Supplementary Materials

Methods S1 Validity of the Step −1 reference

To verify that Step −1 represented a valid reference, the similarity of Step −1 belt speed to the constant-speed baseline was evaluated by calculating the 95% confidence interval (CI) for the within-participant mean difference.

Methods S2 Model adequacy

The normality of residuals from each LME was assessed using the Shapiro–Wilk test. To assess the robustness of the interaction tests to non-normal residuals, a participant-level cluster bootstrap was performed. In each of 2000 replicates, 19 participants were resampled with replacement, with duplicated participants treated as distinct clusters; all 12 models were refitted to the resampled data using the same specification as in the main analysis. The condition × step interaction was tested with a centered bootstrap Wald test, in which the Wald statistic of the original estimates was compared with the distribution of statistics computed from the bootstrap estimates centered on the original estimates; *P* values were adjusted using the BH procedure separately for the primary and secondary models. Because the bootstrap was performed as a sensitivity analysis, results that reached significance only in the bootstrap were not interpreted.

Methods S3. Statistical power

The statistical power of the primary analyses was evaluated using simulations. For each of the four primary models, the power to detect the observed condition × step interaction was estimated using a Monte Carlo simulation (1000 simulations), with the interaction tested using the Kenward–Roger approximation. Power was assessed at $\alpha = .05$ and, as a conservative benchmark approximating a Bonferroni adjustment across the four primary models, at α

= .0125. The minimum detectable effect size was explored by scaling the observed interaction coefficients and re-estimating power (500 simulations per level) to identify the smallest effect retaining 80% power at $\alpha = .0125$.

Methods S4. Learning effects

To confirm that the gait responses were stable across repeated exposures to each condition, the cycles were ranked within each condition for each participant and classified as early (cycles 1–2) or late (cycles 4–5). A separate LME was fitted to each outcome variable and condition. The *P values* for the cycle-phase main effect were corrected using the BH procedure across the eight learning-effect models for the primary outcomes (two outcomes × four conditions).

Results S1 Validity of the Step −1 reference

Within-participant comparisons showed that Step −1 belt speed closely matched the constant-speed baseline in all four conditions (mean differences ≤ 0.021 m/s, Table S2). The offset was negligible in CtoA and CtoD and small in ACC, whereas in DEC the 95% CI excluded zero (+0.021 m/s [0.004, 0.037]), indicating a small but nonzero difference.

Results S2 Model adequacy and sensitivity

Residuals deviated from normality according to the Shapiro–Wilk test (W = 0.921–0.993; Table S3). In the cluster bootstrap, all four primary interactions remained significant ($P_{FDR} < .001$); all secondary interactions that were significant in the main analysis remained significant. The interaction for Peak vGRF 2nd in the CtoA–ACC pair, which was not significant in the main analysis, reached significance in the bootstrap ($P_{FDR} = .003$) but was not interpreted (Table S3). Convergence warnings occurred in 3 of 24,000 refits, and no singular fits occurred.

Results S3 Statistical power

A simulation-based power analysis confirmed that all four primary models were well powered to detect the observed condition × step interactions, with power ≥ 99.5% at α = .05 and ≥ 97.7% at the multiplicity-adjusted α = .0125 (Table S3); the lowest values occurred for the smallest interaction (Peak BF, CtoA–ACC pair). Minimum detectable effect analyses indicated that ≥ 80% power was retained for interactions considerably smaller than those observed—down to approximately 74% of the observed magnitude for the weakest model and 30% for the strongest (Table S3).

Results S4 Learning effects

Among the primary outcomes, Peak BF was higher in the late than in the early cycles in all four conditions (ACC: 15.49 to 16.58 %BW; CtoA: 14.58 to 15.63 %BW; DEC: 11.92 to 12.97 %BW; CtoD: 13.03 to 14.24 %BW; all $P_{FDR} < .01$). For Peak PF, a significant increase from early to late cycles occurred only in ACC (24.16 to 25.33 %BW; $P_{FDR} = .002$); the effect was not significant in CtoA ($P_{FDR} = .069$), DEC ($P_{FDR} = .225$), or CtoD ($P_{FDR} = .740$).

In uncorrected exploratory comparisons of the secondary outcomes, step length and time increased from early to late cycles in ACC, CtoA, and CtoD, and the second vertical GRF peak increased in ACC and CtoA, whereas DEC showed no significant cycle-phase effect on any secondary variable (Table S5).

Results S5 Belt speed by condition and step

Table S4 summarizes belt speed of each step included in the analysis, and Figure S1 shows its distribution. Although belt speed at Steps 0 and +1 differed between transition and continuous conditions, ranges of the two conditions overlapped at every step.

Results S6 Participant characteristics by sex

Table S1 presents participant characteristics separately for women and men. Statistical comparisons between sexes were not performed because of the small number of men.

