A CASE STUDY ON THE MUSCULAR ADAPTATIONS TO ACCELERATE WHILE RUNNING OVERGROUND VS RUNNING ON AN ACCELERATING TREADMILL

Ine Van Caekenberghe and Dirk De Clercq

Department of Movement and Sports Sciences, Ghent University, Ghent, Belgium

The purpose of this study is to explore the differences in muscle activation when accelerating overground compared to running on an accelerated treadmill belt. A case study was conducted evaluating the muscle activation patterns of M. Gastrocnemius, M. Tibialis Anterior, M. Rectus Femoris and M. Biceps Femoris. Preliminary analyses tend to show that the changes in muscular activation needed overground to go from a steady-state to an accelerated run differ from the ones to go from a steady-state to an accelerated run on treadmill. This reinforces the conclusion of previous research on ground reaction forces and joint kinetics that accelerating on a standard motorized treadmill cannot be used as an alternative to train or investigate overground acceleration when running.

KEY WORDS: treadmill, overground, acceleration, EMG, running.

INTRODUCTION: Changing speed while running is an important part of many sports activities. In gait research and sports training, motorized treadmills are often employed because of their ease of use, the possibility to exactly control running conditions and the convenience to perform a variety of measurements. For steady-state locomotion, the motorized treadmill has been shown to replicate overground running fairly well (Riley et al., 2008). However, can the treadmill also be used to train or investigate accelerated running?

First of all, from a purely theoretical mechanical perspective the answer is clear: no, running on an accelerating belt is fundamentally different compared to accelerating overground. Newton's laws state that overground you have to accelerate your own body mass, whereas the treadmill belt accelerates underneath you. In other terms, overground you have to generate propulsive forces to overcome your body's linear inertia, which is something you don't have to do on an accelerating treadmill (Van Ingen Schenau, 1980).

Affirming the theoretical expectation, experimental evidence shows that in order to accelerate overground the horizontal ground reaction forces as observed during steady-state running have to be adapted to achieve less braking and more propulsion (Van Caekenberghe et al., 2013a). The runner tilts the body more forward, which brings the body centre of mass more forward relative to the centre of force application. Furthermore less power is absorbed during the braking phase, an active touchdown is used and a more pronounced extension is noticed during propulsion. In order to run on an accelerating treadmill the adaptations to the steady state gait pattern are, in line with the theoretical expectation, only a fraction of those observed overground (Van Caekenberghe et al., 2013b).

So how could this impact muscle activation patterns? Is accelerating overground a different task compared to running on an accelerating belt? This case study aims to compare the adaptations in muscle activation on one hand between running at a constant speed and accelerating overground; and the adaptations on the other hand between running on a constant speed and an accelerating treadmill.

METHODS: The EMG-data of one female subject who participated to previous studies (Van Caekenberghe et al., 2013a and 2013b) was analysed. The subject was submitted to the protocol which has been described in detail in the studies mentioned above. The subject ran at a variety of constant speeds and accelerations both overground and on treadmill. A motor-driven treadmill (h/p/Cosmos stellar; power: 2.2 kW; running surface: 1.7 m long and 0.65 m wide) was used to perform the treadmill tests. The subject signed informed consent and the protocol was approved by the Ghent University ethical committee.

Trials were matched for the overground and treadmill condition for speed (3 - 3.5 m/s) and acceleration (-0.1 to +0.1 m/s² for the constant speed trials and +0.7 to +1.1 m/s² for the accelerated trials). The following number of stance phases met the criteria above: 18 for the overground constant speed condition, 6 for the overground accelerated condition, 178 for the treadmill constant speed condition and 6 for the treadmill accelerated condition. Speed was defined as the average belt speed during the stance phase for the treadmill condition, and the average speed of the body centre of mass during the stance phase for the overground condition. The body centre of mass was determined by means of a 3D full-body model using Qualisys Pro Reflex (200 Hz) and Visual3D (C-Motion). Acceleration was determined as the average acceleration of the treadmill belt during the stance phase and by means of the average horizontal ground reaction force for the overground trials.

