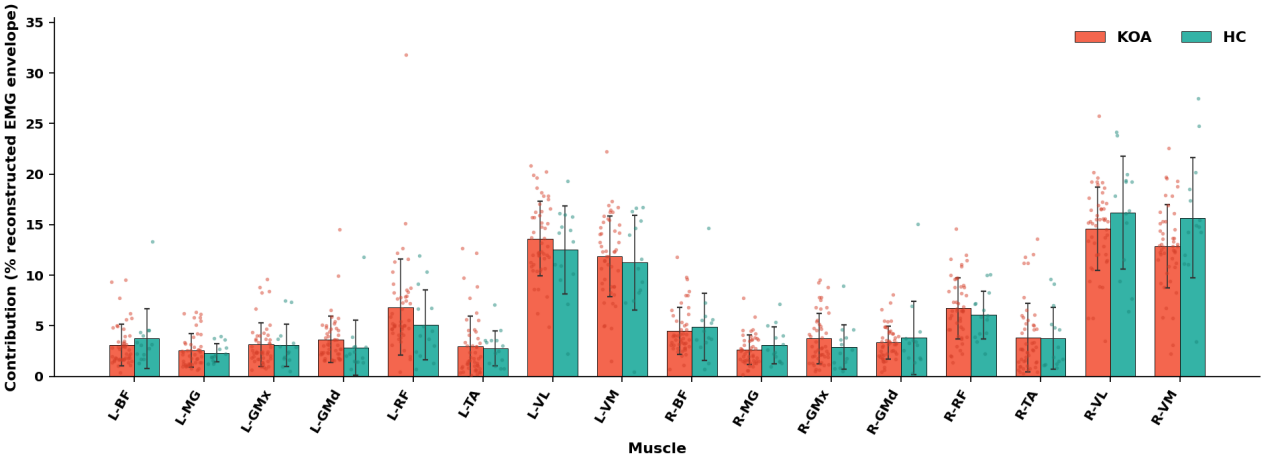


Muscle contribution, KOA versus HC — DJ-L. * permutation $p < 0.05$; † global FDR < 0.05; § condition-wise FDR < 0.05.

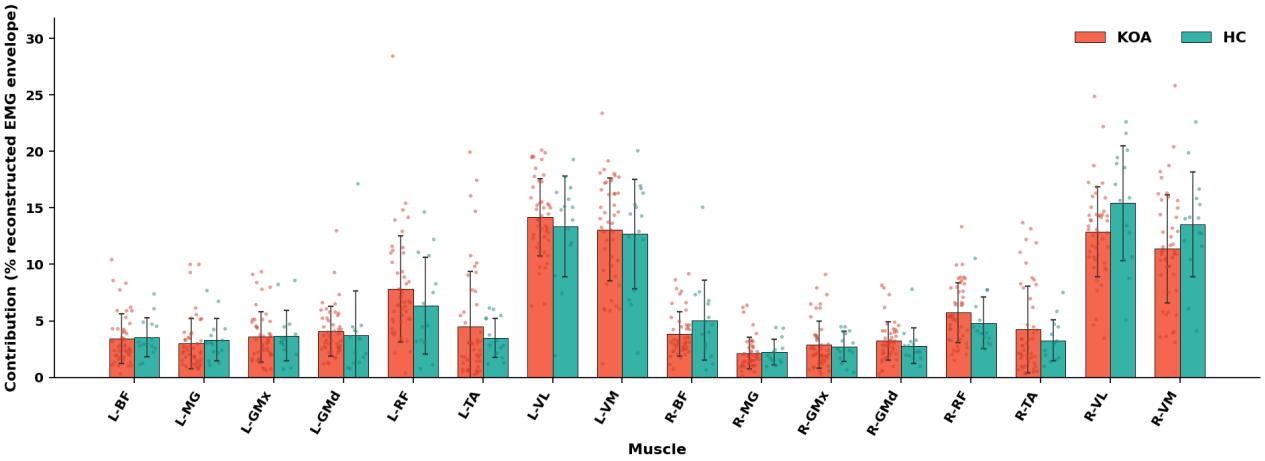


Muscle contribution, KOA versus HC — DJ-R. * permutation $p < 0.05$; † global FDR < 0.05; § condition-wise FDR < 0.05.

Figure S22: Per-condition muscle functional-contribution profiles, KOA versus HC (17 panels). Functional contribution is each muscle's estimated percentage of the summed reconstructed EMG envelope. Bilateral L/R conditions are stacked at full width to preserve muscle labels, participant-level points, uncertainty bars, and significance marks. Continued on the next pages. Abbreviations: KOA, knee osteoarthritis; HC, healthy controls; BF, biceps femoris; MG, medial gastrocnemius; GMx, gluteus maximus; GMd, gluteus medius; RF, rectus femoris; TA, tibialis anterior; VL, vastus lateralis; VM, vastus medialis; L/R prefixes denote left/right side; QS, Opening Form; DJG, Repulse Monkey; LXAB, Brush Knee and Twist Step; YMFZ, Part the Wild Horse's Mane; YS, Cloud Hands; JJDL, Golden Rooster Stands on One Leg; DJ, Heel Kick; LQW, Grasp the Sparrow's Tail; SZS, Cross Hands; SS, Closing Form; L/R, left/right stance leg; NA, no side-specific split.

