TREADMILL RUNNING: AN ELECTROMYOGRAPHIC AND KINEMATIC ANALYSIS

Priscila de Brito Silva[1], Carina Helena Wasem Fraga[1], Sarah Regina Dias da Silva[1], Adalgiso Coscrato Cardozo[1,2], Mauro Gonçalves[1]

[1]Laboratório de Biomecânica – UNESP – Rio Claro – SP.
[2]Departamento de Ciências da Saúde – UNIFESP – Santos – SP.

The aim of this study was to analyze electromyographic (EMG) activity of vastus lateralis (VL), vastus medialis (VM), biceps femoris caput longum (BFCL) and gastrocnemius lateralis (GL) muscles during contact phase, stride length (SL) and stride frequency (SF) among five time intervals of three different speeds during treadmill running incremental test: equivalent to anaerobic threshold (AT) (V_{AT}), 15% below AT (V_{BE}) and 15% above AT (V_{AB}). The results showed that there were differences in stride frequency among intervals of V_{BE} and V_{AB} and the muscle activity presented different responses. It was concluded that this methodology of analysis, that combines EMG with kinematic, enhances the knowledge about important running aspects, contributing to understand this complex pattern of movement performed to improve health and performance.

KEY WORDS: electromyography, running, contact phase, kinematics.

INTRODUCTION:

Running is one of the most popular exercise forms and this trend has been increasing significantly, some running practitioners seek for keeping healthy and some wish to improve performance (Wen, Puffer & Schmalzried, 1998). This modality of sport is often used during incremental tests, which may allow the evaluation of aerobic capacity (Ribeiro, 1995; Denadai, 1995). During such tests, the subject runs in different intensities until exhaustion, thus movement patterns and, consequently, performance levels are influenced by the development of fatigue and running intensity. These changes may lead to kinematic, metabolic and neuromuscular adjustments. This last one mentioned can be verified by electromyographic (EMG) methods, which could allow improvements on understanding of performance evaluation, since it is related to the intensity of effort performed (Hanon, Thepaut-Mathieu & Vandewalle, 2005; Paavolainen et al., 2006).

Some studies analyzed the EMG (Paavolainen et al., 2006; Hausswirth et al., 2000), kinematic (KIN) (Hanon, Thepaut-Mathieu & Vandewalle, 2005; Fraga, 2006) and metabolic (Hausswirth et al., 2000; Fraga, 2006) behavior during running. However, to the best of our knowledge, few ones were carried out during a treadmill incremental test protocol analyzing such variables, within the same speed, which is the focus of present study.

Anaerobic threshold (AT) is a physiological index used to evaluate performance and can be used as reference parameter to prescribe training protocols (Ribeiro, 1995; Denadai, 1995). Intensities above AT will increase the anaerobic metabolism demand to produce energy, which may lead to metabolites accumulation and cause alterations in conductivity and contractility of muscle fibers (Gianesini, Cozzone & Bendahan, 2003).

Considering the mentioned studies, we hypothesize that running at intensities above AT would lead to EMG and KIN adaptations, even though occurring within the same speed. Understanding the behavior of KIN and EMG variables during velocities 15% below (V_{BE}) and 15% above AT (V_{AB}) and during the velocity equivalent to AT (V_{AT}) may provide useful information.

Thus, the aim of the present study was to compare EMG activity during contact phase, stride length (SL) and stride frequency (SF) among five time intervals of three different speeds during a treadmill running incremental test.

METHODS:

Subjects: Nine male subjects took part of the present study (22.6±3.9 years old, 175.9 ± 4.6cm high, 72.5 ± 9.5kg body weight), physically active, with experience in different sports modalities. Anthropometric measurements were made for right (42,6 ± 2,4cm) and left (42,4 ± 1,9cm) thighs as suggested by Lohman et al. (1988). The local Ethic Committee approved the present study.

Experimental Procedures: Initially, the subjects were familiarized to treadmill running during eight minutes. Subsequently, they performed an incremental protocol on a treadmill (INBRAMED SUPER ATL, Porto Alegre, Brazil), with 1% gradient fixed (Jones & Doust, 1996). This test started with 6 $km.h^{-1}$ and speed was increased 1 $km.h^{-1}$ at the end of each 3 minutes stage untill the volunteers reached exhaustion.

In order to calculate SL, SF, contact time and cycle duration two pressure sensors (footswitch – EMG System do Brazil®) were positioned under the right shoe of the volunteer, one corresponding to the heel and the other to the toe, so it was possible to identify each stride (from heel touch to the subsequent) and the contact time (from heel touch to toe off).

