The way to gait transitions:
Spatiotemporal characteristics of the spontaneous overground walk-to-run transition

Kristof De Smet, Philippe Malcolm, Veerle Segers, Matthieu Lenoir & Dirk De Clercq
Ghent University, Department of Movement and Sport Science, Belgium
Email**:** Kristof.DeSmet@ugent.be

Introduction
When increasing speed, humans switch from a walking to a running mode. Up till now, most studies used an increasing belt speed on treadmill to evoke walk-to-run transitions (WRT). However, as speed of locomotion is considered as the control variable on treadmills, it is remarkable that studies of how humans accelerate in a spontaneous submaximal manner are missing. The purpose of this study is to examine the acceleration profile and the WRT step in a more ecological overground transition.

Methodology
11 female subjects were asked to start walking, from a stand still position, with a free chosen acceleration and make the WRT. A synchronised measurement of subjects' speed (Noptel® Distance Laser 1000Hz) and foot contacts (Footscan® insoles 100Hz) permitted to analyse speed, step frequency (SF) and -length (SL). Subjects' acceleration track contains all walking steps, from standing still till the last step before transition. A best curve through least squares regression was fitted for each speed-, SF- and SL- track vs time (ln = natural logarithm, quad = quadratic, lin = linear). Mean acceleration (A), time to transition (TT) and number of steps to transition (ST) were also calculated. Inter-trial variability was low for each subject (ICCs> 0.872).

Results
Table 1 shows subjects' spatio-temporal characteristics of the acceleration track. For speed, 9 of 11 subjects showed a non-linear increasing type of regression curve (6/9 ln and 3/9 quad). This means the acceleration is higher in the first part of the acceleration period. In case of SF, 8 of 11 subjects showed a non-linear type (7/8 ln and 1/8 quad). For SL, 8/11 showed a linear increasing pattern.

Table 1: Individual spatiotemporal characteristics of the acceleration profile. TT = time to transition, ST = steps to transition, A = acceleration, V/time = type of regression curve for speed versus time, SF/time = type of regression curve for SF versus time, SL/time = type of regression curve for SL versus time

	subjects										
	1	2	3	4	5	6	7	8	9	10	11
TT(s)	2.772	2.930	1.890	3.160	2.440	2.770	2.228	2.618	3.554	3.555	2.553
ST (n)	5.8	6.6	4.3	6.3	5.6	6.0	5.2	5.8	7.2	8.0	5.0
A (m/s²)	0.373	0.508	0.764	0.436	0.533	0.395	0.699	0.382	0.380	0.409	0.452
V/time	ln	ln	ln	quad	ln	lin	quad	ln	quad	ln	lin
SF/time	ln	ln	quad	lin	ln	lin	ln	ln	ln	ln	lin
SL/time	lin	ln	lin	quad	lin	lin	lin	ln	lin	lin	lin

Average spatiotemporal values of step -1 (last walking step before transition), step 0 (transition step) and step +1 (first running step after transition) are shown in Table 2. Speed increased significantly from step -1 to step 0 ($t = -17.703$, $df = 10$) till step +1 ($t = -12.167$, $df = 10$). For SF, step +1 was significantly higher then step -1 ($t = -3.332$, $df = 10$) and step 0 ($t = -3.663$, $df = 10$). There was no significant difference between step -1 and step 0. With regard to SL, step -1 was significantly shorter then step 0 ($t = -9.646$, $df = 10$) and step +1 ($t = -5.110$, $df = 10$). There was no significant difference for SL between step 0 and step +1.

Table 2 Table 2: average speed (V), step frequency (SF) and step length (SL) for step -1, step 0 and step +1. Statistics: a = sign diff from step -1; b = sign diff from step 0; c = sign diff from step +1 ($p < 0.01$)

		mean ± sd	Paired T-test
V	step -1 (m/s)	2.247 ± 0.210	b,c
	step 0 (m/s)	2.664 ± 0.294	a,c
	step +1 (m/s)	2.948 ± 0.237	a,b
SF	step -1 (n/s)	2.347 ± 0.147	c
	step 0 (n/s)	2.310 ± 0.179	c
	step +1 (n/s)	2.565 ± 0.162	a,b
SL	step -1 (m)	0.946 ± 0.053	b,c
	step 0 (m)	1.158 ± 0.112	a
	step +1 (m)	1.148 ± 0.110	a

Discussion
When speeding up from standing still, over walking towards the transition to running, most subjects choose to accelerate predominantly in the first part of the acceleration period, followed by smaller speed increments in the last steps before transition. Speed and SF evolve in the same way which leads to the suggestion that speed is mainly guided/controlled by SF, more than by SL.

During the spontaneous overground transitions in the current study, mean transition speed is much higher compared to the reported transition speed on treadmill (2.16 m/s ± 0.12) for anthropometrically comparable subjects (Segers et al., 2006). However, in contrast with the latter study where subjects took a fast and short transition step, the current overground transition step is a rather slow and long step. Furthermore, the mean preferred overground acceleration is much higher compared to treadmill imposed constant accelerations in ramped protocols. The apparent differences in WRT between the spontaneous overground acceleration in the current study and the findings in earlier treadmill studies demonstrate the way people accelerate is important in gait transition studies.

References
Segers, V., Lenoir, M., Aerts P. and De Clercq, D. (2006) Spatiotemporal characteristics of the walk-to-run and run-to-walk transition when gradually changing speed. *Gait Posture* 24, 247-254.