Table S1. Participant characteristics for the whole sample and by sex.

Variable	All (N = 19)	Women (N = 13)	Men (N = 6)
Age (years)	24.5 ± 1.8	24.6 ± 1.8	24.2 ± 2.1
Height (cm)	164.4 ± 7.4	161.7 ± 6.6	170.2 ± 5.7
Body mass (kg)	59.8 ± 12.1	58.3 ± 11.6	63.2 ± 13.7
10 m walk time (s)	4.60 ± 0.53	4.80 ± 0.47	4.15 ± 0.34
Maximum walking speed (m/s)	2.20 ± 0.25	2.10 ± 0.20	2.42 ± 0.19
Baseline belt speed (m/s)	1.09 ± 0.12	1.04 ± 0.10	1.20 ± 0.08

Values are mean ± SD. Maximum walking speed was calculated from the 10 m walk time. Baseline belt speed is the mean belt speed measured during the constant-speed period (set at 50% of each participant's maximum walking speed). Statistical comparisons between sexes were not performed because of the small sample size.

Table S2. Belt speed at the Step −1 reference compared with the constant-speed baseline (N = 19).

Condition	Belt speed (m/s)	Mean difference	95% CI
Baseline	1.09 ± 0.12	—	—
CtoA	1.09 ± 0.12	< 0.001	[>−0.001, < 0.001]
ACC	1.10 ± 0.13	+0.012	[−0.008, 0.032]
CtoD	1.09 ± 0.12	< 0.001	[>−0.001, < 0.001]
DEC	1.11 ± 0.13	+0.021	[0.004, 0.037]

Values are presented as mean ± SD; conditions are as defined in the Methods section. Mean difference denotes the within-participant difference in belt speed at Step −1 relative to baseline (Step −1 minus baseline), with its t-based 95% confidence interval (CI).

SD, standard deviation; ACC, acceleration condition; DEC, deceleration condition; CtoA, constant speed to acceleration; CtoD, constant speed to deceleration.

Table S3. Model adequacy, variance components, and statistical power for the linear mixed-effects models.

Variables	Condition pair	SW W	SW P	$\sigma_{participant}$	$\sigma_{residual}$	ICC	CB P_{FDR}	Power (α = .05)	Power (α = .0125)	k_{MDE} (α = .0125)
Peak BF	CtoA vs ACC	0.983	< .001	2.948	2.439	0.594	< .001	99.5%	97.7%	0.740
	CtoD vs DEC	0.993	.011	2.060	2.137	0.482	< .001	> 99.9%	> 99.9%	0.532
Peak PF	CtoA vs ACC	0.984	< .001	2.740	2.456	0.554	< .001	> 99.9%	> 99.9%	0.547
	CtoD vs DEC	0.987	< .001	1.664	2.281	0.347	< .001	> 99.9%	> 99.9%	0.295
Peak vGRF 1st	CtoA vs ACC	0.990	< .001	5.744	4.721	0.597	.001	—	—	—
	CtoD vs DEC	0.990	< .001	3.862	4.416	0.433	.003	—	—	—
Peak vGRF 2nd	CtoA vs ACC	0.987	< .001	6.808	5.593	0.597	.003	—	—	—

Variables	Condition pair	SW W	SW P	$\sigma_{participant}$	$\sigma_{residual}$	ICC	CB P_{FDR}	Power ($\alpha = .05$)	Power ($\alpha = .0125$)	k_{MDE} ($\alpha = .0125$)
Step Length	CtoD vs DEC	0.990	< .001	3.266	3.724	0.435	.001	—	—	—
	CtoA vs ACC	0.988	< .001	0.049	0.032	0.699	.003	—	—	—
Step Time	CtoD vs DEC	0.970	< .001	0.055	0.041	0.646	.496	—	—	—
	CtoA vs ACC	0.992	.004	0.042	0.027	0.711	.239	—	—	—
	CtoD vs DEC	0.921	< .001	0.078	0.084	0.464	.001	—	—	—

Each row corresponds to a separate linear mixed-effects model fitted to the indicated outcome variable for the indicated condition pair. SW W and SW P denote the test statistic and P value of the Shapiro–Wilk test applied to the model residuals. CB P_{FDR} denotes the false discovery rate-adjusted P value for the condition × step interaction obtained from a participant-level cluster bootstrap (2000 replicates, in which participants were resampled with replacement and each model was refitted), using a centered bootstrap Wald test; the Benjamini–Hochberg correction was applied separately across the four primary and eight secondary models. $P < .001$ corresponds to the resolution limit of 2000 replicates. Power denotes the simulation-based power to detect the observed condition × step interaction (1000 simulations, Kenward–Roger approximation) at the significance level indicated; $\alpha = .0125$ approximates a Bonferroni adjustment across the four primary models. k_{MDE} denotes the smallest scaling factor applied to the observed interaction coefficients that retained 80% power at $\alpha = .0125$ (500 simulations per level), where $k = 1.000$ corresponds to the observed effect. $\sigma_{participant}$ and $\sigma_{residual}$ denote the SDs (square roots of the variances) of the participant random intercept and the residual, respectively, in the units of each outcome (%BW for GRF variables, m for step length, and s for step time). $ICC = \sigma^2_{participant} / (\sigma^2_{participant} + \sigma^2_{residual})$. All models converged without warnings, and no singular fits occurred. Power simulations were performed for the four primary models only.