Surface EMG-electrodes were placed bilaterally on M. Gastrocnemius (medial), M. Tibialis Anterior, M. Rectus Femoris, M. Biceps Femoris (medial) according to ISEK-standards. Data were sampled at 1000 Hz on treadmill and 200 Hz overground using an 8-channel wireless Noraxon ZeroWire EMG-system. The following processing steps were taken to process the data: the average offset was removed, the data were low-pass filtered (400 Hz), and the signals were rectified and were passed through an average root mean square filter (10 samples). The signals were time-normalized from initial contact to toe-off (one stance phase = 100%). The amplitude of the signals was normalized for left/right side and treadmill/overground condition to the peak value of the average of all contacts for each side and condition and muscle separately when running at steady state speed. 100% indicates the average peak activation during steady-state running for overground and treadmill separately.

The following metrics were calculated: the onset and offset of the EMG-signal was determined by a threshold of 0.1. They are expressed as a percentage of stance duration. The duration of EMG-activity is also expressed relative to stance duration. The iEMG was calculated as the average activation times the stance duration.

Rather than comparing accelerated running overground to running on an accelerating treadmill, we opted to compare the adaptations to the steady-state signal to accelerating both overground and on treadmill separately. This allows to exclude differences potentially introduced by the steady-state differences between treadmill and overground running. In this abstract only the stance phases were studied as the largest mechanical differences between treadmill and overground acceleration take place when there is contact with the surface.

RESULTS: Figure 1 shows the EMG-signals. A qualitative interpretation of the data indicates that the adaptations to the EMG-signal from steady-state running to accelerating overground are different than the ones on treadmill.

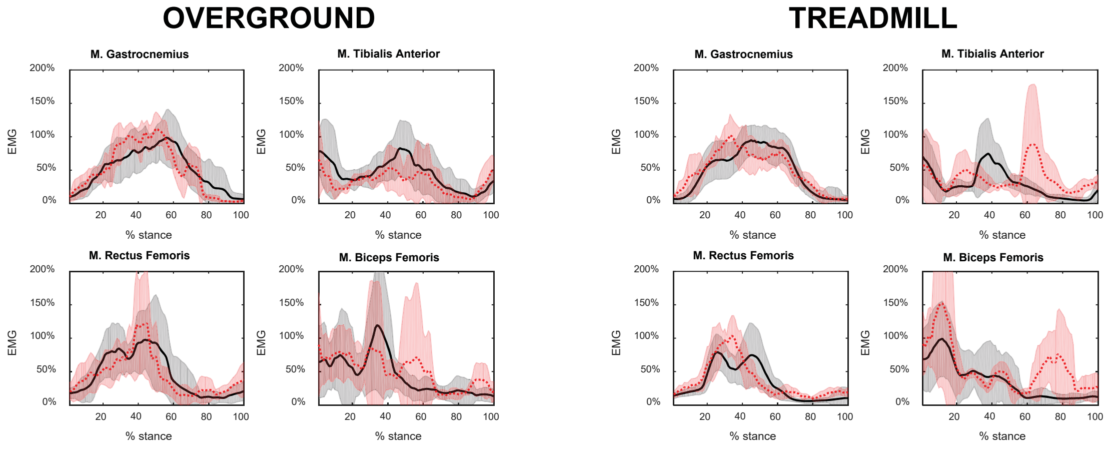

Figure 1: Average EMG-traces normalized to peak activation during steady-state running vs time (expressed as a percentage of stance phase). The black line represents steady-state running. The red dotted line represents accelerated running. The coloured bands indicate 1 standard-deviation.

Table 1
Adaptations to accelerated running compared to steady-state running overground and on treadmill.

		OV	TM
M. Gastrocnemius	START	-1%	-8%
	STOP	-5%	+6%
	iEMG	+4%	-10%
M. Tibialis Anterior	START	0%	0%
	STOP	+2%	+9%
	iEMG	-22%	+13%
M. Biceps Femoris	START	0%	0%
	STOP	+3%	+12%
	iEMG	+16%	+29%
M. Rectus Femoris	START	0%	-1%
	STOP	+3%	+21%
	iEMG	+5%	-1%

Table 1 shows that the increase in duration of muscle activity associated with an accelerating treadmill belt is larger than the one associated with accelerating overground for all muscles. In terms of amount of activity we can see that there is a small increase for M. Gastrocnemius when accelerating overground, whereas there is decreased activity on an accelerating belt compared to a steady-state belt. M. Tibialis Anterior activity decreases when accelerating overground, whereas it increases when running on an accelerating belt. For M. Biceps Femoris the increase in activity on treadmill is larger than the one overground. For M. Rectus Femoris there is a small increase in activity overground, and a small decrease on treadmill.

