Supporting Information

Two independent contributions to step variability during over-ground human walking

S. H. Collins and A. D. Kuo

Table S1 Average step parameters ($N = 14$, mean ± s.d.). Significant difference between conditions is indicated by asterisk (*, $P < 0.05$).

Average	units	Eyes Open condition	Eyes Closed condition
Speed	$m \cdot s^{-1}$	1.510 ± 0.084	1.442 ± 0.104*
Step length	m	0.792 ± 0.036	0.762 ± 0.055*
Step width	m	0.168 ± 0.044	0.179 ± 0.047
Step frequency	s	1.814 ± 0.113	1.806 ± 0.119

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Table S2 Step variabilities, expressed as variance ($N = 14$, mean ± s.d.). Normalization units are given in terms of leg length L and gravitational acceleration g. Short-term variability is defined by applying a high-pass filter to step data, with a cut-off period of 30 steps (and long-term by a low-pass filter).

Variance	units	Eyes Open condition	Eyes Closed condition
Totals			
Speed	gL	0.000133 ± 0.000065	0.000122 ± 0.000058
Step length	L^2	0.000292 ± 0.000121	0.000377 ± 0.000125
Step width	L^2	0.000677 ± 0.000221	0.001380 ± 0.000413
De-trended			
Step length	L^2	0.000163 ± 0.000061	0.000255 ± 0.000079
Step width	L^2	0.000700 ± 0.000219	0.001420 ± 0.000418
Speed trend			
Step length	L^2	0.000121 ± 0.000097	0.000125 ± 0.000061
Step width	L^2	0.000023 ± 0.000028	0.000034 ± 0.000048
Short-term			
Step length	L^2	0.000173 ± 0.000069	0.000272 ± 0.000090
Step width	L^2	0.000590 ± 0.000201	0.001254 ± 0.000421
Long-term			
Step length	L^2	0.000117 ± 0.000081	0.000101 ± 0.000046
Step width	L^2	0.000093 ± 0.000044	0.000154 ± 0.000061

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Table S3 Step variabilities, expressed as root-mean-square values (N = 14, mean ± s.d.). Units are in SI, using the mean normalization factors to re-dimensionalize the data.

RMS Variability	units	Eyes Open condition	Eyes Closed condition
Totals			
Speed	$m \cdot s^{-1}$	0.0343 ± 0.0088	0.0330 ± 0.0073
Step length	m	0.0160 ± 0.0034	0.0183 ± 0.0029
Step width	m	0.0245 ± 0.0039	0.0351 ± 0.0053
De-trended			
Step length	m	0.0120 ± 0.0022	0.0151 ± 0.0023
Step width	m	0.0250 ± 0.0038	0.0356 ± 0.0053
Speed trend			
Step length	m	0.0099 ± 0.0037	0.0103 ± 0.0027
Step width	m	0.0038 ± 0.0026	0.0044 ± 0.0035
Short-term			
Step length	m	0.0123 ± 0.0024	0.0156 ± 0.0024
Step width	m	0.0229 ± 0.0038	0.0333 ± 0.0056
Long-term			
Step length	m	0.0098 ± 0.0034	0.0093 ± 0.0023
Step width	m	0.0090 ± 0.0021	0.0116 ± 0.0024

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Table S4 Results from parameter study on the filter to separate short- and long-term components. Step variabilities of Table S2 (variance) and Table S3 (RMS variability) are recomputed here with filter cut-off period of 10 steps (rather than 30 steps). The choice of filter causes minor differences in tabulated results, but statistically significant findings remain unchanged: The correlation between speed-related and long-term step lengths remained significant with $R^2 = 0.78$ ($P = 0.0005$), and the correlation for step widths remained insignificant with $R^2 = 0.03$ ($P = 0.14$)