—, not applicable.

Abbreviations: ACC, acceleration condition; BF, braking force; CB, cluster bootstrap; CtoA, constant speed to acceleration; CtoD, constant speed to deceleration; DEC, deceleration condition; FDR, false discovery rate; ICC, intraclass correlation coefficient; PF, propulsive force; SW, Shapiro–Wilk; vGRF, vertical ground reaction force.

Table S4. Belt speed by condition and step.

Condition	Step	*N*	Mean ± SD	Range
CtoA	−1	95	1.09 ± 0.12	0.87–1.30
CtoA	0	95	1.12 ± 0.12	0.87–1.38
CtoA	+1	95	1.31 ± 0.14	1.02–1.63
ACC	−1	95	1.10 ± 0.15	0.71–1.40
ACC	0	95	1.37 ± 0.14	1.05–1.64
ACC	+1	95	1.61 ± 0.14	1.33–1.88
CtoD	−1	95	1.09 ± 0.12	0.87–1.30
CtoD	0	95	1.06 ± 0.13	0.77–1.29
CtoD	+1	95	0.81 ± 0.19	0.34–1.18
DEC	−1	95	1.11 ± 0.15	0.76–1.42
DEC	0	95	0.78 ± 0.18	0.33–1.15
DEC	+1	87	0.50 ± 0.12	0.27–0.83

Values summarize the mean belt speed of each step included in the analysis (after exclusion) across all observations ($N = 95$ per cell; $N = 87$ for Step +1 in DEC). Range indicates the minimum–maximum. Units are m/s.

Abbreviations: ACC, acceleration condition; CtoA, constant speed to acceleration; CtoD, constant speed to deceleration; DEC, deceleration condition.

Table S5. Learning effects.

Condition	Variable	Early mean (SE)	Late mean (SE)	*F*	*P*	P_{FDR}
ACC	Peak BF (%BW)	15.49 (0.84)	16.58 (0.84)	9.58	.002	.004
	Peak PF (%BW)	24.16 (0.85)	25.33 (0.85)	11.94	< .001	.002
	Peak vGRF 1st (%BW)	111.22 (1.49)	109.59 (1.49)	4.92	.028	—
	Peak vGRF 2nd (%BW)	102.52 (2.13)	106.00 (2.13)	20.82	< .001	—
	Step length (m)	0.66 (0.01)	0.69 (0.01)	37.79	< .001	—
	Step time (s)	0.49 (0.01)	0.51 (0.01)	37.91	< .001	—
CtoA	Peak BF (%BW)	14.58 (0.63)	15.63 (0.63)	15.03	< .001	< .001
	Peak PF (%BW)	22.11 (0.50)	22.67 (0.50)	3.84	.051	.069
	Peak vGRF 1st (%BW)	105.36 (1.36)	105.74 (1.36)	0.72	.396	—
	Peak vGRF 2nd (%BW)	105.65 (1.26)	107.48 (1.26)	8.19	.005	—
	Step length (m)	0.64 (0.01)	0.65 (0.01)	9.03	.003	—
	Step time (s)	0.55 (0.01)	0.56 (0.01)	11.71	< .001	—
DEC	Peak BF (%BW)	11.92 (0.49)	12.97 (0.49)	11.27	< .001	.002
	Peak PF (%BW)	14.58 (0.50)	14.13 (0.50)	1.68	.197	.225
	Peak vGRF 1st (%BW)	104.34 (0.90)	104.29 (0.90)	0.01	.938	—
	Peak vGRF 2nd (%BW)	101.70 (0.76)	101.73 (0.76)	0.00	.954	—
	Step length (m)	0.55 (0.01)	0.56 (0.01)	0.03	.870	—
	Step time (s)	0.76 (0.02)	0.76 (0.02)	0.01	.925	—
CtoD	Peak BF (%BW)	13.03 (0.57)	14.24 (0.57)	24.63	< .001	< .001
	Peak PF (%BW)	17.14 (0.37)	17.06 (0.37)	0.11	.740	.740
	Peak vGRF 1st (%BW)	104.09 (1.14)	104.37 (1.14)	0.37	.543	—

