94 - ANALYSIS OF THE EMG SIGNAL FROM ELITE CYCLISTS’ PEDLING IN FOUR DIFFERENT CADENCES

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Introduction

The analysis of the electromyographic signal (EMG signal) give information about how the central nervous system controls the human movement. The understanding of the muscular activation during the cyclist, in relation to the crank angle has been extensively studied, with the intention of characterize the intensity of the muscular contraction and the contribution of the lower limb’s different muscles for the pedaling (NEPTUNE KAUTZ & HULL, 1997; 1 READ & CALDWELL, 1998; GREGOR, 2000). However, it is observed differences in the models described in the literature about the muscular activation, and such divergences probably results from the variations in the placement of the electrodes, from several methods of acquisition and data analysis, from differences of bicycle’s configuration and from the posture assumed by the cyclist.

The great majority of the studies using electromyography refers to the functions of mono and biarticular muscles, as joint’s flexors and extensors, and they also refer that the biarticular muscles seems to present larger variability than the monoarticular muscles (GREGOR, 2000). During the propulsion phase of the pedaling, seems to be decisive the muscular activity of the hip and knee extensors, in association with the activity of the ankle’s plantar flexors, for propulsion of the bicycle, while during the recovery phase of the pedaling it is important that the flexors muscles of the hip, knee and ankle’s dorsiflexors act repositioning the lower limb in the superior neutral point, contributing to the task that is being mainly performed by the other leg. That way, it seems that a larger muscular activation happens during the propulsion phase of the pedaling for the monoarticular extensors of the hip and knee, and during the recovery phase of the pedaling for the monoarticular flexors of the ankle. However, in many of those studies it has been demonstrated that the flexors and extensors muscular activation in the lower limb is influence by the movement’s speed of execution, therefore, the cadence of the pedaling (GREGOR, 2000; NEPTUNE, KAUTZ & HULL, 1997; ERICSON, NISELL & ARBORELUS, 1985).

The objective of this study was to verify the pattern of muscular activation of the cyclists’ pedaling, through the point of view of the width of the EMG signal from a right lower limb’s muscles, in four different cadences, during ten consecutive cycles of pedaling. The following hypotheses were formulated: (1) the width of the EMG signal (RMS value’s peak) tends to increase in the largest cadences in a physiological intensity of constant effort and (2), the peak of the RMS value tends to happen sooner in relation to the crank angle, in the pedaling cycle, in the highest cadences, in a physiological intensity of constant effort.

Material and Methods

Eight cyclists were evaluated, males, all with more than six years of practice in the modality and considered in a elite for the state of Rio Grande do Sul. For the cyclists’ evaluation a computerized cycle ergometer CARDIO, (Medical Graphics Corp., St Louis, USA) was used, which gives the load of work of each stage and the cadence, considering that the original saddle, handlebar and pedals of the cycle ergometer were substituted by equipments used in competition bicycles.

The evaluation was accomplished in two days, and in the first day the subjects were submitted to a protocol for determination of the maximum consumption of oxygen, which allowed the determination of the anaerobic threshold, starting from the 2nd individual ventilatory threshold (DENADA1, 1995; RIBEIRO, 1995). In the second day of evaluation, the subjects were submitted to a protocol whose load was that corresponding to the 2nd individual ventilatory threshold. This procedure was used trying to normalize physiologically, for all of the individuals, the evaluation load. Four different frequencies of pedaling were tested in this load (60, 75, 90 and 105 rpm), one each for a three minute period. The order of accomplishment of the tests was defined for each individual through raffle, in order to avoid the possibility of muscular fatigue interfering with the results. In the second day of evaluation, the crank angles, the angles of the pedal in relation to the crank and the electrical activity of six muscles of the cyclists’ right lower limb were registered, simultaneously and synchronized. The angles were obtained from 2-0 kinematics system (Peak Performance Technologies Inc., Englewood, USA, version 5.3).

For obtaining the EMG signal a computer was used (Pentium 200), a similar-digital converter of 16 channels CODAS (Dataq Instruments, Inc., Akron, USES) and an electromyograph of eight channels BORTEC (Bortec Eletronics Inc., Calgary, Canada). The electromyograph has pre-amplifiers and centimeters of the electrodes. For the registration of the electromyographical signal (EMG signal) surface electrodes were used (Ag/AgCl; with diameter of 2.2 cm; with stickers of fixation of double face) in the bipolar configuration. The EMG signals were obtained of each one of the muscles, with a frequency of 1818 Hz. All the pertinent norms were observed strictly to ensure the appropriate registration of signs EMG, as depilation, cleaning of the place with alcohol, placement of the electrodes and verification of the impedance (accepted when inferior to 5KΩ), suggested by MERLET0 (1999) and recommended by the International Society of Electrical Physiography and Kinesiology.