EMG signals were recorded during the whole incremental test. Passive surface electrodes Ag/AgCl (MediTrace®), in bipolar configuration, conductive area of 1 cm diameter, with distance between electrodes of 30 mm, were used to pick up the muscle activity from vastus lateralis (VL), vastus medialis (VM), biceps femoris caput longum (BFCL) and gastrocnemius lateralis (GL) from the right lower limb. The skin area was dry shaved slightly, rubbed with sand paper and cleaned with alcohol; electrodes were positioned as recommended by SENIAM (Hermens et al., 1999), and the reference electrode was placed over the right ulnar styloid process. Electrodes and pressure sensors were connected to a signs conditioner module (EMG System do Brazil®), with four channels with input range from -10 to +10 Volts, sample rate of 1,000Hz, 2,000 fold total gain (20 pre-amplified next to the sensor and 100 on amplifier), high pass filtered (20 Hz), low pass filtered (500 Hz). For acquisition and analysis of data the software WINDAQ (EMG System do Brazil®) was used.

Ear lobe capillary blood samples of 25µl were collected after local assepsia, using a disposable lancet and heparin calibrated capillary tube, before the test and at the end of each stage. The procedure to collect the blood samples lasted approximately 30 seconds. After each collection the blood sample was immediately stored in 1,5 ml eppendorf tubes containing 50 µl 1% sodium fluoret to allow measurement of lactate blood concentration (YSL 2300 STAT PLUS, Ohio, EUA). The anaerobic threshold (AT) was determined using a fixed concentration of 3.5 mmol (Heck et al., 1985). Three different speeds were considered for intra-speed analysis: V_{AT}, V_{BE} and V_{AB}.

The RMS (Root Mean Square) values of muscle activity obtained during running contact phase were normalized by the peak value of each three speeds considered. The EMG signal, SL and SF were obtained from ten strides recorded at each 20% of time, thus, five intervals during each speed were considered for analysis: 20%, 40%, 60%, 80% and 100% of time.

Statistical Analysis: Means and standard deviations of each interval of the analyzed variables were calculated and *Shapiro-Wilk* test was used. Differences among time intervals were tested by analysis of variance for repeated measures (ANOVA *one-way*) and Bonferroni *post hoc* test verified possible significant differences between each interval ($p<0,05$).

RESULTS:

Speed mean values (SD) performed during incremental test were 9.9 (1.4) $km.h^{-1}$ for V_{BE}, 11.7(1.6) $km.h^{-1}$ for V_{AT} and 13.5 (1.8) $km.h^{-1}$ for V_{AB}.

The SF increased within the same speed, it was greater in 80% (88.1 strides/minute) and 100% (88.0 strides/minute) of time interval when compared with 60% (87.3 strides per minute) of running at V_{BE}, and greater in 80% (97.3 strides/minute) of time interval in relation to 20% (91.7 strides/minute) at speed V_{AB}. No differences were found for SL.

The results of RMS values are presented in Table 1. The VL muscle did not show alterations during any stage, on the other hand VM muscle presented increase of its activation within V_{AB}, the values were greater in 60% and 80% when compared to 40% time interval. The activity of BFCL increased from 20% to 40%, presenting greater activation on 40% during V_{BE} running intensity and from 20% to 40% and to 60%, presenting greater values on 40% and 60% time intervals during V_{AB} running intensity. The activation of GL muscle increased from 20% to 60%, presenting greater values on 60% time interval at V_{AT}.

Table 1 – Mean RMS (SD) values for VL, VM, BFCL and GL muscles at each time interval within V_{BE}, V_{AT} and V_{AB} intensities.

	V_{BE}					V_{AT}					V_{AB}				
	20%	**40%**	**60%**	**80%**	**100%**	**20%**	**40%**	**60%**	**80%**	**100%**	**20%**	**40%**	**60%**	**80%**	**100%**
VL	73.5	70.9	75.0	68.7	67.3	78.9	74.5	80.4	76.3	79.6	81.8	82.2	85.6	83.8	86.6
(%)	10.9	8.4	11.5	6.5	11.2	10.8	11.1	14.1	16.8	10.3	9.2	10.8	13.2	9.5	15.4
VM	72.3	71.2	73.0	72.5	68.7	77.4	73.4	78.5	78.3	77.1	87.9	82.6*	87.7*	93.6*	85.3
(%)	10.3	11.2	14.2	13.1	9.7	14.7	11.1	12.2	11.1	9.3	10.8	7.2	8.4	7.8	11.8
BFCL	57.9*	67.6*	63.0	67.3	71.5	62.4	64.5	63.6	72.0	67.9	64.0*	77.8*	78.3*	73.0	70.4
(%)	21.4	22.3	19.0	18.3	18.4	17.5	20.6	13.8	26.0	17.3	18.8	21.0	19.9	16.5	14.4
GL	78.5	78.5	80.8	79.1	79.4	78.2*	81.7	91.8*	83.2	84.0	83.8	81.4	86.9	87.1	76.5
(%)	11.1	11.2	11.3	13.6	11.5	13.3	13.5	6.3	10.6	9.3	13.8	15.8	18.3	19.3	19.0