Condition	Variable	Early mean (SE)	Late mean (SE)	F	P	P_{FDR}
	Peak vGRF 2nd (%BW)	105.65 (0.91)	105.22 (0.91)	0.73	.395	—
	Step length (m)	0.58 (0.01)	0.59 (0.01)	8.69	.004	—
	Step time (s)	0.60 (0.02)	0.62 (0.02)	7.08	.008	—

Comparison of early and late exposures for each outcome within each condition. Conditions are as defined in the Methods section. Values are presented as EMMs (SEs) for the early (cycles 1–2) and late (cycles 4–5) phases; cycle 3 was excluded. A separate LME was fitted per condition and outcome; *F* statistics represent the cycle-phase main effect. The Benjamini–Hochberg correction was applied across the eight primary-outcome models (two primary outcomes × four conditions); uncorrected *P* values are reported for the secondary-outcome models. Peak BF/PF and Peak vGRF 1st/2nd are expressed as %BW, step length as m, and step time as s.

vGRF, vertical ground reaction force; BF, braking force; PF, propulsive force; LME, linear mixed-effects; SE, standard error; EMM, estimated marginal mean; %BW, percentage of body weight; ACC, acceleration condition; DEC, deceleration condition; CtoA, constant speed to acceleration; CtoD, constant speed to deceleration.

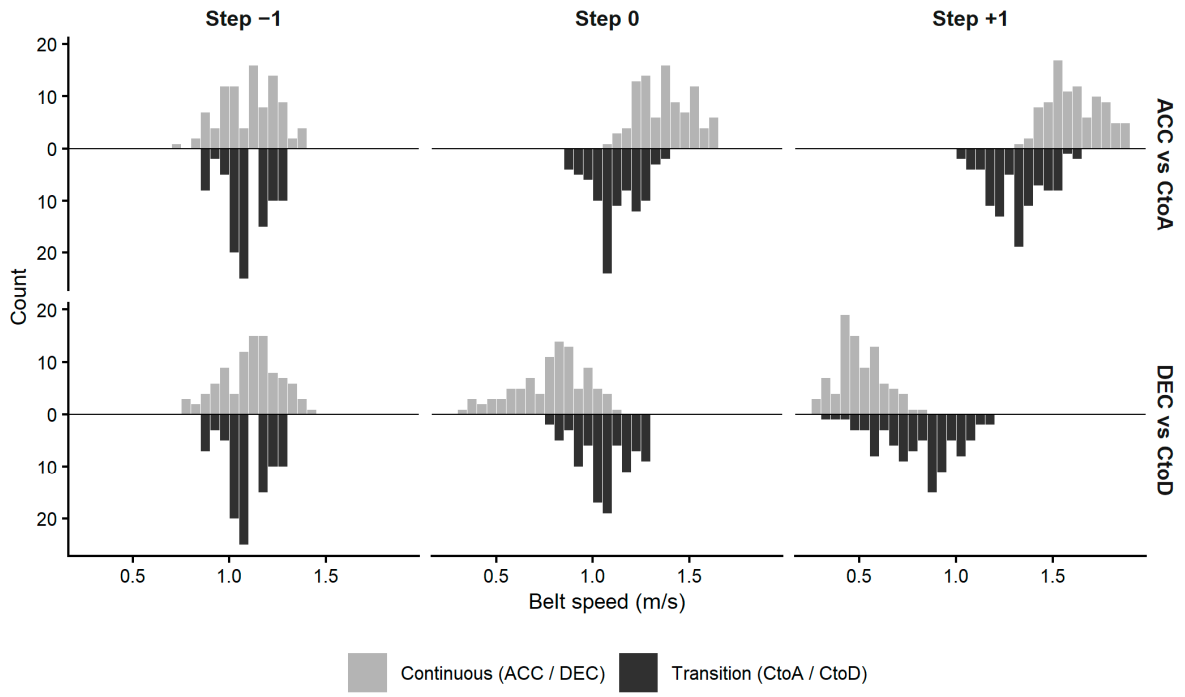


Figure S1. Distribution of belt speed by condition and step.

Mirrored histograms of the mean belt speed of each step included in the analysis (after exclusion) for the CtoA–ACC pair (top row) and the CtoD–DEC pair (bottom row) at Steps −1, 0, and +1. Bars above the horizontal line represent the continuous conditions (ACC, DEC), and bars below represent the transition conditions (CtoA, CtoD); counts are shown as absolute values in both directions. Bin width, 0.05 m/s. $N = 95$ steps per condition and step ($N = 87$ for Step +1 in DEC). Summary statistics are provided in Table S4.

Abbreviations: ACC, acceleration condition; CtoA, constant speed to acceleration; CtoD, constant speed to deceleration; DEC, deceleration condition.