The electrodes were aligned longitudinally to the muscular fibers and fixated on the muscular belly of the muscles: glutteos maximus (GM), rectus femurais (RF), vastus lateralis (VL), biceps femoral (FB), tibialis anterior (TA) and media gastrocnemious (GA). The reference electrode was fixated on the tibia.

To process the EMG signals, the system SAD of acquisition of data (version 2.61.07 mp, 2002) (www.ufg.rs.br/mm) was used. Were analyzed the signals EMG corresponding the mean of ten consecutive cycles of pedaling, registered every three minutes. The EMG signal was filtered, using a digital filter Butterworth of 5th order band pass, with cut frequencies from 20 to 600Hz and analyzed in the time domain, starting from the root mean square (RMS value), in intervals of 40ms (Hamming) (NEPTUNE, KAUTZ & HULL, 1997). To accomplish the normalization of the EMG signal the maximum value reached among the ten analyzed curves was used, expressed in percentage, starting from the pedaling in 60 rpm. That way, the peak values of the RMS value were calculated from the medium curve of the pedaling cycle.

Statistical analyses were accomplished using the software SPSS 10.0. For variables whose normality of data was confirmed (Levine’s test), the analysis of variance of one factor was used (ANOVA one way) and post hoc test of Tukey. The data no non-parametric were submitted to the test U of Wilcoxon-Mann-Whitney. The level of significance adopted was 0.05.
Results and Discussion

The objective of this study was to verify the pattern of muscular activation of the cyclists' pedaling, through the point of view of the width of the EMG in four different cadences.

In the Figure 1 are presented the results obtained with the calculation of the RMS mean value, during ten consecutive cycles of pedaling, in the cadences 60 and 105 rpm. With this Figure it is possible to analyze qualitatively and comparatively the magnitude of the EMG signal, as well as the crank angle where the peak of RMS value happened for each studied muscle. We can also notice that there was a variability in the data found, not presenting, therefore, an uniform tendency among all muscles.

It was verified that the muscles FB, GA and TA presented a tendency of increasing the peak of the RMS value with an increase in the cadence. The GM and VL muscles presented a tendency of reducing the peak of the RMS value with the increase of the cadence. The muscle RF presented a tendency of maintaining constant the peak of the RMS value regardless the increase in the cadence. However, in spite of the presented tendencies, the comparative analysis of the peak of the RMS value didn't demonstrate significant differences among the four cadences (p>0.05), for the six studied muscles, meaning that the RMS value was not influenced by the manipulation of the cadence, what refutes the first hypothesis of that study.

Frequently, muscular groups are activated by the nervous system in order to execute a specific movement, acting as synergists, in other words, a group of agonists-antagonists muscles acting as an unit. In the action of pedaling, the synergy between the active agonists and antagonists muscles happens in the demand of the external force order, as for load or for cadence increases (GROOT, WELBERGEN, CLIJSEN, CARUS, CABRI & ANTONIS, 1994).

According to GREGOR (2000) the patterns of muscular activity for the main flexors and extensors of the lower limb are different with changes in the pedaling rhythm. For NEPTUNE, KAFTZ & HULL (1997) and ERICSON, NISSEL & ARBORELUS (1985) the muscles of the lower limb respond differently to the manipulation in the cadence, in other words, an activation exists more accentuated, particularly of some muscles and muscular groups, associate to the increase of the pedaling cadence.

DUCHATEAU, LEBOZEC & HAINAUT (1986) studied the contribution of the slow and fast fibers of the sural triceps during the pedaling and verified that when the pedaling speed was increased, at a constant load, the integral of the EMG signal of the medial gastrocnemius showed a great increase. In the results of the present study, although it hasn't happened significant difference, the differentiated tendency of response in the activation of the muscles was verified with the manipulation of the cadence, as the literature indicates.