* $p < 0.05$

DISCUSSION:

The lack of differences in SF among V_{AT} intervals shows that from 20% of this running intensity there was no need of much effort to keep the same patterns of this variable. The increases within the same speed for intensities V_{BE} and V_{AB} may reflect patterns of running that do not permit better adaptation level, so that the movement pattern could alter more when compared to V_{AT}.

Considering that the velocity of running was the same and that SF increased in V_{BE} and V_{AB}, it was expected that the SL would decrease during these same intensities, because these variables are directly related to running speed (Hay, 1985). Actually, this parameter had a tendency to decrease, however, there was no statistically significant differences among intervals for the considered speeds. Well-trained runners seem to adopt the most appropriate combination of SL and SF, which is extremely close to their optimal condition that does not alter much within the same speed.

The results of this study agree with papers that demonstrated increases in SF within the last stages of an incremental test for elite runners (Hanon, Thepaut-Mathieu & Vandewalle, 2005). This suggests that the SF, more than the SL, represents an important factor to improve muscle function during each stride cycle (Martin & Sanderson, 2000).

Fatigue may be determined during incremental exercise protocols as a significant increase in EMG amplitude within the same stage. This increase occurs as a result of additional recruitment of muscle fibers (Hanon, Thepaut-Mathieu & Vandewalle, 2005) in order to keep the same running speed. Although the muscles studied perform propulsive roles during running, the activity of each muscle portion presented different responses for different running intensities.

Contrary to our results that demonstrated no alterations in VL activation within any speed, but VM activity increased within speeds V_{BE} and V_{AB}, Bilodeau et al. (2003) study suggests that a higher type II fibers content for VL muscle when compared to VM muscle, which could be related to greater VL fatigue. Therefore, the present study does not agree with current literature, as VL muscle activity did not alter in any running intensity between intervals. There is evidence that factors such as training level of subjects evaluated and their physical characteristics may influence muscle activation behavior (Vuoriamaa et al., 2006).

The increasing muscle activity during the stages V_{BE} and V_{AB} was related to the increasing SF at same intensities. Since the muscle activity increasing occurred earlier, SF alterations seem to be a consequence of BFCL fatigue. Those speeds do not represent the intensity that allows balance between release and utilization of lactate from muscle fibers and may not be the optimal running intensity, leading to neuromuscular adaptations that probably favor fatigue process to be installed.

During running, muscles are subjected to alteration of working time and rest period, which varies greatly according to their role (Hanon, Thepaut-Mathieu & Vandewalle, 2005) and to the running pattern. These authors demonstrated that hip-mobilizing muscles were activated for a longer period of time related to the stride pattern.

Another relation between BFCL activity and SF increases is that this alteration on SF may increase the amount of muscular activity by shortening the duration of relaxation period (Kyröläinen et al., 2000). This muscle is solicited during contact and support phases, besides that, hip extensor muscles are considered the prime forward movers of the body (Hanon, Thepaut-Mathieu & Vandewalle, 2005). Considering that, one may conclude that this muscle portion may be more related to stride parameter alterations than the other ones analyzed in the present study.

The function of gastrocnemius medialis is less dependent of muscle activity for concentric propulsive phase, this muscle portion can more effective use the elastic energy stored which may explain the difference of GL to the other muscles behavior (Ishikawa, Pakaslahti & Komi, 2007). Our results presented an increase in GL activation when BFCL and VM muscles activity did not alter (V_{AT}), which could be due to the more effectively use of elastic energy stored by GL. Besides that, the lack of alteration on muscle activity of GL at other running intensities may result from increased activity of propulsive muscles (VM and BFCL), this behavior seems to decrease the influence of fatigue on this muscle portion.

CONCLUSION:

It was concluded that SF adjustments seem to represent an important factor to improve muscle function during each stride cycle in order to keep the same running speed, and to understand the behavior of these parameters during the same running velocity considering intensities below and above AT may be useful because the regularity is necessary to some endurance running events. Thus, a more regular pattern of movement even considering constant speed may reflect better control of running movement and then improve performance levels.

The activation pattern was not similar among analyzed muscles, which was expected since the movement of running is a complex activity. So, the fatigue process seems to influence the performance in different ways even during a constant speed.

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