Supplementary Material

Subject	SO vs CCI	SO vs EMG	SO vs RMR	CCI vs EMG	CCI vs RMR	EMG vs RMR
K1L	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
K2L	< 0.01	0.29	0.29	< 0.01	< 0.01	0.20
K3R	< 0.01	< 0.01	< 0.01	< 0.01	0.73	< 0.01
K5R	< 0.01	< 0.01	0.81	0.86	< 0.01	< 0.01
K7L	< 0.01	< 0.01	0.04	< 0.01	0.04	< 0.01
K8L	< 0.01	0.29	< 0.01	< 0.01	0.50	< 0.01
Overall	< 0.01	0.23	< 0.01	< 0.01	< 0.01	0.15

Table S1. Pairwise *p*-values comparing KCF estimation errors (RMSE) across four muscle redundancy solvers, by subject and across all subjects combined (Overall). The evaluated solvers were the Static Optimization (SO), original Residual Muscle Redundancy (RMR), EMG-Informed (EMG), and CCI-Informed (CCI) solver. The *p*-values are reported from Wilcoxon signed-rank tests with Holm-Bonferroni correction for multiple comparisons. The *p*-values highlighted in green indicate statistically significant differences in RMSE between compared solver pairs ($p < 0.05$).

Metric	Activity	Static Optimization	Minimum Activation	EMG-informed	CCI-informed
RMSE [BW] (mean $\pm$ std)	Level Walking	0.35 ± 0.12	0.32 ± 0.15	0.34 ± 0.18	0.25 ± 0.11
	Ramp Descent	0.36 ± 0.16	0.33 ± 0.14	0.49 ± 0.21	0.24 ± 0.07
	Stair Descent	0.80 ± 0.23	0.54 ± 0.12	0.58 ± 0.23	0.48 ± 0.10
	Overall	0.47 ± 0.25	0.38 ± 0.17	0.44 ± 0.22	0.31 ± 0.14
R^2 [-] (mean $\pm$ std)	Level Walking	0.84 ± 0.10	0.88 ± 0.08	0.84 ± 0.14	0.93 ± 0.05
	Ramp Descent	0.89 ± 0.08	0.91 ± 0.08	0.78 ± 0.15	0.95 ± 0.03
	Stair Descent	0.45 ± 0.34	0.77 ± 0.08	0.71 ± 0.19	0.81 ± 0.09
	Overall	0.75 ± 0.26	0.86 ± 0.10	0.80 ± 0.17	0.90 ± 0.08
Peak Force Error [BW] (mean $\pm$ std)	Level Walking	0.42 ± 0.42	0.40 ± 0.30	0.36 ± 0.27	0.33 ± 0.27
	Ramp Descent	0.63 ± 0.54	0.34 ± 0.24	0.50 ± 0.32	0.28 ± 0.18
	Stair Descent	2.06 ± 0.85	0.71 ± 0.41	0.74 ± 0.52	0.64 ± 0.37
	Overall	0.89 ± 0.91	0.47 ± 0.35	0.49 ± 0.39	0.40 ± 0.32

Table S2. Summary of RMSE in body weight (BW), R^2 and peak force error of the second peak in stance phase for each activity and overall across all activities. Metrics are compared across four muscle redundancy solvers: Static Optimization, Minimum Activation (RMR), EMG-informed, and CCI-informed. For each activity and the overall results, the best-performing solver is highlighted in green and the worst-performing solver in red. The results show that the CCI-informed simulations performed overall the best in each evaluation metric.

Activity	SO vs CCI	SO vs EMG	SO vs RMR	CCI vs EMG	CCI vs RMR	EMG vs RMR
Level Walking	< 0.01	0.36	0.37	0.08	< 0.01	0.85
Ramp Descent	< 0.01	0.14	0.37	< 0.01	< 0.01	0.08
Stair Descent	< 0.01	0.03	< 0.01	0.10	< 0.01	0.55

Table S3. Pairwise *p*-values comparing KCF estimation errors (RMSE) across four muscle redundancy solvers by activity. The evaluated solvers were the Static Optimization, original Residual Muscle Redundancy (RMR), EMG-Informed (EMG), and CCI-Informed (CCI) solver. The *p*-values are reported from Wilcoxon signed-rank tests with Holm-Bonferroni correction for multiple comparisons. The *p*-values highlighted in green indicate statistically significant differences in RMSE between compared solver pairs ($p < 0.05$).