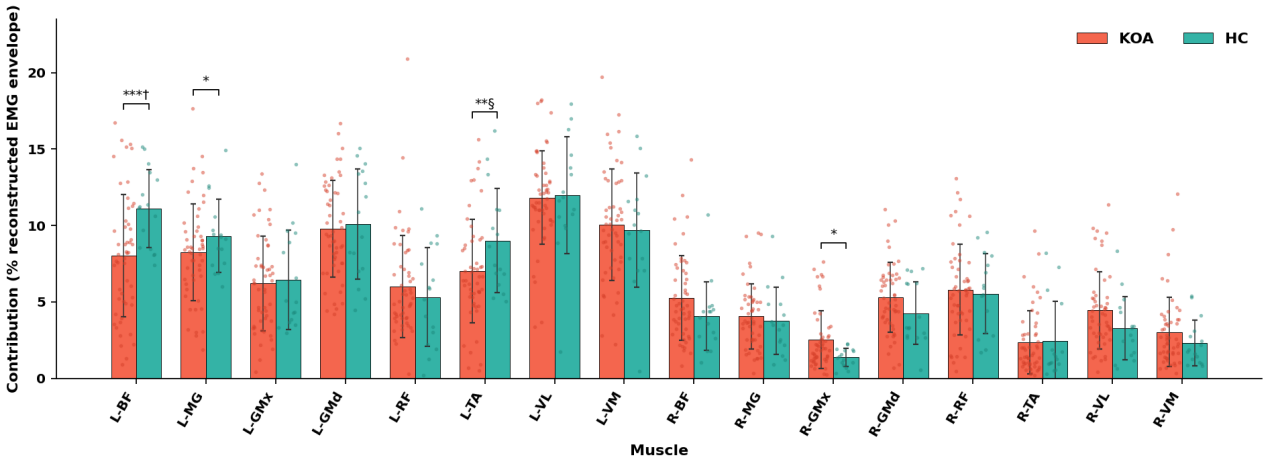


Muscle contribution, KOA versus HC — DJG-L. * permutation $p < 0.05$; † global FDR < 0.05; § condition-wise FDR < 0.05.

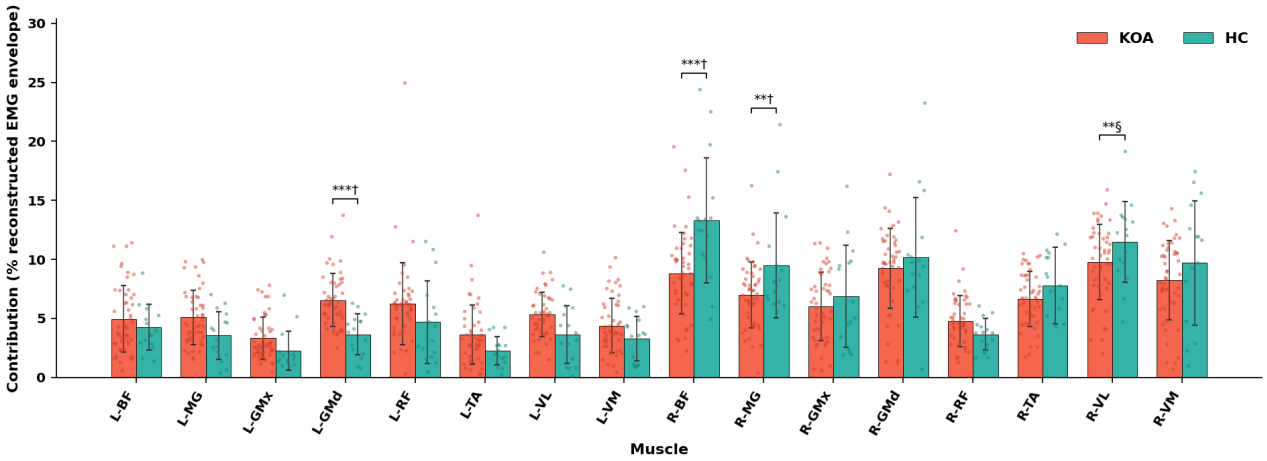


Muscle contribution, KOA versus HC — DJG-R. * permutation $p < 0.05$; † global FDR < 0.05; § condition-wise FDR < 0.05.

Figure S22: Per-condition muscle functional-contribution profiles (continued): Repulse Monkey (DJG).

