RUNNER'S STRIDE ANALYSIS UNDER FIELD CONDITIONS

Bernard Auvinet[1], Régis Le Bris[2], Denis Chaleil[1], Eric Barrey[3]
[1]Hôpital de Laval, F- 53015 Laval Cedex
[2]Pégase-Mayenne, F- 53015 Laval Cedex
[3]INRA-SGQA, F- 78352 Jouy en Josas Cedex

The purpose of this study was to analyse the strides of middle distance runners using a new ambulatory gait analysis system adapted to field and track conditions. Nine middle distance runners performed a locomotor test which consisted of three step-tests close to their anaerobic threshold with an increase of 0.5 m.s-1 between each step-test. The increase in velocity was correlated to an increase in stride length ($p < 0.001$), and a decrease of stride symmetry and regularity ($p < 0.05$) and a decrease of left and right stance duration ($p < 0.05$). Wavelet analysis provided a pictorial description of gait particularities which could be of interest for trainers or practitioners.

KEY WORDS: runner, acceleration measurements

INTRODUCTION: Despite the great interest in the gait biomechanics of runners, few methods are available to provide relevant information for athletes and trainers in field conditions. Recently, a new system using accelerometric measurements (patented) has been developed for equine locomotion analysis (Equimetrix, TM) and human locomotion under field and track conditions (Locometrix,TM). The aim of this study was to measure the stride characteristics related to the running velocity.

METHODS: the apparatus consisted of three transducers which measured acceleration along the cranio-caudal, medio-lateral and antero-posterior axes of the athlete. The transducers were incorporated into a semi-elastic belt attached onto the lumbar region, so that the location was close to the body's centre of gravity (fig 1). The transducers were connected to a small signal conditioning system which recorded the data at the sampling rate of 100 Hz. Three successive analyses were carried out: from a sample (1024 points) of the vertical acceleration signal four variables were calculated : stride frequency (SF), stride symmetry (Sym) which measured the similarity between right and left steps, stride regularity (Reg), which measured the acceleration pattern similarity of successive strides over time. Stride length (SL) was deduced from the relationship : SL = V/SF.

Three acceleration curves were displayed : the medio-lateral acceleration curve allowed us to determine the right and left steps ; from the vertical and antero-posterior curves some particular points (which had been linked to specific events of the gait cycle) were identified, thus the swing and stance phases were calculated and expressed in percentage of the half stride duration from three strides (Fig. 2).

A wavelet analysis provided a description of the signal giving the location in time of the energy distribution in the frequency domain by means of a spectral analysis in 3 dimensions (time, frequency and energy module).

Nine male top level middle distance runners (33 ± 4 y ;175 ± 4 cm ; 65 ± 5 kg) performed a locomotor test. This locomotor test consisted of an incremental exercise of three 400 m steps (4.82 m.s-1, 5.33 m.s-1, 5.88 m.s-1 respectively) under track conditions.

Figure 1 - The accelerometers housed in a box are held over the middle of the lower back by a semi-elastic belt fastened around the subject's waist.
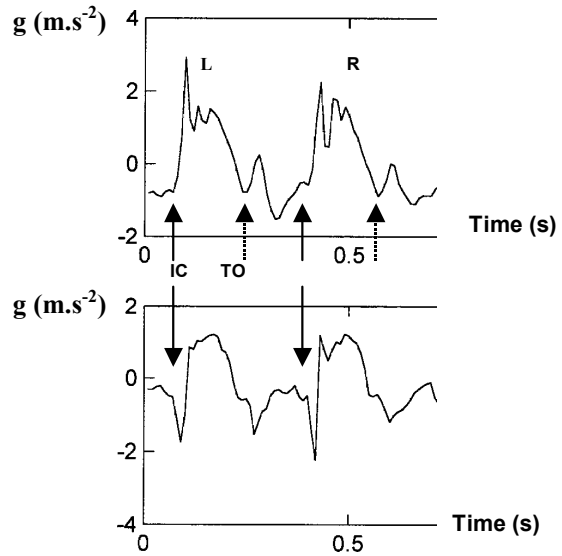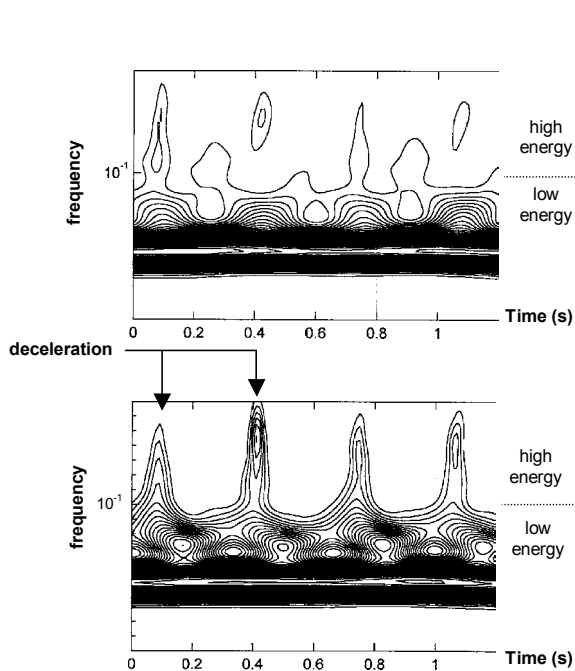
Figure 2 - Vertical and antero-posterior acceleration curves. Identification of specific events of Gait cycle: initial contact (IC) and toe-off (TO).