Parameter (10-step cut-off)	units	Eyes Open condition	Eyes Closed condition
Variance			
Short-term			
Step length	L^2	0.000120 ± 0.000047	0.000202 ± 0.000070
Step width	L^2	0.000483 ± 0.000172	0.001063 ± 0.000380
Long-term			
Step length	L^2	0.000159 ± 0.000097	0.000156 ± 0.000058
Step width	L^2	0.000163 ± 0.000055	0.000262 ± 0.000097
RMS Variability			
Short-term			
Step length	m	0.0103 ± 0.0019	0.0134 ± 0.0022
Step width	m	0.0207 ± 0.0036	0.0307 ± 0.0054
Long-term			
Step length	m	0.0116 ± 0.0035	0.0117 ± 0.0022
Step width	m	0.0120 ± 0.0020	0.0152 ± 0.0029

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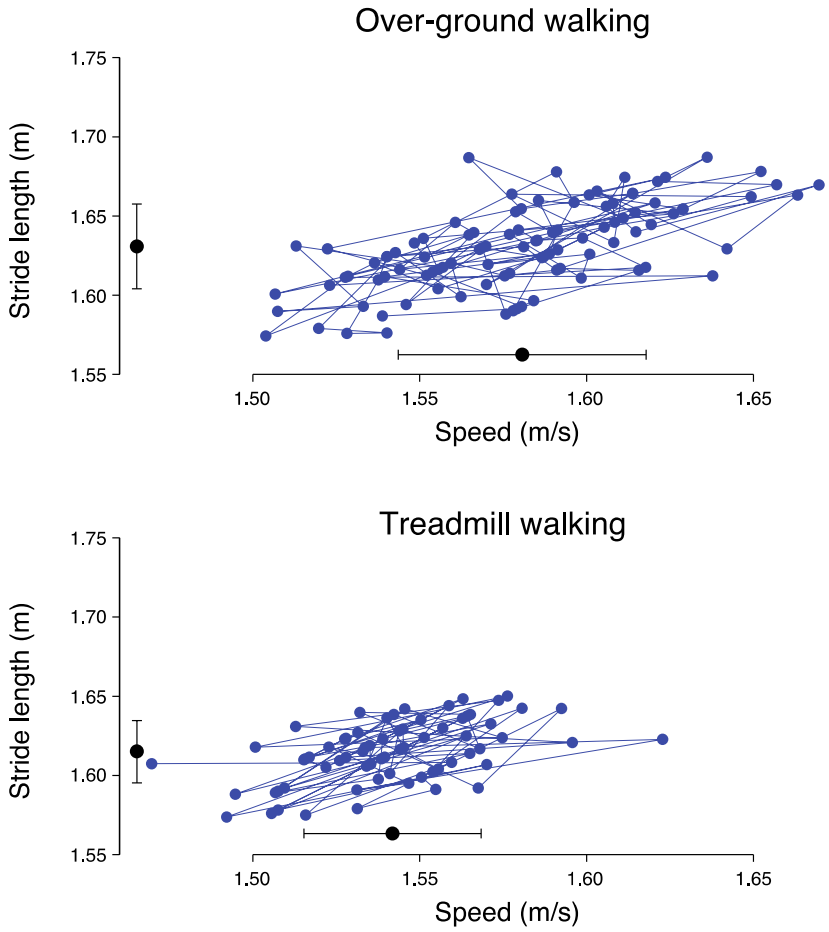

Figure S1 Sample stride length data for one foot of a young adult walking over-ground compared to the same person walking on a treadmill. Contiguous strides are shown, along with error bars indicating mean and standard devations. Walking speed fluctuates somewhat during over-ground walking, contributing some variability to stride length due to the stride length vs. speed relationship alone. Treadmill walking places an additional constraint on speed, leading to a smaller contribution of the stride length vs. speed relationship to stride length variability. For the trials shown here, speed variance was 96.2% greater over-ground than on treadmill, and stride length variance was 88% greater (and in terms of RMS variability, 40.1% more and 37.2% more, respectively).