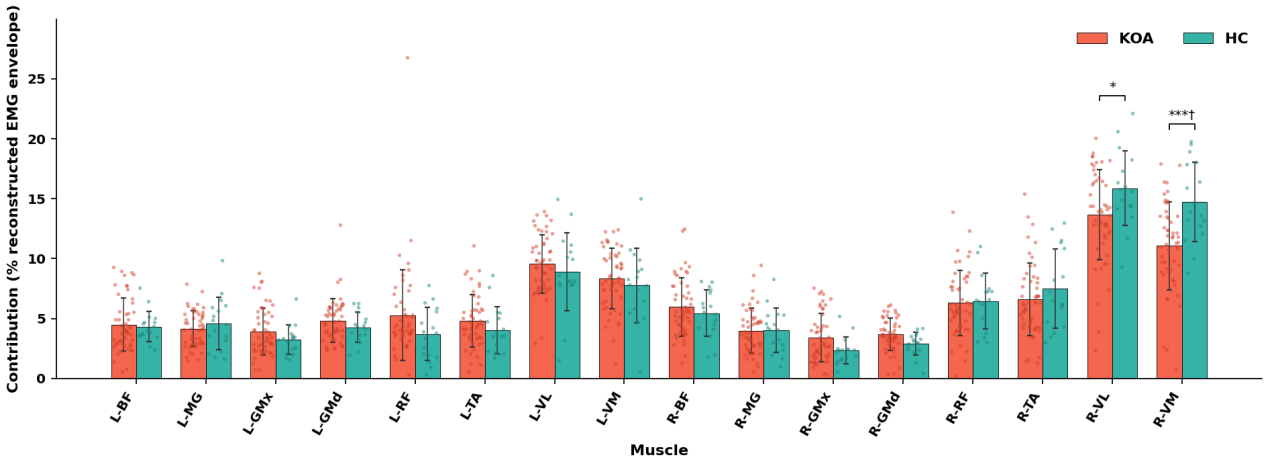


Muscle contribution, KOA versus HC — JJDL-L. * permutation $p < 0.05$; † global FDR < 0.05; § condition-wise FDR < 0.05.

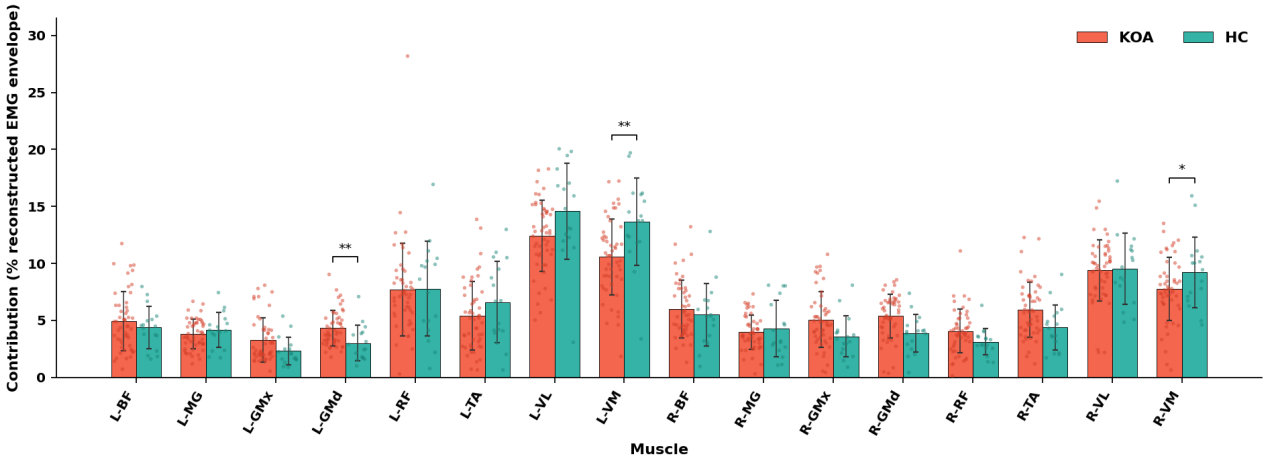


Muscle contribution, KOA versus HC — JJDL-R. * permutation $p < 0.05$; † global FDR < 0.05; § condition-wise FDR < 0.05.

Figure S22: Per-condition muscle functional-contribution profiles (continued): Golden Rooster Stands on One Leg (JJDL).

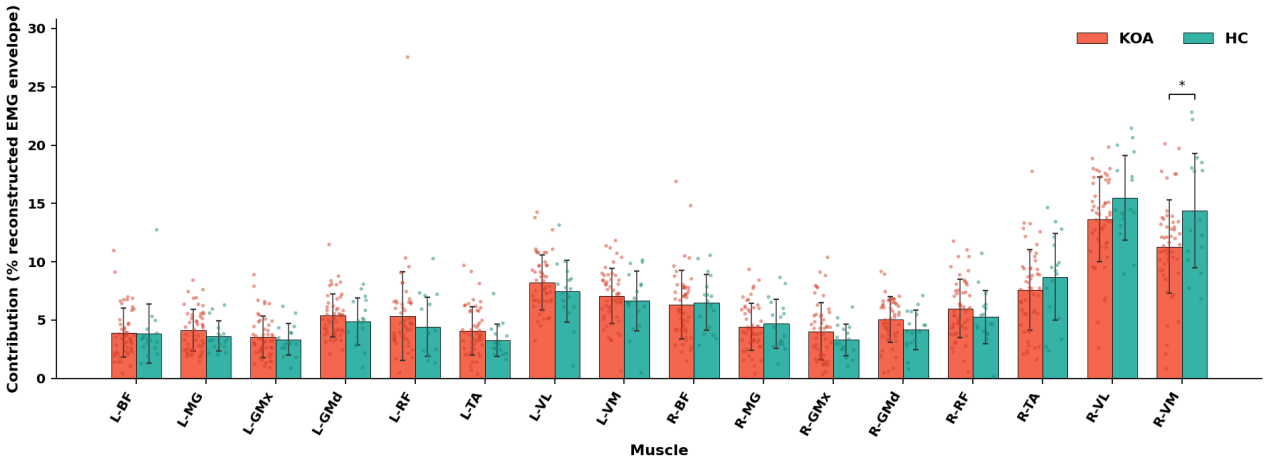


Muscle contribution, KOA versus HC — LQW-L. * permutation $p < 0.05$; † global FDR < 0.05; § condition-wise FDR < 0.05.