In fact, although in this study it has not happened significant difference, one cannot deny that the differences happened. MARSH & MARTIN (1995) found a significant effect of the cadence over the muscular activation, considering that an increase of the cadence caused a systematic increase in the width of the EMG signal for the muscle GA. However, the authors also verified that there was an absence of the cadence's effect on the muscular activation of FB, VL and RF. The authors speculated that this difference of results can be due to the characteristics of the type of muscular fiber and their mechanical properties and, they concluded that is necessary more investigations about the complex interaction of the cadence, of the load, of the fiber type and of the alterations in the muscular length during the pedaling.

More recently it was found by BAUM & LI (2003) that the cadence has a significant effect on the muscular activation, although each muscle responds in a different way to the manipulation of the cadence, because more than 56% of the variables studied by them (value of the beginning of the activation, value of the end of the activation, value of the activation peak, average of the duration of the activation) were influenced significantly by the alteration of the cadence. In the present study, although it has observed a tendency of alteration of the muscular activity with the change in the cadence, one cannot affirm that with the increase of the cadence it happens an increase of the muscular activation, contradicting, therefore the discoveries by GREGOR (2000).

The results also demonstrated that the muscles FB, GA and GM presented the peak of the RMS value sooner according to the crank angle, with the increase of the cadence. The RF muscle presented the peak of the RMS value in the superior point, in all cadences. The TA muscle presented the peak of the RMS value in the fourth quadrant of the pedaling cycle, in all cadences. The VL muscle presented a later peak of the RMS value, in relation to the crank angle, with an increase in the cadence. However, the comparative analysis of the crank angles where happened the peak of the RMS value didn't demonstrate significant differences among the four cadences (p>0.05), for all six studied muscles, what refutes the second hypothesis of this study.

BAUM & LI (2003) demonstrate that as the pedaling's cadence is increased, significant alterations happen in the beginning of the periods of muscular activation of the muscles GM, RF, FB, VL and TA. The authors found that the periods of activation of these muscles happened sooner, according to the crank angle and they suggest that this leads to a change in coordination alteration among the muscles of the lower limb. These results are similar to the tendency found in the present study, but they are not confirmed by the results here presented, that differently, did not indicate significant changes in the crank angle where happened the peak of the RMS value with the manipulation of the cadence.
Figure 1 Mean and standart deviations (positive values) of normalized RMS values from FB, GA, GM, RF, TA e VL muscles in (a) 60 rpm and (b) 105 rpm, during ten consecutive pedaling cycles.

Conclusions
The results of this study demonstrate that the peak of the RMS value as well as the crank angle where this peak occurred was not significantly different among the four studied cadences. That way, the pattern of muscular activation presented by the cyclists was not influenced by the manipulation of the cadences.

Bibliographical references

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ANALYSIS OF THE EMG SIGNAL FROM ELITE CYCLISTS’ PEDLING IN FOUR DIFFERENT CADENCES

Abstract
The purposes of this study were to verify the EMG signal magnitude of right lower limb muscles and analyze the muscle activation pattern at four different pedaling rates (60, 75, 90 and 105 rpm) through ten cycling strokes. Eighth cyclists were assessed in two different days: at the first day the anaerobic threshold was determined by means of the individual ventilatory threshold identification; in the second day, it was taken an assessment protocol in a load corresponding to the second individual ventilatory threshold and the crank angles and the electric activity from five muscles of the cyclist right lower limb were registered synchronically in a simultaneous way. Surface electrodes were aligned longitudinally to the muscle fibers and placed overlaying the muscles: gluteus maximus (GM), rectus femoris (RF), vastus lateralis (VL), biceps anterior (TA), biceps femoris (BF) and gastrocnemius medialis (GA). The reference electrode was placed over the tibia. EMG signal was analyzed in time domain, it was calculated the root mean square value (RMS), windows of 40 ms (Hamming). To normalize the EMG signal, the larger RMS value, obtained from the ten 60 rpm curves, was used, expressed in percentage. These results suggest that either RMS peak value and crank angle where these peak occurred do not were statistically significant between the four study cadences (p<0.05). Therefore the muscle activation pattern was not influenced by the change of cadence.