Table 1 Means and Standard Deviations for Running Velocities and Stride Characteristics for Each Step Test

Variables	Step Test 1		Step Test 2		Step Test 3	
	M	SD	M	SD	M	SD
Velocity ($m.s^{-1}$)	4.81***	0.05	5.33***	0.05	5.84***	0.06
Stride frequency (Hz)	1.46	0.07	1.50	0.08	1.55	0.08
Stride length (m)	3.29***	0.18	3.59***	0.20	3.79***	0.21
Vertical oscillation of the lumbar region (cm)	8.82	1.39	8.24	1.24	7.47	1.48
Symmetry (dimensionless)	209.6*	54.5	191.0	27.2	171.7*	20.9
Regularity (dimensionless)	330.5*	50.3	301.9	46.8	269.3*	36.1
Left Stance phase (% of half stride)	77.9*	2.2	76.8	1.9	75.1*	2.3
Right Stance phase (% of half stride)	77.8*	2.7	77.2	2.6	74.6*	2.0

Note. * $P < 0.05$, *** $P < 0.001$

- running velocity increased regularly. The velocity of each of the three step-tests was different (p< 0.001),
- stride frequency increased moderately (tendency),
- stride length increased significantly between each step-test (p< 0.001),
- vertical oscillation of lumbar region decreased moderately (tendency),
- symmetry and regularity indexes decreased regularly with a significant difference between the first and third step-tests (p< 0.05),
- there was no difference between left and right steps for each step-test, left and right stances decreased with a significant difference between the first and third step-test (p< 0.05),
- spectral wavelet analysis described the energy content of each stride along the cranio-caudal and antero-posterior axis. The patterns of loading, braking and propulsion could be compared between runners and between strides (Fig. 3.1, 3.2).

Figure 3.1 - Wavelet analysis from vertical and antero-posterior accelerations from an athlete with a smooth stride; v = 5.33 m.s^{-1}.
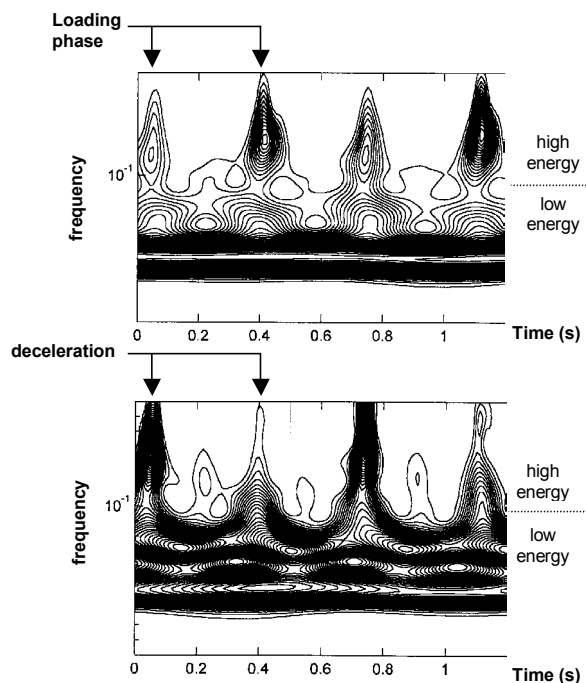
Figure 3.2 – Wavelet analysis from vertical and antero-posterior accelerations from an athlete with major asymmetric loading and braking; v=5.33m^{-1}.