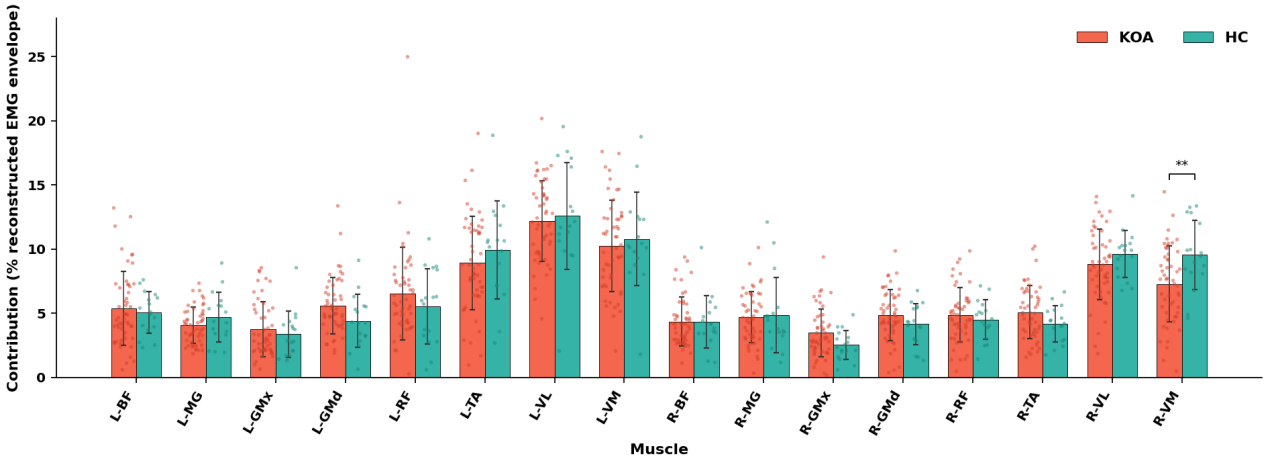


Muscle contribution, KOA versus HC — LQW-R. * permutation $p < 0.05$; † global FDR < 0.05; § condition-wise FDR < 0.05.

Figure S22: Per-condition muscle functional-contribution profiles (continued): Grasp the Sparrow's Tail (LQW).

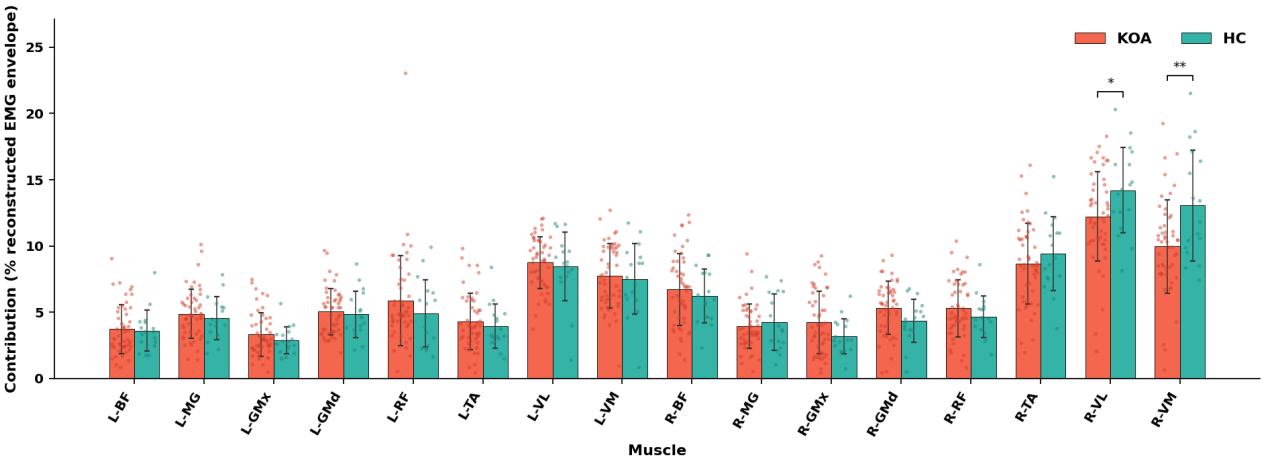


Muscle contribution, KOA versus HC — LXAB-L. * permutation $p < 0.05$; † global FDR < 0.05; § condition-wise FDR < 0.05.