Key Words: cycling, electromyography, cadence

ANALYSES DE SIGNAL D'EMG DU CYCLE DES CYCLISTES D'ELITE DANS QUATRE CADENCES DIFFERENT

Résumé
Les buts de cette étude étaient vérifier l'importance de signal d'EMG de muscles inférieurs droits de membre et d'analyser le modèle d'activation de muscle à quatre 90 et 105 t/min des tâches (60, 75) pedaling différents par dix cycles de cycle. Des cyclistes d'Eighth ont été évalués en deux jours différents: au premier jour le seuil anaérobie a été déterminé au moyen de l'identification ventilatoire individuelle de seuil ; en le deuxième jour, il a été pris un protocole d'évaluation dans une charge correspondant au deuxième seuil ventilatoire individuel et les angles de manivelle et l'activité électrique de cinq muscles
ANÁLISIS DE LA SEÑAL DEL EMG DE CYCLISTES DE ÉLITE EN CUATRO CADENCIAS DIFERENTES

Resumen

Los propósitos de este estudio eran verificar la magnitud de la señal del EMG de músculos más bajos derechos del miembro y analizar el patrón de la activación del músculo en cuatro diversas cadencia (60, 75, 90 y 105 rpm) a través de diez ciclos. Determinaron ocho ciclistas en dos diversos días: en el primer día la emulación anaeróbica fue determinada por medio de la determinación ventilatoria individual del umbral; en el segundo día, fue tomado un protocolo del gravamen en una carga que correspondía al segundo umbral ventilatorio individual y los ángulos de la manivela y la actividad eléctrica a partir de cinco músculos del ciclista de la derecha del miembro más bajo fueron colocados en una manera simultánea. Los electrodos superficiales fueron alineados longitudinalmente con las fibras del músculo y pusieron cubrir los músculos: maximus del glúteo (GM), músculo recto femoris (RF), lateralis del vastus (VL), tibialis anteriores (TA), biceps femoris (BF) y medialis del gastrocnemius (GA). El electrodo de referencia fue colocado sobre la tienda. La señar del EMG era analizada en el dominio de tiempo, él era calculado el valor del cuadrado malo de la raíz (RMS), ventanas del ms 40 (Hamming). Para normalizar la señar del EMG, el valor máximo del RMS, obtenido de las diez curvas de la 60 RPM, fue utilizado, expresado en porcentaje. Estos resultados sugieren que cualquier valor máximo y la manivela del RMS pesquen donde con caña que estaban estadísticamente significativos éstos no lo hacen máximos ocurridos entre las cuatro cadencias del estudio (p<0.05). Por lo tanto el patrón de la activación del músculo no fue influenciado por el cambio de la cadencia.

Palabras clave: cicloismo, electromiografía, cadencia

ANÁLISE DO SINAL EMG DA PEDALADA DE CICLISTAS DE ÉLITE EM QUATRO DIFERENTES CADÊNCIAS

Resumo

O objetivo deste estudo foi verificar a magnitude do sinal EMG de músculos do membro inferior direito e analisar o padrão de ativuação muscular, em quatro diferentes cadências (60, 75, 90 e 105 rpm), durante dez ciclos da pedalada. Foram avaliados oito ciclistas em dois dias, sendo que no primeiro dia foi determinado o limiar anaeróbio, a partir de 2º limiar ventilatório individual. No segundo dia de avaliação, foi realizado um protocolo cuja carga foi aquela correspondente ao 2º limiar ventilatório individual e foram registrados, simultaneamente e de forma sincronizada, os ângulos do pé de vela e a atividade elétrica de seis músculos do membro inferior direito dos ciclistas. Os eletrodos foram alinhados longitudinalmente às fibras musculares e fixados sobre o ventre muscular dos músculos glúteo máximo (GM), reto femoral (RF), vasto lateral (VL), tibial anterior (TA), biceps femoral (BF) e gastrocnêmio medial (GA). O electrodo de referência foi fixado sobre a tienda. O sinal EMG foi analisado no domínio do tempo, a partir do root mean square (valor RMS), em intervalos de 40ms (janelamento de Hamming). Para a normalização do sinal EMG foi utilizado o valor máximo atingido durante a pedalada a 60 rpm, entre as dez curvas analisadas, sendo expresso em porcentagem. Os resultados desse estudo demonstram que tanto o pico do valor RMS quanto o ângulo do pé de vela onde ocorreu este pico não foram significativamente diferentes entre as quatro cadências estudadas (p>0.05). Desse modo, o padrão de ativação muscular apresentado pelos ciclistas não foi influenciado pela manipulação das cadências.

Palavras-Chave: cicлизmo, eletromiografia, cadência.