Activity	Solver	β	Standard Error	95% CI	p-value	N (observations)
All Activities	Static Optimization	1.25	0.70	[-0.55, 3.06]	0.13	92
	Minimum Acitvation	1.55	0.30	[0.79, 2.30]	0.00	92
	EMG-Informed	1.34	0.76	[-0.60, 3.28]	0.14	92
	CCI-Informed	0.78	0.25	[0.14, 1.43]	0.03	92
Level Walking	Static Optimization	0.16	0.69	[-1.62, 1.94]	0.83	48
	Minimum Acitvation	1.50	0.64	[-0.14, 3.14]	0.07	48
	EMG-Informed	0.75	1.22	[-2.39, 3.90]	0.56	48
	CCI-Informed	0.29	0.63	[-1.34, 1.92]	0.67	48
Ramp Descent	Static Optimization	2.12	0.45	[0.88, 3.36]	0.01	20
	Minimum Acitvation	1.53	0.35	[0.56, 2.51]	0.01	20
	EMG-Informed	-0.61	0.62	[-2.33, 1.12]	0.38	20
	CCI-Informed	0.34	0.30	[-0.50, 1.17]	0.32	20
Stair Descent	Static Optimization	-0.25	0.75	[-2.19, 1.68]	0.75	24
	Minimum Acitvation	0.96	0.36	[0.03, 1.89]	0.04	24
	EMG-Informed	1.30	0.88	[-0.96, 3.55]	0.20	24
	CCI-Informed	0.43	0.37	[-0.53, 1.39]	0.30	24

Table S4. Results of linear regression analyses with cluster-robust standard errors examining the association between the CCI and the RMSE of estimated compressive KCF for each solver and activity condition. The six subjects were treated as clusters. Regression coefficients (β, in BW per unit CCI), cluster-robust standard errors, 95 % confidence intervals (95 % CI), p-values, and the number of observations (N) are reported for the Static Optimization, Minimum Activation (RMR), EMG-informed, and CCI-informed solvers across all activities combined, as well as separately for level walking, ramp descent, and stair descent.

Activity	Solver	β	RE SD	95% CI	R^2_{marg}	ICC	N (observations)
All Activities	Static Optimization	2.44	0.14	[0.96, 3.66]	0.23	0.30	92
	Minimum Acitvation	1.94	0.11	[1.55, 2.73]	0.37	0.52	92
	EMG-Informed	1.47	0.18	[1.03, 2.31]	0.14	0.69	92
	CCI-Informed	NA†	NA	NA	NA	NA	NA
Level Walking	Static Optimization	1.83	0.14	[0.82, 2.88]	0.24	0.78	48
	Minimum Acitvation	2.62	0.14	[1.66, 3.24]	0.42	0.83	48
	EMG-Informed	-0.31	0.19	[-0.83, 1.05]	0.01	0.94	48
	CCI-Informed	0.90	0.11	[0.01, 1.64]	0.11	0.75	48
Ramp Descent	Static Optimization	NA†	NA	NA	NA	NA	NA
	Minimum Acitvation	1.18	0.12	[0.64, 1.77]	0.16	0.93	20
	EMG-Informed	0.71	0.22	[0.23, 1.69]	0.02	0.91	20
	CCI-Informed	NA†	NA	NA	NA	NA	NA
Stair Descent	Static Optimization	0.60	0.22	[-1.00, 3.67]	0.02	0.80	24
	Minimum Acitvation	NA†	NA	NA	NA	NA	NA
	EMG-Informed	0.77	0.21	[-0.20, 2.12]	0.04	0.80	24
	CCI-Informed	NA†	NA	NA	NA	NA	NA

Table S5. Results of the linear mixed-effects regression analysis between the CCI and the RMSE of estimated compressive KCF for each solver and activity condition. The fixed-effect slope (β, in BW per unit CCI), its 95 % confidence interval (95 % CI), the between-subject random-effect standard deviation (RE SD), the marginal coefficient of determination (R^2_{marg}, variance explained by CCI alone), the intraclass correlation coefficient (ICC, proportion of total variance attributable to between-subject differences), and the number of observations (N) are reported for Static Optimization, Minimum Activation (RMR), EMG-informed, and CCI-informed solvers across all activities combined, as well as separately for level walking, ramp descent, and stair descent. The mixed-effects model included subject as a random intercept to account for between-subject variability in baseline RMSE across repeated trials. Models that did not converge are indicated by † and were excluded from the analysis.