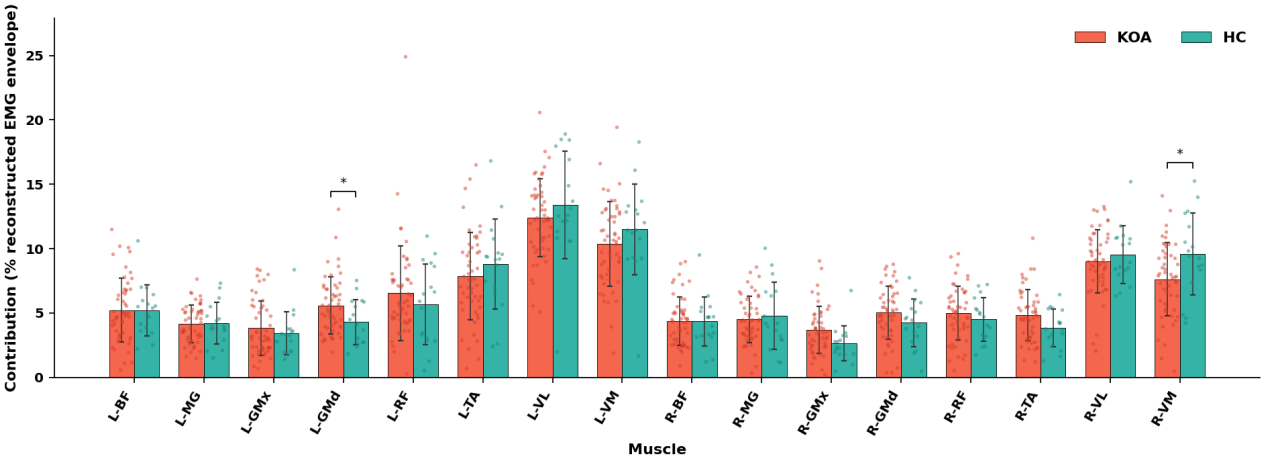


Muscle contribution, KOA versus HC — LXAB-R. * permutation $p < 0.05$; † global FDR < 0.05; § condition-wise FDR < 0.05.

Figure S22: Per-condition muscle functional-contribution profiles (continued): Brush Knee and Twist Step (LXAB).

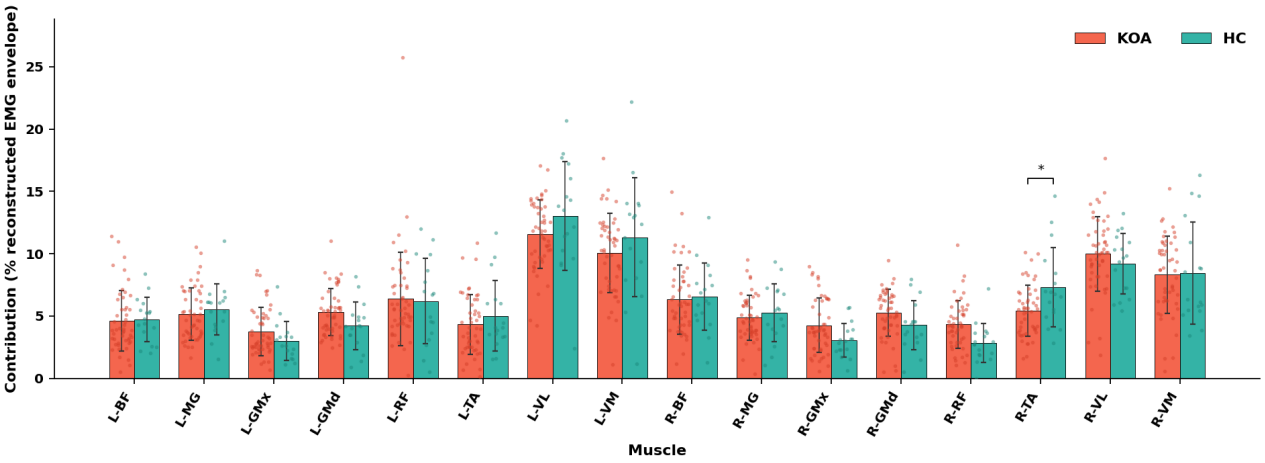


Muscle contribution, KOA versus HC — YMFZ-L. * permutation $p < 0.05$; † global FDR < 0.05; § condition-wise FDR < 0.05.