DISCUSSION: Accelerometers are sensors that pick up instantaneous variations of speed. Although they have been used for measuring the energy expenditure in daily life (Bouten, 1994), they have not previously been used for a runner's stride analysis. Locométrix has been validated for walking gait analysis (Auvinet et al., 1999). However, this program has not been proposed for running tests. In the future, such tests should take into account the speciality of the athlete (sprinter, short, middle or long distance runners). However in this preliminary study, the trainer chose a three step-test, as is usual for anaerobic threshold determination. The distance of each step was limited to 400m and the increase of the velocity between each step-test was rather small (0.5 m.s-1). The velocity of the second step-test was chosen close to the anaerobic threshold. All the results obtained in this study were in accordance with current research, i.e : an increase of velocity was mainly achieved by increasing the step length (Roy, 1982) and the increase of stride frequency was related to a decrease of stance phase (Vaughan, 1984; Novacheck, 1998). Our results were similar to those obtained by Vaughan (at the speed of 5m/s the ipsi and controlateral stance phases last 30 % of total cycle time). The reduction of

45

vertical oscillation of the lumbar region could be linked to the vertical oscillation of the body's centre of gravity. The reduction of the oscillation of the centre of gravity with increasing velocity had been reported as a factor of better running economy (Anderson, 1986). Symmetry and regularity indexes decreased significantly with increasing velocity, such facts have previously been described for race walkers (Auvinet et al., 2000). This could be linked to non fluid motions which are disadvantageous to performance (Anderson, 1986). The wavelet analyses presented here allow a direct comparison of the running style of different subjects; spectra of wavelet analyses revealed characteristics of each stride which can alert trainers or practitioners to some abnormalities of the running technique (e.g : excessive braking from one side).

CONCLUSION: The Locométrix system (portable easy to use, fast, non invasive, allowing immediate interpretation), provided relevant information on stride length, stride frequency, vertical oscillation of the lumbar region, duration of stance phase, symmetry and regularity from steps and strides, and running stride kinetics according to running velocity. Using this ambulatory gait analysis system, practical applications of biomechanical measurements will become available for trainers and practitioners under track conditions. Further investigations are necessary to establish quantitative and qualitative reference data over wide range of velocity and type of running.

REFERENCES:
Anderson, T. (1986). Biomechanics and running economy. Sports Medicine, 22 (2), 76-89.
Auvinet, B., Coureau, C., Biau, S., Chaleil, D., Barrey, E. (2000). Analyse ambulatoire de la foulée du marcheur athlétique; intérêt et limite pour l'aide à la conduite de l'entraînement. EquAthlon, 30, 72-75.
Auvinet, B., Chaleil, D., Barrey, E. (1999). Accelerometric gait analysis for use in hospital outpatients. Revue du Rhumatisme, 66 (7-9), 389-397.
Barrey, E., Auvinet, B., Couroucé, A. (1995). Gait evaluation of race trotters using an accelerometric device. Equine Veterinary Journal, 18 (suppl), 156-160.
Bouten, C.V., Westertoerp, K.R., Verduin M., Janssen, J.D. (1994). Assessment of energy expenditure for physical activity using a triaxial accelerometer. Medicine and Sciences in Sports and Exercises, 26, 1516-1523.
Meyer, Y. (1992). Les ondelettes, algorithme et applications. Paris : Armand Colin.
Novacheck, T.F. (1998). The biomechanics of running. Gait and Posture, 7 (1), 77-95.
Roy, B. (1982). Caractéristiques biomécaniques de la course d'endurance. Canadian Journal of Applied Sports Science, 7, 104-115.
Vaughan, C. (1984). Biomechanics of running gait. Critical Review of Biomedical Engineering, 12 (1), 1984.