DISCUSSION: For the limited amount of stance phases studied in this abstract the adaptations to muscle activity to change a steady-state running pattern to an accelerated running pattern differ between the overground and treadmill conditions. Both adaptations in timing and amplitude can be remarked. These observations indicate that accelerating overground requires different motor control compared to running on an accelerating treadmill, which is in line with results of earlier studies examining the ground reaction forces and joint kinematics and kinetics when accelerating overground and on treadmill (Van Caekenberghe et al., 2013a and 2013b).

Overground, the acceleration-related EMG-changes can be associated with kinematical and kinetical adaptations to the running pattern (Van Caekenberghe et al., 2013b). Less M. Tibialis Anterior activation at the start of the stance phase could be associated with an active touchdown (including a flatter foot placement and a larger ankle plantarflexion velocity). This is immediately followed by a lower dorsiflexion velocity, which is additionally supported by a larger M. Gastrocnemius activation. The larger plantarflexion velocity in approach to toe-off is not supported by changes in muscular activation, but might be a (passive) consequence of a more pronounced proximo-distal extension sequence. A higher M. Rectus Femoris activation might be related to a smaller knee flexion velocity (and lower power absorption) and keeping the hip more flexed for a more forward tilt of the trunk during the braking phase. Except for the M. Tibialis Anterior, the changes in EMG when accelerating overground might seem rather limited. However, this should not be surprising as earlier research indicated joint moments are only marginally adapted to accelerate overground. One hypothesis to explain this observation was that in order to realize the more anterior orientation of the ground reaction forces, the body is brought in a more forward inclined position.

The acceleration-induced changes on treadmill might be related to the increase ‘pull’ of the belt on the stance leg. At the end of the propulsion phase this pull on the stance foot might evoke a hypothetical external plantarflexion moment. The higher M. Tibialis Anterior activity observed in that phase might act to partially counteract this moment, and as such limit the increase in plantarflexion velocity. As a result of the hypothetical externally induced plantarflexion moment there might be a lower need for an internal plantarflexion moment, and as such the reduced activity of the M. Gastrocnemius could maybe also be understood.

The reported EMG-signals clearly show inter-trial variability. These might be due to confounding variables which have not been accounted for (due to the small sample size). Among these factors might be the movement of the subject in the earthbound frame of reference on treadmill (i.e. moving forward or backward on the treadmill). Only a small amount of stance phases has been analysed so far. Further analyses will include the swing phase, more subjects, accelerations and speeds and will account for confounding variables.

CONCLUSION: This case-study offers some first indications that different adaptations to the steady-state running muscular activation pattern are necessary to accelerate overground versus running on an accelerating motorized belt. This could reinforce the conclusion of previous research (comparing ground reaction forces and joint kinetics) that accelerating overground is fundamentally different than running on an accelerating treadmill. However, in order to fully understand the difference, further research is needed which includes, next to the stance phase, also the swing phase, and which is conducted on a larger number of subjects and a broader range of speeds and accelerations.

REFERENCES:

Riley, P.O., Dicharry, J., Franz, J.A. & Croce, U.D. (2008). A kinematics and kinetic comparison of overground and treadmill running. *Medicine and science in sports & exercise*, 50: 1093.

Van Caekenberghe, I., Segers, V., Willems, P., Gosseye, T., Aerts, P. & De Clercq, D. (2013a). Mechanics of overground accelerated running vs. running on an accelerated treadmill. *Gait & posture*, 38: 125.

Van Caekenberghe, I., Segers, V., Aerts, P., Willems, P. & De Clercq, D. (2013b). Joint kinematics and kinetics of overground accelerated running versus running on an accelerated treadmill. *Journal of the Royal Society Interface*, 84: 20130222.

Van Ingen Schenau (1980). Some fundamental aspects of the biomechanics of overground versus treadmill locomotion. Medicine and science in sports & exercise, 12: 257.