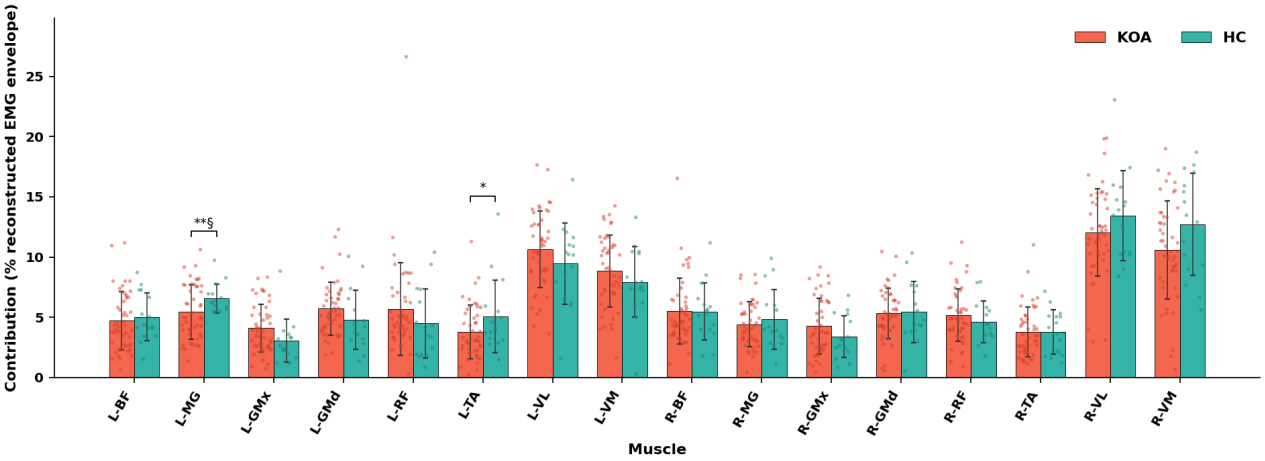


Muscle contribution, KOA versus HC — YMFZ-R. * permutation $p < 0.05$; † global FDR < 0.05; § condition-wise FDR < 0.05.

Figure S22: Per-condition muscle functional-contribution profiles (continued): Part the Wild Horse's Mane (YMFZ).

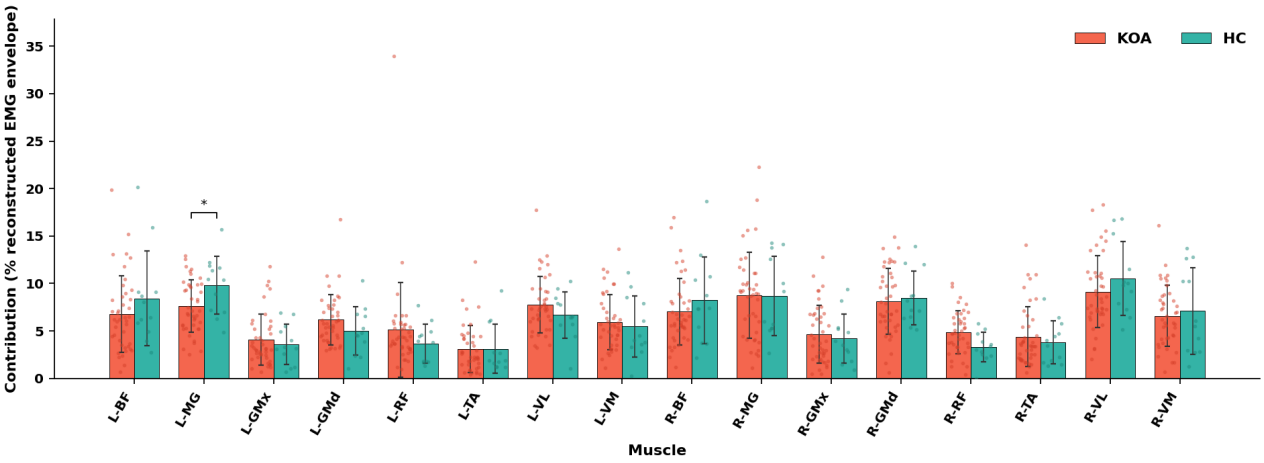


Muscle contribution, KOA versus HC — YS-L. * permutation $p < 0.05$; † global FDR < 0.05; § condition-wise FDR < 0.05.

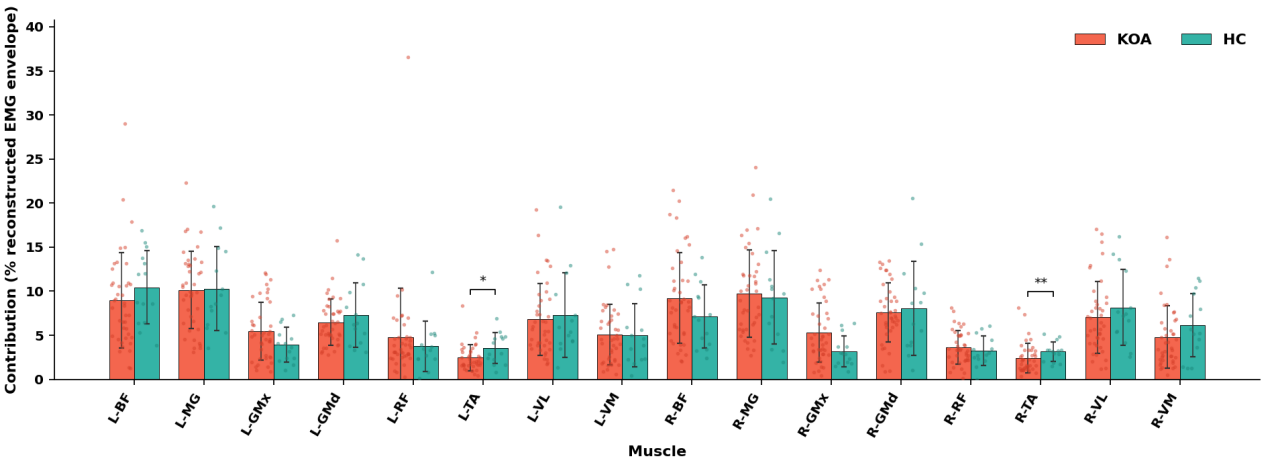


Muscle contribution, KOA versus HC — YS-R. * permutation $p < 0.05$; † global FDR < 0.05; § condition-wise FDR < 0.05.

Figure S22: Per-condition muscle functional-contribution profiles (continued): Cloud Hands (YS).

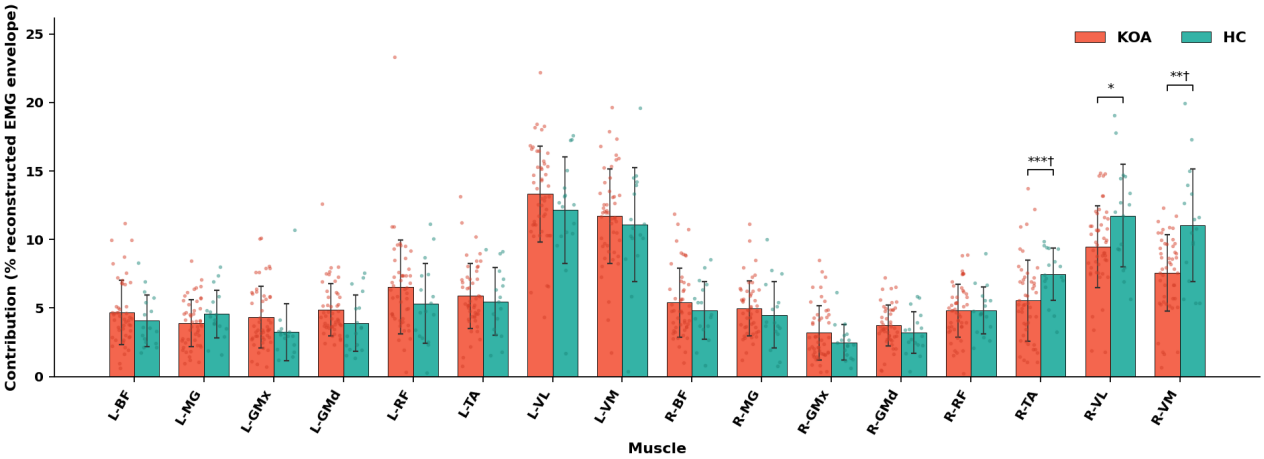


Muscle contribution, KOA versus HC — QS. * permutation $p < 0.05$; † global FDR < 0.05; § condition-wise FDR < 0.05.



Muscle contribution, KOA versus HC — SS. * permutation $p < 0.05$; † global FDR < 0.05; § condition-wise FDR < 0.05.

Figure S22: Per-condition muscle functional-contribution profiles (continued): Opening Form (QS) and Closing Form (SS).



Muscle contribution, KOA versus HC — SZS. * permutation $p < 0.05$; † global FDR < 0.05; § condition-wise FDR < 0.05.

Figure S22: Per-condition muscle functional-contribution profiles (continued): Cross Hands (SZS).

Table S10 ranks muscles by how often they discriminated the groups across conditions.

Table S10: Muscle ranking by discriminative involvement across the 17 conditions: number of conditions significant under the primary global BH-FDR family across 272 comparisons (split by direction), and mean absolute/signed Hedges' g on CLR-transformed contribution (positive = higher in KOA). Abbreviations and marks: KOA, knee osteoarthritis; HC, healthy controls; CLR, centered log ratio; FDR, false discovery rate; ES, effect size; KOA↑/HC↑, higher relative contribution in KOA/HC; BF, biceps femoris; MG, medial gastrocnemius; GMx, gluteus maximus; GMd, gluteus medius; RF, rectus femoris; TA, tibialis anterior; VL, vastus lateralis; VM, vastus medialis; L/R prefixes denote left/right side.

Rank	Muscle	FDR-sig conditions	KOA↑	HC↑	Mean |ES|	Mean signed ES
1	L GMd	2	2	0	0.555	0.445
2	R VM	2	0	2	0.464	-0.402
3	R TA	2	0	2	0.377	-0.231
4	L TA	1	0	1	0.334	-0.241
5	R BF	1	0	1	0.296	-0.085
6	L BF	1	0	1	0.293	-0.224
7	R MG	1	0	1	0.285	-0.118
8	R RF	1	0	1	0.271	0.133
9	R VL	0	0	0	0.418	-0.349
10	L MG	0	0	0	0.403	-0.198
11	L RF	0	0	0	0.332	0.299
12	R GMx	0	0	0	0.318	0.228
13	L VL	0	0	0	0.306	0.146
14	L GMx	0	0	0	0.255	0.153
15	L VM	0	0	0	0.249	0.076
16	R GMd	0	0	0	0.221	0.113

S8 Across-movement key-muscle contribution values

Figure 6 in the main text displays the complete 16-muscle distribution, participant-level values and KOA–HC comparison. Table S11 provides the exact values for the ten muscles with the largest mean contributions.

Table S11: Top ten key muscles of Tai Chi, ranked by mean functional contribution (% of the summed reconstructed EMG envelope) across all movements.

Rank	Muscle	Overall (%)	KOA (%)	HC (%)
1	R-VL	10.5	10.2	11.1
2	L-VL	10.2	10.3	10.1
3	L-VM	8.8	8.8	8.6
4	R-VM	8.7	8.3	10.0
5	L-RF	6.1	6.3	5.3
6	R-BF	6.0	5.9	6.1
7	L-GMd	5.7	5.8	5.1
8	R-GMd	5.6	5.7	5.2
9	R-TA	5.3	5.2	5.6
10	R-RF	5.2	5.4	4.9

Abbreviations: KOA, knee osteoarthritis; HC, healthy controls; VL, vastus lateralis; VM, vastus medialis; RF, rectus femoris; BF, biceps femoris; GMd, gluteus medius; TA, tibialis anterior. L/R prefixes denote left/right side.

S9 Descriptive assessment synthesis: per-measure scores

Composite synergy index combining all five measures (main-text Fig. 8, Table 4). Each measure is z-scored across the 17 conditions (higher = more KOA–HC divergence): D1 number (effect-size magnitude), D2 similarity (1−mean cosine), D3 muscle weights (mean effect-size magnitude), D4 contribution (mean absolute CLR-scale Hedges' g), D5 timing (total significant duration). Composite (equal) = mean of the five; composite (recruit) = mean of D4–D5. AUC = per-condition L1-logistic classifier (repeated stratified 5-fold CV) on combined subject-level features (muscle weights + CLR contribution + activation), with a label-permutation p. The composite index is a descriptive ranking; the per-condition AUCs are exploratory and underpowered (control $n \approx 12$–17 per condition against a high-dimensional feature set), and four conditions (DJ-L, DJ-R, SZS-NA, YMFZ-L; bold) exceeded the unadjusted permutation threshold ($p < 0.05$), two of which (DJ-L and DJ-R) are top-ranked by the composite. The composite ranking and classifier signal remain weakly concordant (Spearman $\rho = 0.31$, $p = 0.224$). Machine-readable: `Supplementary_Tables.xlsx`, sheet `S12_screening_index`.

Table S12: Per-measure z-scores, composite indices, and per-condition classifier AUC (with permutation p), ranked by equal-weighted composite. D1, synergy-number effect-size magnitude; D2, structural dissimilarity (1−mean cosine similarity); D3, muscle-weight effect-size magnitude; D4, mean absolute Hedges' g on CLR-transformed functional contribution; D5, total duration of activation-profile differences; Comp. (eq), equal-weighted composite; Comp. (rec), recruitment-only composite; AUC, area under the receiver-operating-characteristic curve; Perm p, label-permutation p value. Bold AUC and permutation values mark exploratory unadjusted classifier significance at $p < 0.05$. The composite is descriptive and not a validated screening or diagnostic score. Abbreviations: KOA, knee osteoarthritis; HC, healthy controls; CLR, centered log ratio; QS, Opening Form; DJG, Repulse Monkey; LXAB, Brush Knee and Twist Step; YMFZ, Part the Wild Horse's Mane; YS, Cloud Hands; JJDL, Golden Rooster Stands on One Leg; DJ, Heel Kick; LQW, Grasp the Sparrow's Tail; SZS, Cross Hands; SS, Closing Form; L/R, left/right stance leg; NA, no side-specific split.

Condition	D1 num	D2 str	D3 wt	D4 con	D5 tim	Comp. (eq)	Comp. (rec)	AUC	Perm p
DJ-L	+1.56	-0.03	+0.85	+2.33	+0.10	+0.96	+1.22	**0.77**	**0.020**
DJG-R	+1.71	+2.22	+0.59	-0.94	+0.32	+0.78	-0.31	0.60	0.448
DJ-R	+1.04	-0.74	+1.15	+1.38	+0.23	+0.61	+0.81	**0.69**	**0.045**
JJDL-R	+1.28	-0.70	+0.31	+1.90	-0.53	+0.45	+0.68	0.63	0.403
YS-L	-0.76	+0.26	-0.70	-0.01	+2.31	+0.22	+1.15	0.69	0.383
YS-R	-0.92	+0.50	-0.77	-0.16	+1.97	+0.12	+0.90	0.58	0.269
JJDL-L	+0.54	-1.28	+2.01	-0.16	-0.73	+0.08	-0.44	0.59	0.159
LQW-R	+0.35	-0.62	-0.21	+0.53	+0.17	+0.05	+0.35	0.69	0.184
QS-NA	-1.16	+1.01	+1.70	-0.08	-1.31	+0.03	-0.70	0.61	0.189
DJG-L	-1.50	+2.26	-1.06	-0.81	+0.80	-0.06	-0.01	0.56	0.557
LQW-L	+0.17	-0.60	-0.65	-0.32	-0.07	-0.30	-0.20	0.53	0.826
LXAB-R	-0.13	-0.07	-1.38	-0.85	+0.48	-0.39	-0.19	0.56	0.229
SZS-NA	-0.43	-1.14	+0.53	+0.35	-1.31	-0.40	-0.48	**0.69**	**0.020**
LXAB-L	-0.19	-0.08	-0.55	-0.95	-0.77	-0.51	-0.86	0.49	0.871
SS-NA	+0.66	-0.32	-1.46	-0.13	-1.31	-0.51	-0.72	0.44	0.627
YMFZ-R	-0.72	-0.88	-0.52	-0.79	+0.09	-0.56	-0.35	0.60	0.109
YMFZ-L	-1.51	+0.19	+0.15	-1.29	-0.43	-0.58	-0.86	**0.81**	**0.005**